PUBLIC HEALTH ASPECTS OF

PHYSICAL ACTIVITY

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Promotoren:

Prof. dr. ir. D. Kromhout
Hoogleraar Volksgezondheidsonderzoek
Wageningen Universiteit, Wageningen

Prof. dr. ir. W.H.M. Saris
Hoogleraar Humane Voeding
Universiteit Maastricht, Maastricht

Co-promotor:

Dr. ir. A.J. Schuit
Projectleider Preventie
Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven

Promotiecommissie:

Prof. dr. H.C.G. Kemper	(Vrije Universiteit, Amsterdam)
Prof. dr. ir. P. van ’t Veer	(Wageningen Universiteit, Wageningen)
Dr. M. van Baak	(Universiteit Maastricht, Maastricht)
Prof. dr. J. Brug	(Erasmus Universiteit, Rotterdam)

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PHYSICAL ACTIVITY

Gerrie Cornelia Wanda Wendel-Vos

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Abstract

In this thesis different public health aspects of physical activity in the Netherlands were addressed, taking into account its broad scope. Research was carried out on physical activity methodology, determinants of physical activity and the relationship between physical activity and different health outcomes.

As to physical activity methodology, we established reproducibility and relative validity of the short questionnaire to assess health enhancing physical activity (the SQUASH).

With regard to determinants of physical activity, we found that adherence to the Dutch physical activity guideline was inversely associated with the cognitive attitude towards increasing physical activity and positively with self efficacy and the perception of having sufficient affordable exercise facilities in the neighbourhood. Results of another study showed that the time people spent on walking and bicycling was associated with the square area of green and recreational space close to their home.

Concerning the relationship between physical activity and health outcomes we performed a meta-analysis on 31 observational studies addressing the association between physical activity and stroke. The results of this meta-analysis indicated an inverse association between physical activity and stroke risk with a 25-40% lower risk of stroke among those who were physically active. This association was stronger in Europe than in the USA. Furthermore, we studied the association between physical activity, body mass index and 12-year cardiovascular mortality in a cohort of 35,650 healthy Dutch men and women aged 20-59 years at baseline. Results showed that especially inactive, obese individuals were at high risk of coronary heart disease (HR: 3.1; 95%CI: 1.3-7.6), stroke (HR: 4.8; 95%CI: 1.1-20.7), as well as cardiovascular diseases mortality (HR: 3.2; 95%CI: 1.7-6.0) compared with very active, normal weight individuals. Finally, we studied cross-sectional and longitudinal associations between physical activity and health-related quality of life among 1,871 men and women aged 26-65 at baseline. Cross-sectional associations were not confirmed by longitudinal analyses. Cross-sectional associations were mainly found for physical components of health-related quality of life, whereas longitudinal associations were predominantly observed for mental components of health-related quality of life.

The research described in this thesis emphasises the large public health potential of physical activity. In our general discussion we argued that the present situation on physical inactivity in the Netherlands makes it crucial for researchers and policy makers to act now.

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[1]

Introduction

Historical perspective

In the Stone Age, physical activity constituted a vital part of life since in that time period hunting and gathering were men's core business. Our original genome was selected to support daily physical exertion and to make our biochemistry and physiology function optimally in such circumstances.[1-3] During the course of history, hunting was replaced by agriculture and later on by industry and information technology, eventually creating conditions to allow and sometimes even promote a sedentary lifestyle. Researchers have argued that our genome and therefore our biochemistry and physiology remained similar through time.[1-3] Therefore, average physical activity levels in industrialised countries became disconcordant with energy requirements.[1] The adverse effects of men's evolution through industrialisation led to an increased prevalence of cardiovascular diseases in the second half of the 20th century.[4] This left us with the key issue of how much physical activity would equal the standard for which the human genome was originally selected.[1-3]

Physical activity research started in the 1950's.[5] In that period, Morris and colleagues observed that men in physically active jobs suffered less coronary heart disease than men in sedentary jobs did. Moreover, they observed that if this disease developed among the active, it was less severe and stroke at later ages.[6;7] Recommendations for physical activity and health at that time were based on systematic comparisons of effects from different exercise training programs and were always specific regarding type, frequency, intensity and duration of activity.[4] In 1990, the American College of Sports Medicine published their first position statement in which they recognised that activities of moderate intensity may have health benefits too. Epidemiological research had shown that the quantity and quality of exercise needed to obtain health-related benefits may differ from what is recommended for fitness benefits.[8] It was not until 1995 that a new physical activity guideline was introduced that shifted the focus towards a broader scope, adopting a lifestyle approach to physical activity.[9]

Physical activity: definitions and methodology

When physical activity science evolved, it became obvious that clear terminology was needed to avoid confusion. Subsequently, definitions were constructed for physical activity, exercise and physical fitness (Box 1.1).[4;10;11]

> *Physical activity* is defined as bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above the basal level.
>
> *Physical activity* is comprised of activities of daily living, leisure time (including sports, gardening, commuting and activities such as bicycling), occupational and household activities.
>
> *Exercise* is defined as physical activity that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is the objective.
>
> *Physical fitness* includes a set of attributes that people have or achieve that relates to the ability to perform physical activity.

Box 1.1: Definitions of physical activity, exercise and physical fitness.[4;10;11]

Also, much effort was put into developing valid and reproducible methods to assess physical activity. Physical activity has been measured based on self-report (diaries, recall surveys, retrospective quantitative histories and global self-reports) and direct monitoring (behavioural observation, mechanical or electronic devices, or physiologic measurements).[12-14] Surveys are practical for use in large populations because they are not costly, they are relatively easy to administer and they are generally acceptable to study participants. Direct monitoring does not have the problems of poor memory and biased self-report but is limited by high costs and the burden on participants and staff. Consequently, epidemiological and public health research mostly include a physical activity questionnaire instead of a monitoring device.[14]

Behavioural determinants of physical activity

In the 1980's the determinants of behaviour model (Figure 1.1) was developed based on Fishbein and Ajzen's model of reasoned behaviour and Bandura's concept of self-efficacy.(15)

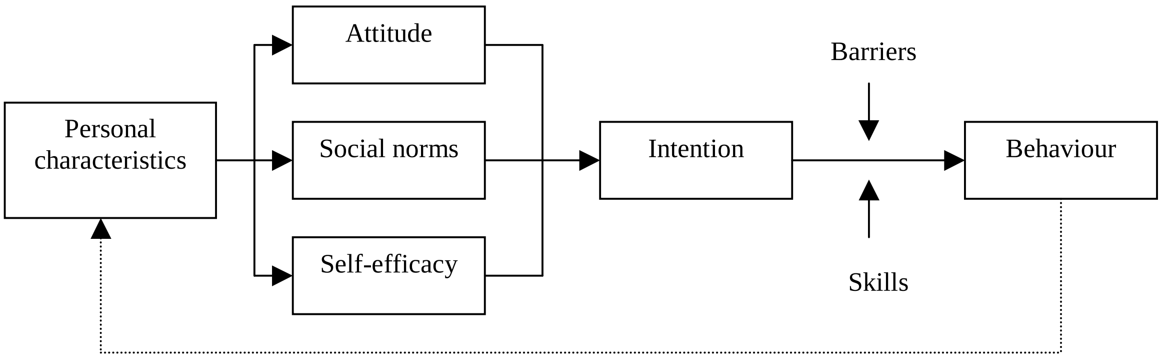

Figure 1.1: The determinants of behaviour model.(15)

In this theoretical model, attitudes, social norms and self-efficacy (see Box 1.2 for definitions) predict the intention to behave in a certain way, which in turn predicts the behaviour. Personal characteristics (for example gender, age and educational level) influence these behavioural determinants. Barriers and skills determine when or why the intention is turned into behaviour.

> *Attitude* is defined as the weighing of all the advantages and disadvantages of the behaviour.
>
> *Social norm* is defined as the weighing of all the expectations of relevant others about the person's behaviour.
>
> *Self-efficacy* is the estimation of the person about his/her ability to perform a specific behaviour in a specific situation.

Box 1.2: Definitions of attitude, subjective social norm and self-efficacy.(15)

Personal characteristics such as age, gender, ethnicity and educational level have been thoroughly studied in association with physical activity. Age and ethnicity (being non-white) have consistently been found to be inversely related to physical activity, whereas educational level, socio-economic status and being male were positively related to physical activity.[16-18] Generally, self-efficacy proofed to be the most consistent behavioural determinant of physical activity. A high level of self-efficacy was associated with a high level of physical activity.[16;17] Constructs like social norms, attitudes and intention were not consistently associated with physical activity.[16;17]
Compared to other health-related behaviours such as smoking and diet, research on behavioural determinants of physical activity has been published considerably less frequently. In particular, knowledge on behavioural determinants of specific domains and specific types of physical activity as well as knowledge on determinants of adherence to the new physical activity guideline is scarce.[17]

Environmental determinants of physical activity

Barriers (Figure 1.1) to physical activity such as lack of time, tiredness, bad weather and no facilities have an influence on whether or not people become and remain physically active.[19;20] The physical environment, which contains numerous potential barriers, is associated with physical activity at two levels: the individual level and the community level.[21] Within these categories, aspects can be measured subjectively (*how do people experience their physical environment*) and objectively (*what does the physical environment look like in terms of for example the square area of recreational space, amount of bicycle paths or proximity to sports facilities*). Examples of individual aspects of the physical environment are exercise equipment at home, access to facilities and satisfaction with recreational facilities. Examples of community aspects of the physical environment are neighbourhood safety, hilly terrain and enjoyable scenery.[21]
Physical environments have the capacity to obstruct or to facilitate physical activity and yet research on the association between physical environment and physical activity is limited. This is particularly true for research including objectively measured features of the physical environment.[21;22]

Physical activity, obesity and cardiovascular diseases

In general, epidemiological studies showed that low levels of physical activity increase the risk of cardiovascular diseases (CVD). In addition, a dose-response relationship was found, indicating that the benefit caused by a certain amount of physical activity is further increased by a higher level of physical activity.(4;23;24) Numerous studies have been published on the association between physical activity and coronary heart disease (CHD) and in 1990 Berlin and Colditz published a meta-analysis on physical activity in the prevention of coronary heart disease.(25) Table 1.1 summarises their results. Based on these results Berlin and Colditz concluded that lack of physical activity is a potentially modifiable risk factor for coronary heart disease.

Table 1.1: Pooled relative risks (RR (95%CI)) from cohort studies on physical activity (occuptional and leisure time) and risk of heart disease.(25)

Outcome †	Occupational physical activity		Leisure time physical activity	
	Mod / High	Low / High	Mod / High	Low / High
CHD incidence	1.1 (0.9 , 1.3)	1.4 (1.0 , 1.8)	--	--
CHD death	1.4 (1.2 , 1.8)	1.9 (1.6 , 2.2)	1.3 (1.1 , 1.7)	1.6 (1.2 , 2.2)
MI	1.3 (0.9 , 1.9)	1.4 (0.9 , 2.1)	1.4 (1.1 , 1.7)	2.9 (1.9 , 4.5)

† CHD: coronary heart disease, MI: myocardial infarction.

The association between physical activity and stroke is less clear. Although some studies found U-shaped or even positive relationships, most studies indicate an inverse relationship between physical activity and stroke.(4;10;26) In general, moderately intense physical activity seemed sufficient to achieve significant reduction in stroke risk.(26) Nevertheless, more research is needed to quantify this relationship in general, as well as for subtypes of stroke and different levels of physical activity.

Obesity, a factor closely related to physical activity, is also a risk factor for coronary heart disease.(27) Table 1.2 summarises the results of a prospective study among 48,287 Dutch men and women on the association between body mass index (BMI) and CHD mortality.(28) Especially among obese individuals (BMI ≥30.0 kg/m^2), an increased risk of CHD mortality was found. Other observational studies showed that BMI is also associated with stroke risk.(29-31) However, relative risks were generally lower than for the association between BMI and CHD mortality.

Table 1.2: Age-adjusted relative risks of 12-year CHD mortality as reported in the Dutch Consultation Bureau Project on Cardiovascular Diseases.[28]

BMI (kg/m^2)	Men	Women
18.5-24.9	1.00	1.00
25.0-26.9	1.40 (0.98 , 2.00)	1.95 (0.83 , 4.55)
27.0-29.9	1.66 (1.13 , 2.43)	2.38 (0.97 , 5.85)
≥30.0	3.01 (1.83 , 4.94)	2.96 (1.14 , 7.96)

In observational studies, both overweight (BMI 25.0-30.0 kg/m^2) and obesity (BMI ≥30 kg/m^2) were correlated with physical activity, with inactive persons having a higher body mass index.[32] This makes it of interest to know whether (over)weight and physical activity interact in relation to CHD and stroke mortality. Research has shown that the protective effect of physical activity on CHD is often stronger among those with a higher body mass index.[33] Sometimes this even resulted in overweight or obese individuals who were physically active having a lower risk of morbidity and mortality than normal weight individuals leading sedentary lives. This trend was mainly seen for CHD in combination with cardiorespiratory fitness. It is not clear to what extend this trend results from inactivity or from elevated weight.[33] No studies have been published on the interaction between physical activity and obesity in relation to stroke mortality. More research on the interaction between physical activity and obesity in their association with mortality is necessary in order to make quantitative statements on this subject concerning various types of outcome measures.

Physical activity and health-related quality of life

Since 1948, the World Health Organisation defines health[i] as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Consequently, interest in the assessment and promotion of health-related quality of life grew.[4] It has been shown that participation in physical activity is associated with a higher level of health-related quality of life.[4;34] However, the vast majority of studies addressed this association cross-sectionally. Studies that dealt with this association in a longitudinal design were conducted mainly in clinical settings and

[i] Preamble to the Constitution of the World Health Organisation as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 states (Official Records of the World Health Organisation, no. 2, p. 100) and entered into force on 7 April 1948.

involved patient populations with cardiovascular diseases, pulmonary disease, arthritis, cancer and diabetes.[4;34] These longitudinal studies generally showed that physical activity was associated with improvements in different aspects of health-related quality of life such as perceived change in mental and physical functioning, life satisfaction and perceived health status.[4;34] Studies aiming to explore this longitudinal association in the general population are scarce.

Aim and outline of this thesis

Physical activity epidemiology studies the association of physical activity with disease and other health outcomes, the distribution of physical activity in the population, the determinants of physical activity as well as the interrelationship of physical activity with other behaviours.[11] Because of this broad definition, we made some choices concerning the studies included in this thesis.

We chose to address a methodological issue in physical activity epidemiology by studying reproducibility and relative validity of a newly developed physical activity questionnaire. With respect to determinants of physical activity, we chose to focus this thesis on specific types and domains of physical activity such as walking, bicycling and adherence to the Dutch physical activity guideline. With respect to health outcomes, we concentrated on cardiovascular diseases and health-related quality of life.

The overall aim of this thesis was to quantify public health aspects of physical activity in the Netherlands. Specifically, we explored the following issues:

a) reproducibility and relative validity of a newly developed physical activity questionnaire,
b) environmental, behavioural and lifestyle determinants of physical activity,
c) the association of physical activity with stroke morbidity and mortality,
d) the interaction between physical activity and BMI in relation to CHD, stroke and CVD mortality, and
e) the cross-sectional and longitudinal association between physical activity and health-related quality of life in the general population.

Chapter 2 of this thesis represents our validation study of the short questionnaire to assess health-enhancing physical activity (the SQUASH). In chapter 3 behavioural and lifestyle determinants of adherence to the Dutch physical activity guideline and of moderate to vigorous levels of physical activity are described. Chapter 4 presents the association between surface of green and recreational space close to home and time spent on walking and bicycling. Chapter 5 deals with the association between physical activity and stroke morbidity and mortality by means of a meta-analysis. In chapter 6, the association between physical activity, BMI and CHD, stroke and CVD mortality is highlighted. Chapter 7 describes the cross-sectional and longitudinal association between physical activity and health-related quality of life in the general population. A general discussion of the different topics described in this thesis is given in chapter 8.

[2]

Reproducibility and relative validity of the short questionnaire to assess health enhancing physical activity[*]

Abstract

Purpose To determine reproducibility and relative validity of the short questionnaire to assess health enhancing physical activity (the SQUASH).

Methods Participants (36 men and 14 women, aged 27-58) were asked to complete the SQUASH twice with an in-between period of approximately 5 weeks. In addition, participants wore the Computer Science and Applications (CSA) Activity Monitor for a 2-week period following the first questionnaire.

Results The Spearman correlation coefficient for overall reproducibility of the SQUASH was 0.58 (95%CI: 0.36-0.74). Correlation for the reproducibility of the separate questions varied between 0.44 and 0.96. Spearman's correlation coefficient between CSA readings and the total activity score was 0.45 (95%CI: 0.17-0.66).

Conclusion The SQUASH is a fairly reliable and reasonably valid questionnaire and may be used to order subjects according to their level of physical activity in an adult population. Because the SQUASH is a short and simple questionnaire, it may proof to be a very useful tool for the evaluation of health enhancing physical activity in large populations.

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Introduction

Epidemiological studies often use questionnaires to assess physical activity levels, because it is an inexpensive and generally useful tool in categorising subjects in high and low levels of physical activity. In addition, questionnaires are relatively easy to administer and generally acceptable to study participants.[4;13] Consequently, self-report questionnaires remain the most commonly used method of assessing physical activity.[35] However, because statistics on physical activity depend on the questionnaire used to assess physical activity, it is often not possible to compare results of population studies. Especially for national and regional health institutes this constitutes a definite need to standardise measures of physical activity.[4;35]

Following the Americans, Dutch physical activity experts reached consensus about a physical activity guideline, which states that every adult should accumulate 30 minutes or more of moderate intense physical activity (≥ 4 MET) on most, preferably all days of the week. Most of the frequently used physical activity questionnaires like the Baecke, the EPIC and the Voorrips questionnaire are not designed to estimate compliance to this guideline.[36-39]

Therefore, the Dutch National Institute for Public Health and the Environment developed the Short QUestionnaire to ASsess Health enhancing physical activity (the SQUASH). The basic assumption for the questionnaire was that it should (a) be reproducible and valid, (b) be short (less than 5 minutes to fill in) and (c) contain questions on habitual activities with respect to occupation, leisure time, household, transportation means and other daily activities. It should be noted that the questionnaire was not designed to measure energy expenditure, but to give an indication of the habitual activity level. The SQUASH was structured in such a way that it would be possible to assess compliance to physical activity guidelines.

The aim of this study was to investigate reproducibility and relative validity of the SQUASH in measuring the habitual activity level of a population.

Methods

Study population

Participants were recruited from a commercial bank in the cities of Arnhem and Zoetermeer in the Netherlands. The age range of the source population was 18-65 years. Recruitment took place in July and August 1999. The aim was to recruit 60 participants, equally divided over men and women. Of the eligible source population 55 employees voluntary applied for the study. Five men withdrew from the study because of time restraints. Eventually, 50 subjects (36 men and 14 women) were enrolled. All subjects signed an informed consent form. The study was executed during the summer season with no large fluctuations in weather conditions.

Study design

Participants were submitted to a physical examination and were asked to fill in the SQUASH. In addition to the SQUASH some demographic questions were asked. During the following two weeks the participants wore the Computer Science and Applications (CSA), Inc. activity monitor and they kept a monitor diary in which periods of non-compliance to the CSA were noted. The SQUASH was administered for a second time after a period of approximately five weeks.

Physical activity questionnaire

Appendix A contains the SQUASH. Completing the SQUASH takes about 3-5 minutes (monitored during the first SQUASH measurement). To guide participants through the questionnaire, questions were pre-structured in (A) commuting activities, (B) leisure time activities, (C) household activities and (D) activities at work and school. To make it easier for subjects to know which types of activities were applicable, examples of activities were mentioned under sports, household activities and activities at work. The choice of activities included in the SQUASH was based on their intensity (≥4 MET), except for light household activities and light activities at work and school. These activities usually represent a considerable amount of time per day and therefore they contribute to the habitual activity level of a population. Hobbies were not included in the SQUASH. These activities often have very low MET-values (<2 MET) and were

therefore considered to contribute negligibly to habitual activity levels. Hobbies that do have meaningful MET-values are often noted as sports.
The SQUASH consists of three main queries: days per week, average time per day and intensity. Pre-structuring in frequency and duration has proven to give more reliable results.[13] In parts (C) and (D), intensity was pre-structured into two categories in order to keep the questionnaire short and easy to fill in. In part (D), the 'days per week' query was omitted for the same reason. Moreover, it was assumed that participants are used to quantify their time at work and school in terms of hours per week.

All 50 subjects completed the SQUASH twice. They were asked to refer to an average week in the past months. Between the first and second SQUASH measurement there was a period of approximately 5 weeks. This period was thought to be long enough to ensure that participants could not copy the SQUASH from memory and short enough to prevent large changes in physical activity levels. The SQUASH was checked for completeness by the researcher. If applicable, missing answers were added later to the questionnaire, after consulting the subjects.

Calculating the activity score per week from the questionnaire

Activities were divided into three intensity categories: 2-<4.0 MET (light), 4.0-<6.5 MET (moderate) and ≥6.5 MET (vigorous) with the help of Ainsworth's compendium of physical activities.[40] Activities with a MET-value lower than 2 MET were not included in the SQUASH for reasons mentioned earlier. Cut off points for intensity categories were based on the Dutch physical activity guideline.[41] Based on the reported effort in the questionnaire, activities were given an intensity score (ranging from 1 to 9) as depicted in Table 2.1.

Table 2.1: Intensity scores used for calculation of the SQUASH activity scores.

	Intensity scores based on reported effort †		
	Light	***Moderate***	***Intense***
Commuting activities			
Walking to/from work or school	1	2	3
Bicycling to/from work or school	4	5	6
Leisure time activities			
Walking	1	2	3
Bicycling	4	5	6
Gardening	4	5	6
Odd jobs	1	2	3
Sports			
2-<4 MET	1	2	3
4-<6.5 MET	4	5	6
≥ 6.5 MET	7	8	9
Household activities			
Light household work		2	
Intense household work		5	
Activity at work or at school			
Light work		2	
Intense work		5	

† Intensity scores ≥ 3 were assumed to represent health enhancing physical activity.

For example: bicycling received an intensity score of either 4, 5 or 6 based on reported effort being slow, moderate or fast respectively. For walking these intensity scores were 1, 2 and 3. Household work and activities at work or school were pre-structured for intensity. Therefore, for these items we used a basic intensity score of 2 and 5 for light and intense activities respectively. Total minutes of activity were calculated for each question by multiplying frequency (days/week) by duration (min/day). Activity scores for separate questions were calculated by multiplying total minutes of activity by the intensity score. The total activity score was calculated by taking the sum of the activity scores for separate questions.

Activity monitor

In the present study we used the CSA Inc. Activity Monitor (model AM7164-2.2), which is a small (5.1 x 3.8 x 1.5 cm), lightweight (45 g), single channel accelerometer. This accelerometer was designed to measure and record time varying accelerations ranging in magnitude from approximately 0.05 to 2 times gravitational acceleration. The activity monitor is band limited with a frequency response from 0.25 to 2.5 hertz. Operating this way, the monitor detects normal human motions and rejects motions from other sources.[42] Data were collected for each minute beginning at the time the monitor was programmed to start and finishing at the time the monitor was manually stopped by the researcher. The data collected by the activity monitor are counts per minute representing the intensity of activity in each minute.

Participants were instructed to wear the monitor for a period of two weeks during the time they were not asleep, except for swimming and showering. Placement of the monitor was attached to a belt on the waist (sagital line), the notch on the case pointing upward. Participants were instructed to keep the monitor snugly against the body so it was not allowed to flop around.

Calculating activity counts per minute from the activity monitor

Total activity counts per minute were calculated by dividing the total activity count over two weeks by the total number of minutes that the monitor was worn. Cut off points for the intensity groups were consistent with those of the SQUASH (2, 4 and 6.5 MET). Activity counts were converted to MET-values using the equation published by Freedson et al..[43] For the purpose of reproducibility of this reference method, the activity level was only calculated for days on which the monitor was worn for 12 hours or longer. Assuming one sleeps for 8 hours a day, collecting data for a minimum of 12 hours represents at least 75% of the available time (16 hours) per day. Furthermore, the monitor had to be worn for at least 7 days, because of comparability to the SQUASH reference period. As a consequence, valid CSA data were available for 37 participants (26 men and 11 women). The main reason for participants not to wear the CSA was forgetting to wear it. In only one subject we encountered a technical problem; one of the belt notches broke of which made that accelerometer unusable.

Physical examination

The physical examination consisted of measurement of height, weight, waist circumference, blood pressure and the submaximal Astrand test (aerobe fitness test). Height was measured to the nearest 0.5 cm without shoes, while weight was measured to the nearest 0.5 kg in subjects wearing indoor clothing and no shoes, after they had emptied their pockets. Waist circumference was measured with a tape measure in the middle between the bottom of the lower rib and the top of the pelvis. Blood pressure was measured with a fully automatic sphygometer (Omron 711, Omron Healthcare Europe B.V., Hoofddorp, the Netherlands). The submaximal Astrand test was executed with a mechanically braked bicycle ergometer (Monark).(44) The purpose of this test is to estimate physical fitness by predicting maximal oxygen consumption. The predicted maximal oxygen consumption is based upon the steady-state heart rate of a person exercising at a submaximal power level for 6 minutes. These measures were used to characterise the study population.

Statistical analysis

Reproducibility of the SQUASH was examined by calculating Spearman's correlation coefficient between the total activity scores from both administrations (overall and separate for each activity). We hypothesised that reproducibility of the SQUASH lies within the upper range of reproducibility of other questionnaires (correlation coefficient between 0.37 and 0.92).

Overall relative validity was investigated by assessing Spearman's correlation coefficient between the total activity score of the first SQUASH administration and the counts per minute of the CSA. We used the first SQUASH administration in order to a) avoid a possible bias caused by increased awareness of activity as a result of wearing a CSA and b) to exclude the possibility of bias as a result of a learning effect. Validity of the SQUASH should be within the upper range of validity (Spearman correlation coefficient between 0.32 and 0.45) of other questionnaires validated with accelerometers. The aimed size of our study population (n=60) was calculated to be sufficient to find a significant correlation coefficient of at least 0.43. In addition to the overall relative validity, the ability of the SQUASH regarding categorising subjects according to their physical activity level was examined. For this purpose the Kappa statistic was calculated for the tertiles of both activity scores and activity counts. Kappa values of 0.4 and higher are assumed to represent fair to good agreement. For the same purpose we calculated exact agreement between tertiles. An exact agreement of 50% or higher are assumed to represent fair agreement.

Table 2.2: Characteristics (mean ± sd) of the study population.

	Total n = 50	Men n = 36	Women n = 14
Age (years)	44 ± 6	45 ± 6	41 ± 7
Height (m)	1.75 ± 0.10	1.79 ± 0.08	1.64 ± 0.09
Weight (kg)	81.0 ± 14.4	85.6 ± 12.6	69.3 ± 12.2
Body Mass Index (kg/m^2)	26.3 ± 3.9	26.6 ± 3.9	25.6 ± 3.9
Waist circumference (cm)	91.3 ± 12.6	95.5 ± 11.1	80.3 ± 9.5
Systolic bp (mmHg)	127 ± 17	132 ± 16	117 ± 13
Diastolic bp (mmHg)	83 ± 10	84 ± 11	79 ± 7
Fitness (%)†			
Low	0	0	0
Fair	12.0	13.9	7.1
Average	40.0	44.4	28.6
Good	38.0	27.8	64.3
High	8.0	11.1	0
Very high	2.0	2.8	0
Social economic status (%)‡			
Low	66	61	79
Medium	10	11	7
High	24	28	14
Physical activity (min/day)			
SQUASH			
2-< 4 MET	360 ± 128	370 ± 138	350 ± 100
4-<6.5 MET	60 ± 67	63 ± 66	54 ± 72
≥ 6.5 MET	10 ± 24	12 ± 28	2 ± 5
CSA			
2-< 4 MET	120 ± 40	130 ± 37	109 ± 43
4-<6.5 MET	10 ± 10	12 ± 10	5 ± 6
≥ 6.5 MET	2 ± 3	3 ± 4	1 ± 0.5

† Categories of fitness according to the submaximal Astrand bike test.[44]

‡ Social economic status is based on educational level: low = lower vocational and primary, medium = intermediate vocational and secondary, high = higher vocational and university.

Results

The average age of the study population was 44 years and about 70% were men. Approximately two thirds of the study population had a primary or lower vocational education. Approximately 50% of the study population had a good, high or very high fitness (Table 2.2). According to the SQUASH 84% of the total minutes of activity per week was spent in the intensity category 2-<4 MET, whereas according to CSA readings 91% of registered time was spent in this category. The mean absolute amount of time spent in all three intensity categories was consistently higher for the SQUASH than for the CSA (Table 2.2).

In total, 60% of the reported time concerned activities at work. Household activities took up 22% of the reported time. For leisure time and commuting activities this was 16% and 2% respectively (Table 2.3).

Reproducibility

Spearman's correlation coefficient for the total activity score was 0.58. Reproducibility of the separate questions had a mean value of 0.75 (range: 0.44-0.96; Table 2.3). Intense household work was least reliable and commuting by bike was most reliable.

Reproducibility (Spearman's correlation coefficient) within the intensity categories (2-<4 MET, 4-<6.5 MET and ≥ 6.5 MET) was 0.58, 0.54 and 0.92 respectively (not in Table).

Relative validity

Spearman's correlation coefficient between the calculated activity levels from the SQUASH and the CSA was 0.45 ($p = 0.005$; 95%CI: 0.17-0.66). When comparing tertiles of the activity score with tertiles of the activity counts, exact agreement was 46% and the weighed kappa was 0.30 (Figure 2.1).

Table 2.3: Mean (sd) amount of minutes per week, activity score for the dual measurement, and reproducibility (Spearman correlation coefficient (95%CI)) for all items of the SQUASH together and separate for each item.

Item	Minutes / week SQUASH-I n = 50		Activity Score† SQUASH-I n = 50		Activity Score† SQUASH-II n = 50		Reproducibility $r_{Spearman}$ (95%CI) n= 50
All items together	3,045	(931)	7,787	(3,061)	7,912	(3,071)	0.58‡ (0.36 , 0.74)
Commuting							
Walking	10	(34)	25	(95)	26	(73)	0.72‡ (0.55 , 0.83)
Bicycling	45	(71)	224	(357)	223	(367)	0.96‡ (0.94 , 0.98)
Activities at work							
Light	1,738	(803)	3,475	(1,606)	3,161	(1,629)	0.73‡ (0.56 , 0.84)
Intense	89	(341)	445	(1,704)	661	(2,284)	0.89‡ (0.82 , 0.94)
Household activities							
Light	618	(644)	1,236	(1,288)	1,113	(1,165)	0.74‡ (0.59 , 0.85)
Intense	60	(111)	298	(552)	728	(1,994)	0.44§ (0.18 , 0.64)
Leisure time							
Walking	93	(178)	209	(426)	136	(259)	0.80‡ (0.68 , 0.88)
Bicycling	69	(120)	369	(684)	355	(619)	0.73‡ (0.57 , 0.84)
Gardening	100	(207)	467	(977)	478	(817)	0.68‡ (0.50 , 0.81)
Odd jobs	80	(169)	158	(339)	186	(364)	0.64‡ (0.44 , 0.78)
Sports	143	(254)	881	(1,688)	845	(1,378)	0.90‡ (0.83 , 0.94)

† Activity score = minutes * intensity, ‡ $p \leq 0.0001$, § $p \leq 0.001$

Discussion

The SQUASH is a short physical activity questionnaire which general purpose is to assess habitual physical activity. Overall reproducibility of the SQUASH was 0.58 (95%CI: 0.36-0.74). High intense activities were more reliable than low intense activities. The SQUASH activity score was significantly correlated with the activity counts per minute measured by the CSA ($r_{Spearman}$=0.45, 95%CI: 0.17-0.66). Consequently, the SQUASH is able to explain 4 - 49 percent of the total variation in physical activity. When comparing tertiles of activity scores with tertiles of activity counts, exact agreement was 46%. This means that approximately half of the population was classified in the same tertile using either CSA or SQUASH. The kappa value of this comparison was 0.30, which is rather low.

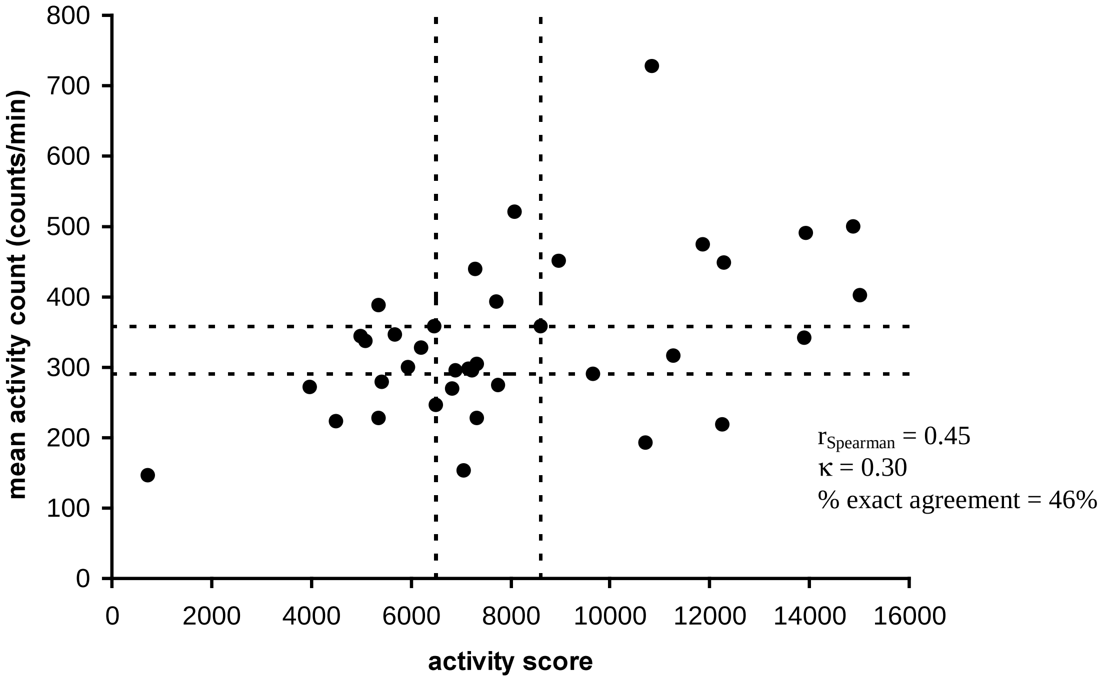

Figure 2.1: Tertiles (dotted lines) of the activity score per week (SQUASH-I) and the mean activity counts per minute (CSA) representing relative validity of the SQUASH.

A few methodological aspects of this study need to be considered. The study population consisted of relatively inactive but fit subjects. This might have influenced reproducibility and relative validity of the physical activity questionnaire, because light, often highly variable activities are the most difficult to recall.[45] The fact that we found a relatively low reproducibility of intense household work can be explained by the frequency of this type of activity. Nowadays, few people spend a lot of time on intense household work on a regular basis, which probably results in a less accurate remembrance of frequency, duration and intensity of this activity.[45] Also the low percentage of women (who are the main performers of the housework) in our study population could have influenced reproducibility of this item.

Reproducibility may also have been influenced by the study design in which the CSA was worn in-between the two measurements of the SQUASH. This may have increased awareness about physical activity among participants during the second measurement. However, we believe this to be of minor influence because of three reasons. First, the

CSA has no display so subjects were not informed about their physical activity level. Second, the CSA is a lightweight (45 grams) device that does not constantly remind subject of wearing it. Third, the period between wearing the CSA and completing the SQUASH for the second time was at least 2 weeks, which makes it less plausible that participants were still better aware of their physical activity level. Nevertheless, if increased awareness did play a role during the second measurement it would have probably led to underestimation of the reproducibility of the SQUASH.

Using the CSA as reference method had some disadvantages. First, the CSA is, unlike the doubly labelled water method, not a golden standard for measurement of physical activity. Using the doubly labelled water method was not an option in this study, because of the costs involved and because it does not measure intensity of physical activity. Second, the CSA is not waterproof and therefore cannot be worn during activities involving water, such as swimming, showering and rowing. However, since these activities do not substantiate the majority of activities in a free-living population, one should be able to estimate the total physical activity level with the CSA. Third, the CSA is a one-axial accelerometer for vertical movement. Consequent to wearing this type of activity monitor on the waist, activities such as bicycling and fitness may not be measured accurately, leading to a possible underestimation of the activity level by the CSA. However, leaving these activities out of the calculation of the activity score did not significantly alter the correlation coefficient between the total activity score and the activity count per minute of the SQUASH. Fourth, the CSA clearly measured lower absolute activity levels (in min/day) than the SQUASH. Although our population was not very active, this difference also seems to represent an underestimation of activity by the activity monitor. A reason could be that the Freedson equation we used for transforming activity counts to MET-values might not be valid in a population with a low level of physical activity. The equation was derived from data collected in a laboratory setting using a motorised treadmill and three types of exercise conditions (slow walking, fast walking and jogging). The range of MET-values represented by these conditions was 3.7-9.7 MET. No data points were available for the 6.5-8 MET range.[43] More research might be needed to develop an equation that represents a wider range of activities, particularly for the lower MET-values, possibly leading to a better estimate of absolute activity levels.

Reproducibility of physical activity questionnaires has been frequently determined in adults in the past.[13] Philippaerts et al. examined repeatability of three physical activity questionnaires and found kappa values varying from 0.61-0.70.[46] Pols et al. found Spearman's correlation coefficients varying from 0.47-0.89 in one study and 0.70-0.76 in another study.[38;47] In two other studies correlation coefficients were reported ranging from 0.37 till 0.92.[48;49] In our reproducibility study we found correlation coefficients for the SQUASH varying from 0.44 till 0.96 for separate items of the questionnaire and a correlation coefficient of 0.58 for all items together. Reproducibility of the SQUASH is therefore comparable to other physical activity questionnaires. The SQUASH has some distinct advantages compared to other physical activity questionnaires, because it is short (only 1 page) and quick to fill in (3-5 minutes). Moreover, the SQUASH provides the opportunity to estimate compliance to physical activity guidelines.

Philippaerts et al. used the doubly labelled water method to validate three physical activity questionnaires in adults (Baecke, Five-city questionnaire and an adapted version of the Tecumseh community health study questionnaire). They found Pearson correlation coefficients varying from 0.34-0.69 for total activity levels.[50] Miller et al. used Caltrac (one-axial accelerometer) readings of 26 adult subjects and compared these to activity levels of five questionnaires (7-day recall ($r_{Spearman}$ 0.79), 3-day recall ($r_{Spearman}$ 0.25), Godin ($r_{Spearman}$ 0.45), Baecke ($r_{Spearman}$ 0.40) and NASA ($r_{Spearman}$ 0.32)).[51] The Caltrac and the CSA were compared by Melanson et al. during walking, fast walking and jogging on treadmill. The two instruments were found to be equally able to measure amount and intensity of physical activity.[52] The correlation coefficient we found in our validation study of the SQUASH lies within the range of correlation coefficients found in the study by Miller et al.. In that study the highest Spearman correlation coefficient was found for the 7-day recall method, which is (together with the 3-day recall method used in that study) in principal a different method than the SQUASH. Comparing validity of the SQUASH with validity of the Godin, Baecke and NASA questionnaire, it can be concluded that validity of the SQUASH lies within the upper range of validity found for other questionnaires that were validated with an accelerometer. Therefore, the correlation coefficient we found ($r_{Spearman}$ = 0.45; 95%CI: 0.17-0.66) for the SQUASH can be marked as reasonable and acceptable. Furthermore, our study population had a relatively sedentary lifestyle since the percentage (58% versus at least 45%) of subjects not complying with the physical activity guideline was approximately 10% higher than in the general Dutch population.[53] This suggests that the overall relative validity of the SQUASH is acceptable for sedentary populations. Based on the assumption that more intense activities are usually easier to recall relative validity of the SQUASH may be higher in the general, more active population. However, this still needs to be further investigated.

In conclusion, the SQUASH is a fairly reliable and reasonably valid questionnaire and may be used to order subjects according to their level of physical activity in an adult population. Because the SQUASH is a short and simple questionnaire, it may proof to be a very useful tool for the evaluation of health enhancing physical activity in large populations.

Appendix A

The short questionnaire to assess health enhancing physical activity

Think about an average week in the past months. Please indicate **how many days per week** you performed the following activities, how much time **on average** you were engaged in this, and (if applicable) how strenuous this activity was for you?

[A] COMMUTING ACTIVITIES (round trip)	**days per *week***	**average time per *day***	**effort (circle please)**
Walking to/from work or school	…. days	…. hours …. minutes	slow/moderate/fast
Bicycling to/from work or school	…. days	…. hours …. minutes	slow/moderate/fast
Not applicable	☐		

[B] LEISURE TIME ACTIVITIES	**days per *week***	**average time per *day***	**effort (circle please)**
Walking	…. days	…. hours …. minutes	slow/moderate/fast
Bicycling	…. days	…. hours …. minutes	slow/moderate/fast
Gardening	…. days	…. hours …. minutes	light/moderate/intense
Odd jobs	…. days	…. hours …. minutes	light/moderate/intense
Sports (please write down yourself)			
e.g.: tennis, fitness, skating, swimming, dancing			
1. ……………………………………	…. days	…. hours …. minutes	light/moderate/intense
2. ……………………………………	…. days	…. hours …. minutes	light/moderate/intense
3. ……………………………………	…. days	…. hours …. minutes	light/moderate/intense
4. ……………………………………	…. days	…. hours …. minutes	light/moderate/intense

[C] HOUSEHOLD ACTIVITIES	**days per *week***	**average time per *day***
Light household work *e.g. cooking, washing dishes, ironing, child care*	…. days	…. hours …. minutes
Intense household work *e.g. scrubbing floor, walking with heavy shopping bags*	…. days	…. hours …. minutes

[D] ACTIVITY AT WORK AND SCHOOL		**average time per *week***
Light work *e.g. sitting/standing with some walking such as in a desk job*		…. hours …. minutes
Intense work *e.g. regularly lifting heavy objects at work*		…. hours …. minutes
Not applicable	☐	

[3]

Psychosocial and lifestyle factors associated with moderate to vigorous levels of physical activity in an adult population

Abstract

Purpose To study the association of psychosocial and lifestyle factors with moderate to vigorous levels of physical activity among adult men and women.

Methods Participants (3,950 men and women, aged 23–70) were asked to fill in a questionnaire on physical activity, behavioural determinants of physical activity, such as attitude towards increasing physical activity levels, social norms and self-efficacy, perception of sufficient affordable exercise facilities in their neighbourhood and other lifestyle factors such as smoking, fruit and alcohol consumption.

Results In general, physical activity was inversely associated with the cognitive attitude and positively with the affective attitude towards increasing physical activity. Also, physical activity was associated with a higher fruit consumption and a lower prevalence of smoking cigarettes. The perception of sufficient affordable exercise facilities in the neighbourhood was positively associated with vigorous physical activity, but not with moderately intense activity. The strength and, in some cases, the direction of the associations varied between subgroups of the population divided by gender, age and educational level.

Conclusion The results of the present study emphasise the need for tailored intervention strategies taking into consideration the population's characteristics, but also the level of physical activity on which the intervention is focussed.

Introduction

Physical inactivity has been noted as the second leading modifiable risk factor for chronic disease.(54) Also, as in many western countries, in the Netherlands approximately six percent of total mortality is attributable to physical inactivity.(55;56) Moreover, approximately half of the Dutch population fails to meet the guideline which states that every adult should accumulate 30 minutes or more of at least moderately intense physical activity per day.(9;41;53;57) Therefore, substantial improvement in public health is expected through an increase of physical activity at the population level.(41;58)

In promoting physical activity on a national and local scale, the key issue is to know how to create opportunities and to decrease barriers for moderately intense and vigorous activities. Furthermore, information is needed to help characterise people that fail to adhere and people that do adhere to the physical activity guideline. In the past, physical activity research emphasised on supervised or structured vigorous physical activity and its associated factors. Less is known about the factors associated with conducting moderately intense physical activities that are easily included in daily life, such as cycling to work or school and/or taking the stairs instead of the elevator.(17;59;60)

The present study investigated factors potentially related to moderate and vigorous physical activity as well as factors discriminating people who do and do not adhere to the physical activity guideline. We distinguish demographic factors, psychosocial factors and lifestyle factors. The demographic factors are of interest to identify subgroups that are at increased risk of inactivity. The psychosocial factors give insights that may be of help in the development of intervention and prevention strategies, whereas lifestyle factors may provide a clearer understanding of the complex behavioural pattern that physical activity is a part of.

Methods

Study population

All participants had previously been involved in monitoring studies carried out in three Dutch towns (Amsterdam, Doetinchem and Maastricht) by the National Institute for Public Health and the Environment in the period 1987-1997.[61;62] In 1998, 3,000 respondents of the Maastricht population were re-examined (response rate: 74%), while in 1999, 1,075 respondents of the Doetinchem population where re-examined (response rate: 72%). All respondents provided a written informed consent.

Data collection

Data used in this study was assessed with a self-administered questionnaire with questions on demographic factors, psychosocial factors, physical activity and other lifestyle factors.

Demographic factors

Demographic factors included gender, age and educational level. A low educational level was defined as lower vocational training or primary school. A medium educational level included secondary school and intermediate vocational training. A high educational level was defined as higher vocational training or university.

Psychosocial factors

The psychosocial factors in this study were derived from the ASE-model.[15;63] This is a theoretical model, in which attitudes, social influences and self-efficacy predict the intention to behave in a certain way, which in turn predicts the behaviour. External variables (for example gender, age and educational level) influence these determinants of behaviour. Barriers or lack of skills determine when or why the intention is turned into behaviour. The ASE-model has been previously used to study predictors of various kinds of behaviour.[15;64]

Attitude towards increasing physical activity was measured by two items. The first (‘Do you consider it good or bad to become more active?’) as well as the second item (‘Do you consider it pleasant or unpleasant to become more active?’) were measured on a five-point scale. Both scales ranged from –2 to +2, with a positive score representing a more positive attitude towards increasing physical activity. Consistent with recent research on the structure of attitudes, these items were treated as separate measures of respectively the cognitive (bad/good) and affective (unpleasant/pleasant) attitude.[(65)]

Social influences were also measured by two items. Perceived physical activity of important others was measured by asking participants to categorise the average activity level of these important others on a five-point scale, with categories ranging from ‘hardly active’ to ‘highly active’. Similar to the attitude scales, this scale ranged from –2 to +2. Perceived social support from these important others was assessed by asking ‘Do these important others encourage you to become more active?’ Possible answers were ‘often’, ‘sometimes’ and ‘no’.

Self-efficacy was measured by asking participants how confident they were about their ability to increase their physical activity level. Answers were rated on a five-point scale (ranging from -2 to +2) with answers ranging from ‘very unsure’ to ‘very confident’.

The intention to increase physical activity was measured by means of the question ‘Do you intend to become more active in the future?’. Answer categories ranged from 'yes' to 'definitely not' on a five-point scale.

In addition, one barrier was measured with the question ‘Are there, for you as an individual, sufficient affordable exercise facilities in your neighbourhood in order to be regularly active?’ Thus, this barrier consisted of a financial and an availability component.

Physical activity

The physical activity questionnaire used was designed for the ‘European prospective investigation into cancer and nutrition’ (EPIC) and was extended with a question on sports and other strenuous leisure time physical activities. Therefore, the questionnaire included questions on time spent on leisure time activities for summer and winter separately and questions on sports and activities at the place of work irrespective of season. Leisure time physical activity included walking, bicycling, odd jobs and gardening. The question on sports and other strenuous physical activities enabled the respondents to report on type, frequency and duration of three different activities. Activities at the place of work were measured in the following categories: ‘sitting’, ‘sitting and standing’, ‘walking regularly while carrying light objects’, ‘walking regularly while carrying heavy objects’.[38]

For leisure time activities the lowest amount of time reported during either summer or winter was used in order to cautiously estimate physical activity levels. All reported sports were provided with a MET-value according to Ainsworth’s compendium of physical activities.[40] [66]Total time (hours/week) spent on moderately intense (4.0–6.5 Metabolic equivalents (MET)) physical activity was calculated by taking the sum of the time reported on bicycling, gardening, sports (4.0-6.5 MET) and moderately intense activity at work (i.e. walking regularly while carrying heavy objects). Time (hours/week) spent on vigorous (≥6.5 MET) physical activity was calculated by taking the sum of the time reported on sports ≥6.5 MET.

In addition, participants were categorised as either complying or not complying with the physical activity guideline.[9;53] We assumed that participants complied if they engaged in at least moderately intense physical activity for a minimum of 3.5 hours a week (interpreted as half an hour of activity, seven days per week)

Other lifestyle factors

Fruit (grams per day) and alcohol consumption (glasses per day) were calculated based on a semi-quantitative food frequency questionnaire, which was developed for the EPIC study.[67] This questionnaire contains questions on habitual consumption per week during the last year of one item for fruit and five items for alcohol (beer, white wine, red wine/rose wine, port/sherry/vermouth/eggnog and spirits). Participants were defined to be smokers if they reported to have smoked one or more cigarettes in the past seven days.

Statistical analysis

All respondents with missing values on key variables (i.e. demographics, psychosocial factors and physical activity) were excluded (3%), leaving a study population of 3,950 men and women aged between 23 and 70 years. Due to the fact that dietary information was not available in Maastricht and due to additional non-response on the food frequency questionnaire in Doetinchem, information on fruit and alcohol consumption was only available for 1,011 of the respondents living in Doetinchem and none of the respondents from Maastricht.

Factors associated with moderately intense and vigorous physical activity

Linear regression analysis was used to study psychosocial and lifestyle factors that predict the time (hours/week) spent on moderately intense and vigorous. In order to detect possible effect modification by age, gender and educational level, analyses were stratified by gender, age and educational level. For this purpose, age was divided into two groups: adults (23-60 years) and elderly (60 years and over), and educational level was defined as low or medium/high. If stratified results showed opposite directions in the association with physical activity, an interaction term was added to the model to test the significance of the possible effect modifier.

Factors discriminating compliance and non-compliance with the activity guideline

Analysis of variance was used to characterise respondents who did and did not comply with the physical activity guideline regarding demographic, lifestyle and psychosocial factors. Analyses were performed stratified by gender, age (adults and elderly) and educational level (low and medium/high) in order to detect possible effect modification by these variables. To test for significance of possible effect modifiers, logistic regression analysis with interaction terms was used. Because these analyses did not reveal effect modification by age, gender or educational level, only results for the total study population will be presented in the results section.

In all analyses, a two-sided p-value of less than 0.05 was assumed to be statistically significant.

Results

Half of the study population consisted of men and both men and women had a mean age of 50 years (Table 3.1). A low educational level was reported by 46% of the male and 59% of the female participants. On average, men spent seven hours per week on moderately intense physical activity and 0.7 hours per week on vigorous physical activity. Women spent approximately four and 0.2 hours per week on these types of activity. Among men, 49% of the participants complied with the physical activity guideline, whereas 41% of the women was sufficiently active according to the guideline (Table 3.1).

Table 3.1: Characteristics (mean ± sd or %) of the study population.

	Men (n = 1,971)	**Women (n = 1,979)**
Age (years)	50 ± 10	49 ± 10
Educational level (%)		
Low	45.7	59.2
Medium	28.2	21.8
High	26.1	18.9
Physical activity		
Moderately intense (hrs/wk)	6.9 ± 12.3	4.3 ± 6.3
Vigorous (hrs/wk)	0.7 ± 2.0	0.2 ± 1.0
Compliance with the physical activity guideline (%)	49.0	40.8

Factors associated with moderately intense physical activity

Time spent on moderately intense physical activity was inversely associated with the cognitive attitude towards increasing physical activity in all subgroups with the exception of the participants with a medium/high educational level and elderly participants (Table 3.2).

Table 3.2: Psychosocial and lifestyle factors associated (β) with moderately intense physical activity in the total study population and stratified by gender, age and educational level.[†]

	Total	Gender		Age		Educational level	
		Men	**Women**	**23-60 years**	**≥60 years**	**Low**	**Medium/high**
cognitive attitude	-1.42[‡]	-1.56[‡]	-1.00[‡]	-1.52[‡]	-0.85	-1.67[‡]	-0.95
affective attitude	0.12	-0.43	0.59	-0.26	1.06[‡]	0.94	-1.03
perceived behaviour of important others	0.36	0.67	0.03	0.57	0.00	0.47	0.20
perceived social support from these important others	-0.91	-1.02	-0.77	-1.35	0.64	-1.42	-0.24
self-efficacy	0.26	0.38	0.22	0.42	0.02	-0.14	0.74
intention to become more active in the near future	-1.79	-2.75	-1.35	-1.90	1.17	-2.17	-1.08
sufficient affordable facilities in the neighbourhood	0.78	1.29	0.29	0.31	1.47	0.87	0.46
current smokers	-0.60	-0.64	-0.95	-0.38	-1.94[‡]	-0.33	-1.14
fruit consumption	0.01[‡]	0.01[‡]	0.00	0.01[‡]	0.00	0.01[‡]	0.01
alcohol consumption	-0.11	-0.10	-0.13	-0.28	0.00	-0.08	-0.20

[†] Analyses in the total study population were adjusted for gender, age and educational level; analyses stratified by gender were adjusted for age and educational level; analyses stratified by age were adjusted for gender and educational level ; analyses stratified by educational level were adjusted for gender and age. [‡] $p<0.05$.

Depending on the subgroup of the population, moderately intense physical activity was inversely or positively associated with the affective attitude towards increasing physical activity, but only among elderly participants a statistically significant association was found (β=1.06). Smoking cigarettes was inversely associated with moderately intense physical activity, but was only found significant among elderly participants (β=-1.94). A positive association (β=0.01) between fruit consumption and moderately intense physical activity was found among men, adults and participants with a low educational level.

Educational level was identified as an effect modifier in the association between the affective attitude towards increasing physical activity and moderately intense physical activity (p for interaction = 0.03; not in Table)

Factors associated with vigorous physical activity

Time spent on vigorous physical activity was inversely associated with the cognitive attitude towards increasing physical activity and positively associated with the affective attitude towards increasing physical activity among all subgroups with the exception of women and elderly participants (Table 3.3). Among elderly participants a positive association (β=0.10) was found between perceived behaviour of important others with vigorous physical activity. The perception of sufficient affordable exercise facilities in the neighbourhood was positively associated with vigorous physical activity among women (β=0.26), adults (β=0.47) and participants with a medium/high educational level (β=0.46). Time spent on vigorous physical activity was inversely associated with smoking cigarettes among men (β=-0.51), adults (β=-0.38) and those with a medium/high educational level (β=-0.44; Table 3.3).

Age was an effect modifier in the association between vigorous physical activity and the affective attitude (p for interaction = 0.02; not in Table), whereas educational level was identified as being an effect modifier in the association between vigorous physical activity and the intention to become more active in the near future (p for interaction = 0.03; not in Table).

Table 3.3: Psychosocial and lifestyle factors associated (β) with vigorous physical activity in the total study population and stratified by gender, age and educational level.[†]

	Total	Gender		Age		Educational level	
		Men	**Women**	**23-60 years**	**≥60 years**	**Low**	**Medium/high**
cognitive attitude	-0.25[‡]	-0.42[‡]	-0.11	-0.31[‡]	-0.02	-0.25[‡]	-0.25[‡]
affective attitude	0.25[‡]	0.47[‡]	0.05	0.32[‡]	-0.03	0.20[‡]	0.32[‡]
perceived behaviour of important others	-0.02	-0.07	0.08	-0.05	0.10[‡]	0.04	-0.11
perceived social support from these important others	0.01	-0.10	0.11	0.01	0.04	0.05	-0.03
self-efficacy	-0.06	-0.08	-0.02	-0.08	0.02	-0.03	-0.12
intention to become more active in the near future	-0.07	0.04	-0.18	-0.03	-0.21	0.21	-0.34
sufficient affordable facilities in the neighbourhood	0.31[‡]	0.22	0.26[‡]	0.47[‡]	0.16	0.25	0.46[‡]
current smokers	-0.34[‡]	-0.51[‡]	-0.12	-0.38[‡]	-0.05	-0.26	-0.44[‡]
fruit consumption	0.00[‡]	0.00	0.00	0.00	0.00	0.00	0.00
alcohol consumption	0.05	0.05	0.07	0.06	0.01	0.02	0.09

[†] Analyses in the total study population were adjusted for gender, age and educational level; analyses stratified by gender were adjusted for age and educational level; analyses stratified by age were adjusted for gender and educational level ; analyses stratified by educational level were adjusted for gender and age. [‡] $p<0.05$.

Table 3.4: Demographic, psychosocial and lifestyle factors (mean (95%CI)) associated with compliance and non-compliance with the physical activity guideline.[†]

	Non-compliance n = 1,774		**Compliance n = 2,176**	
Gender (% male)	49.3	(47.1 , 51.4)	57.4	(55.0 , 59.8)[‡]
Age (years)	49.3	(48.8 , 49.7)	48.4	(47.9 , 48.8)[‡]
Educational level (% low)	52.7	(50.7 , 54.7)	52.2	(50.0 , 54.4)
Cognitive attitude (score)	1.31	(1.27 , 1.35)	1.12	(1.08 , 1.16)[‡]
Affective attitude (score)	0.89	(0.85 , 0.94)	0.93	(0.88 , 0.98)
Perceived behaviour of important others (score)	0.07	(0.03 , 0.12)	0.07	(0.03 , 0.12)
Perceived social support from these important others (% no support)	60.1	(57.9 , 62.2)	61.6	(59.2 , 63.9)
Self-efficacy (score)	0.89	(0.85 , 0.93)	0.98	(0.94 , 1.03)[‡]
Intention to become active in the near future (% yes)	13.6	(12.2 , 15.1)	11.4	(9.8 , 12.9)[‡]
Sufficient affordable facilities in the neighbourhood (% yes)	73.5	(71.7 , 75.4)	81.7	(79.6 , 83.7)[‡]
Smoking status (% current smokers)	27.2	(25.3 , 29.1)	18.8	(16.8 , 20.9)[‡]
Fruit consumption (g/day)	168	(156 , 180)	195	(184 , 207)[‡]
Alcohol consumption (glasses/day)	1.5	(1.3 , 1.6)	1.3	(1.1 , 1.4)[‡]

[†] Adjusted for gender, age and/or educational level, [‡] $p<0.05$.

Factors discriminating compliance and non-compliance with the activity guideline

Participants that adhered to the physical activity guideline, were predominantly male and were younger than participants not complying with the physical activity guideline (Table 3.4). Participants who complied with the guideline scored significantly lower on the cognitive attitude (1.12 vs 1.31 score points) and significantly higher on self-efficacy (0.98 vs 0.89) compared to those who did not comply with the physical activity guideline. Non-compliers more often intended to become more active in the near future than compliers did. In addition, the proportion of participants perceiving sufficient affordable exercise facilities in their neighbourhood was higher among those who complied with the guideline compared to those who did not comply (81.7% vs 73.5%). Also, participants who complied with the physical activity guideline consumed more fruit, fewer glasses of alcohol per day and were less often smokers (Table 3.4).

Discussion

In this cross-sectional study among adult men and women, psychosocial and lifestyle factors associated with moderate to vigorous levels of physical activity were studied.

Moderate to vigorous physical activity was inversely associated with the cognitive attitude towards increasing physical activity and positively associated with the affective attitude towards increasing physical activity. The perception of sufficient affordable exercise facilities in the neighbourhood was positively associated with vigorous physical activity, but not with moderately intense physical activity. Both moderately intense and vigorous physical activity were associated with a higher fruit consumption and a lower prevalence of smoking cigarettes. Participants who complied with the physical activity guideline were characterised as scoring lower on the cognitive attitude towards increasing physical activity and higher on self-efficacy. In addition, these participants more often perceived sufficient affordable exercise facilities in the neighbourhood and reported a healthier lifestyle pattern.

Before discussing our results in light of other studies, the internal validity of this study needs to be discussed. The questionnaire used to assess physical activity was validated (excluding the sports item) with an activity diary in a previous study. Spearman correlation coefficients for total energy expenditure were 0.43 in men and 0.51 in women. This represents an acceptable relative validity for a self-report instrument on physical activity.[38] The food frequency questionnaire used to assess fruit and alcohol consumption was validated with 12 monthly 24-hour recalls. Spearman rank correlation coefficients for fruit consumption were 0.68 in men and 0.56 in women. For alcoholic beverages these coefficients were 0.74 and 0.87 respectively. Based on relative validity of these and other food groups Ocké et al. concluded that this questionnaire seems reasonably valid for ranking individuals according to food group intake.[67] The questionnaire used to assess psychosocial factors was relatively short and contained only single items, which means that these factors were assessed in a rather crude manner. However, relative validity of these single items proved to be acceptable, since secondary analyses within this study showed the correlation between intention and respectively self-efficacy, the cognitive and the affective attitude to range from 0.37 till 0.47.

As in all studies using self-reported measures of physical activity, differential over-reporting may have caused bias in the associations found in this study. However, it is not clear to what degree this problem could have biased our results. The associations described in the present study might also have been influenced by non-response bias. Nevertheless, previous research showed that response bias will not necessarily cause bias in the associations under study.[68]

Previous studies showed a consistent association between attitude towards physical activity and physical activity as well as between self-efficacy and physical activity. Most of these studies focused on vigorous physical activity.[18;20;69-72] In the present study, we only found an association between adherence to the physical activity guideline and self-efficacy. Also, we took two attitude scores (cognitive and affective) towards increasing physical activity into account and looked at both moderately intense and vigorous physical activity. Previous studies mostly investigated the attitude towards physical activity and not the attitude towards increasing physical activity. In the present study, the association between physical activity and the cognitive attitude was present independently of the intensity of physical activity, whereas the association with the affective attitude was predominantly found for vigorous physical activity. However, the direction of these associations needs to be discussed. It seems that active people less frequently perceive it to be good to become more active than inactive people do. At the same time they more often perceive it to be pleasant to become more active than inactive respondents do. Apparently, increasing physical activity because it is good is no longer an important motivational factor among those who already are active, whereas increasing physical activity because it is pleasant still is.

Social influences, in particular social support from friends and family, has also shown to be consistently and strongly associated with physical activity.[73-75] In the present study, no significant associations between social influences and physical activity were found in the general study population. As already proposed by Smith and Biddle, it might be that social support is more related to vigorous activity and less to moderately intense physical activity.[73] Our study partly supports this point of view. We found a positive association between perceived behaviour of important others and vigorous physical activity in respondents aged 60 years and older.

In general, previous studies showed that active people experience fewer barriers to physical activity than inactive people do.[75-77] However, only a few studies examined financial barriers.[77;78] Mitchell et al. studied financial barriers, as part of an integrated measure of perceived barriers. They found that highly active group members perceived fewer barriers than inactive group members did.[77] Chinn et al. found that lack of money became less of a barrier with increasing age and education.[78] In the present study we adjusted for both age and educational level and still found an association between sufficient affordable exercise facilities in the neighbourhood and vigorous physical activity. Also, participants who complied with the physical activity guideline more often perceived sufficient affordable exercise facilities in the neighbourhood. Therefore, the present study showed that the association between the perceived financial barrier and physical activity may be present only for vigorous activities and that this association is likely to be present independently of age and educational level.

Physical activity has been shown to be associated with other healthy lifestyle factors, such as a healthy diet and a higher prevalence of non-smoking.[18;79;80] In the present study, compliance with the physical activity guideline was associated with fruit consumption, alcohol consumption and non-smoking. King et al. concluded that the association between smoking and physical activity is probably small to modest.[18] Our results indicate that the strength of this association depends on the intensity level of physical activity and the subgroup of the population. In the present study, smoking cigarettes was inversely associated with vigorous physical activity among men, among adults up to 60 years of age and among participants with a medium/high educational level. An association with moderately intense physical activity was found only among elderly (60 years and older).

In conclusion, this study provides evidence that interventions aimed at increasing moderately intense or vigorous physical activity should focus on increasing self-efficacy and on the fact that increasing one's physical activity level might be a pleasant experience. Moreover, availability and financial accessibility of sports and recreational facilities in the neighbourhood may play an important role in enabling people to become and stay active. Furthermore, interventions may benefit from an integrated health message including fruit consumption and/or smoking. The results of the present study showed that in spite of an overlap in associated factors across levels of physical activity, each level of physical activity seems to be associated with specific factors. In addition, the factors associated with various levels of physical activity probably differ across subgroups of the population divided by gender, age and educational level.

In summary, this study emphasises the need for tailored intervention strategies taking into consideration the characteristics of the population, but also the level of physical activity on which the intervention is focussed.

[4]

Factors of the physical environment associated with walking and bicycling*

Abstract

Purpose To identify factors of the physical environment that may influence time spent on walking and bicycling.

Methods Demographic factors and time spent on walking and bicycling (during leisure time and for commuting purposes) were assessed with a self-administered questionnaire. GIS databases were used to objectively measure the total square area of green and recreational space (woods, parks, sport grounds, allotments for vegetable gardens and grounds for day trips) in a circle around the postal code of a respondent with a radius of 300 and 500 metres. Multilevel regression analysis was used to study the association between time spent on walking and bicycling on the one hand and the surface of green and recreational space on the other hand. Analyses were adjusted for gender, age and educational level.

Results In a neighbourhood defined as a circle with a 300-meter radius the square area of sport grounds was associated with time spent on bicycling in general and the square area of parks was associated with time spent on bicycling for commuting purposes.

Conclusion The present study showed green and recreational space, specifically sport grounds and parks, to be associated with time spent on bicycling. It is however very likely that these results reflect the association of living in the outskirts of town and time spent on bicycling.

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Introduction

Physical activity is one of the leading modifiable risk factors for various chronic diseases in western countries.[54] Extensive literature on the various health benefits of physical activity has led to the need to understand the determinants of physical activity. Previous studies have described the association with physical activity for psychosocial determinants such as attitudes, social norms and self-efficacy.[19;81-83] Another group of potential determinants of physical activity belongs to the physical environment. These factors are the least studied determinants of physical activity despite their ability to influence large populations.

Physical environments have the capacity to obstruct or to facilitate physical activity. For example, the presence of bicycle paths may make it easier and saver for people to be physically active, whereas the absence of such facilities or a high crime rate may pose as a barrier to physical activity. Recently, Humpel and co-workers reviewed the findings of 19 quantitative studies addressing the association of particular environmental attributes with physical activity. In only four of these studies objective measures of the environment were used. The methods used varied from place of residence using postal codes, till physical distance to and accessibility of facilities.[21] Because only a small subset of possible physical environmental characteristics has been studied and because the use of objective measures of the physical environment is clearly staying behind compared to the use of self-reported measures, further research in this field is needed.

In the present study we made an effort to identify factors of the physical environment that may influence walking and bicycling during leisure time and for commuting purposes. In order to do so, time spent on walking and bicycling in these domains of physical activity were associated with the amount of green and recreational space within a radius of 300 and 500 metres of the homes of the participants as documented in GIS databases.

Methods

The data used in this study was collected at two levels. The individual level included a self-administered questionnaire on demographic factors and leisure time physical activity. The neighbourhood-level included information on green space and recreational space derived from GIS databases. These two levels were connected by the postal code, creating a multilevel design for data analyses since one postal code corresponded to more than one individual.

Data collection at the individual level

Respondents of this study were living in and around Maastricht, a medium sized town in the southern part of the Netherlands. All these people were former participants of two monitoring studies of the National Institute for Public Health and the Environment conducted in the periods 1987–1992 and 1993-1997.[61;62] Each of these years, a random sample of men and women aged 20-59 years was selected from the municipal registry. The measurement included a physical examination at the Municipal Health Service and a self-administered questionnaire that was checked for errors at the Health Centre in the presence of the participant. Respectively the Medical Ethical Committee of the University of Leiden and the external Medical-Ethical Committee of the TNO Toxicology and Nutrition Institute approved these former studies. In 1998, 19,857 people were invited to participate in a mailed survey. In total, 13,184 people (66.4%) completed the 1998 questionnaire. All participants signed a consent form allowing us to use the information from this questionnaire for scientific purposes.

Demographic factors in the self-administered questionnaire included gender and age. Data on educational level was not available within this measurement. However, assuming that this attribute does not substantially change over time among adults, information on educational level was derived from the former measurement of these participants. Educational level was classified into three categories: low (lower vocational training or primary school), medium (secondary school and intermediate vocational training) and high (higher vocational training or university). The assessment of health status included questions about perceived health status (5-point scale ranging from excellent till poor), height and weight (both self-reported). Physical activity was administered using the short questionnaire to assess health enhancing physical activity (the SQUASH). This questionnaire includes questions (frequency, duration and intensity) on four domains of physical activity, i.e. commuting activities (walking and bicycling), occupational physical activity, household activity and leisure time physical activity (walking, bicycling, gardening, doing odd jobs and sports). In a previous study, the SQUASH was validated with a CSA activity monitor in a population of 36 men and 14 women, aged 27-58.[(84)] The correlation coefficient for validity was 0.45 (95%CI 0.17-0.66). Reproducibility of the separate questions ranged from 0.44 till 0.96.[(84)]

In the present study, we assumed that the physical environment of the home would be mostly related to activities that are conducted directly from the home, such as walking and bicycling. The physical activity questionnaire used provided data on walking and bicycling during leisure time as well as for commuting purposes. Therefore, we addressed our research question for walking and bicycling in both of these domains separately as well as in both domains combined.

Data collection at the neighbourhood-level

The Maastricht region is the hilliest region of the Netherlands, but does not include mountains. The largest areas of green and recreational space that could be used for walking and bicycling during leisure time are situated in the outskirts of the city as well as outside the city. Destinations for walking and bicycling for commuting purposes (e.g. companies) are scattered around town. The two railroad stations of Maastricht are situated away from the city centre. One is situated at walking distance (15 minutes) of the city centre and one is situated in the outskirts.

Data on the physical environment were derived from existing GIS databases of Statistics Netherlands on land utilisation including the amount of green and recreational space. Green and recreational space included woods, parks, sport grounds, allotments where people grow vegetables for personal use and grounds used for day trips such as the zoo and amusement parks. Sport grounds included things like soccer fields and tennis courts, but not gymnasiums and fitness centres.

The databases were coded at the level of postal codes with maximal precision (i.e. six positions). In the GIS-databases an x, y-co-ordinate, represents these postal codes most of the time representing one street or one side of a street. On average, a six position postal code in the Netherlands represents 16.2 households. Among the postal codes used in the present study, a postal code represented an average of 20.9 households.

Two ‘neighbourhoods’ around the six position postal codes were defined. One with a radius of 300 meters and one with a radius of 500 meters. These two radiuses were thought to be applicable for activities conducted directly from the home such as walking and bicycling. Moreover, the 500 meter radius is included in the quality characteristics (i.e. more recreational space within 500 meters of the home represents a higher quality of the recreational environment) for recreation close to the home as raised by the Dutch recreational counsel.

For every neighbourhood the square meters of woods, parks, sport grounds, allotments and day trip grounds within the 300-meter and the 500-meter radius neighbourhood were calculated in the GIS database. Then, these results were transferred to a flat data file and merged with the individual data. Consequently, the data set used for statistical analyses had a multilevel structure. Every individual was linked to a neighbourhood through his/her postal code and every postal code was linked to an amount of square metres of green or recreational space.

Data analysis

Respondents with missing data on age, educational level, walking and bicycling (n = 641) were excluded from the analyses. In addition, respondents who had moved out of the Maastricht area (n = 1,002) were excluded. Consequently, complete data was available for 11,541 respondents. In this data set, the amount of individuals per postal code ranged from one to thirty with a median value of five individuals per postal code.

Multilevel regression analysis was used to study the association between physical activity (dependent variable) and physical environment variables (independent variables). This method is appropriate, because the data structure was hierarchical with physical environments including more than one participant. The Mixed procedure within the statistical package SAS (version 8.2) was used to carry out multilevel regression analysis using random intercept models, restricted maximum likelihood estimation and an unstructured covariance structure. The intercept of these models is interpreted as the average amount of physical activity if the physical environment variable would be equal to zero. The slope of these models is interpreted as the average change in physical activity caused by a one-unit change in the physical environment variable. Multivariate analyses included age, educational level and gender.

Table 4.1: Characteristics (mean (sd) or %) of the study population stratified by gender.

	Men N = 5,353	**Women** N = 6,188
Age (years)	49.6 (10.5)	48.7 (10.9)
Educational Level (%)		
Low	52.2	63.4
Medium	24.7	20.2
High	23.1	16.4
Perceived health status (%)		
Excellent / very good	26.6	22.9
Good	60.2	61.4
Mediocre / poor	13.2	15.7
Body mass index (%)		
<25 kg/m^2	45.8	62.7
25 – 30 kg/m^2	44.4	28.0
≥ 30 kg/m^2	9.8	9.3
Physical activity		
Walking (hours/week)	2.8 (4.7)	2.5 (3.6)
Bicycling (hours/week)	1.5 (3.6)	1.3 (2.8)

Results

Table 4.1 shows the characteristics of the study population. The study population consisted of 5,353 men (46%) and 6,188 women (54%). The mean age of the study population was 49 years and the majority of the participants had a low educational level. Women more often than men reported a body mass index below 25 kg/m^2, whereas a body mass index between 25 and 30 kg/m^2 was more prevalent among men. In general, men tended to be more active than women (Table 4.1).

Table 4.2: Distribution of the amount (in hectares) of green and recreational space in the neighbourhood.

		Percentiles					
	min	**50th**	**75th**	**90th**	**95th**	**99th**	**max**
Neighbourhoods with a 300 meter radius							
Woods	0.0	0.0	0.0	0.0	0.3	3.0	12.0
Parks	0.0	0.0	0.4	2.9	4.4	7.2	10.7
Sport grounds	0.0	0.0	1.1	3.2	4.6	8.7	12.6
Allotments	0.0	0.0	0.0	0.0	0.4	1.6	4.6
Day trip grounds	0.0	0.0	0.0	0.0	0.0	4.0	17.9
Neighbourhoods with a 500 meter radius							
Woods	0.0	0.0	0.0	1.4	4.2	9.2	35.0
Parks	0.0	0.2	3.1	6.2	9.7	17.6	21.5
Sport grounds	0.0	1.5	4.5	7.9	11.2	20.9	32.2
Allotments	0.0	0.0	0.0	0.9	1.6	3.7	4.6
Day trip grounds	0.0	0.0	0.0	0.0	2.4	11.8	34.4

The distribution of the amount of green and recreational space in the neighbourhood is described in Table 4.2. Parks and sport grounds were more common among the neighbourhoods in our study than woods, allotments and day trip grounds.

Table 4.3 shows the results of the multilevel regression analyses between time spent on walking and bicycling for leisure time and physical environmental variables. Table 4.4 and 4.5 show the results for time spent on walking and bicycling for commuting purposes and total time spent on walking and bicycling respectively. On average, the between person variance was approximately one hundred times greater than the between postal code variance (data not shown). No associations were found for attributes of green and recreational space and walking.

Table 4.3: Associations (β (95%CI))[†] between walking and bicycling during leisure time and square area of green and recreational space.

	Neighbourhoods with a 300 meter radius		**Neighbourhoods with a 500 meter radius**	
	Crude analyses	**Adjusted for age, gender and educational level**	**Crude analyses**	**Adjusted for age, gender and educational level**
Walking (hours per week)				
Woods (ha)	0.06 (-0.06 , 0.18)	0.08 (-0.03 , 0.20)	0.00 (-0.04 , 0.04)	0.01 (-0.03 , 0.04)
Parks (ha)	0.03 (-0.02 , 0.08)	0.02 (-0.03 , 0.07)	0.01 (-0.01 , 0.03)	0.00 (-0.02 , 0.02)
Sport grounds (ha)	0.03 (-0.02 , 0.07)	0.02 (-0.03 , 0.06)	0.02 (0.01 , 0.04)[‡]	0.01 (-0.01 , 0.03)
Allotments (ha)	0.10 (-0.14 , 0.34)	0.09 (-0.14 , 0.33)	-0.01 (-0.13 , 0.10)	-0.02 (-0.13 , 0.10)
Day trip grounds (ha)	-0.06 (-0.17 , 0.05)	-0.07 (-0.18 , 0.04)	0.01 (-0.03 , 0.04)	0.00 (-0.03 , 0.04)
Bicycling (hours per week)				
Woods (ha)	0.01 (-0.08 , 0.10)	0.02 (-0.07 , 0.11)	0.02 (-0.01 , 0.05)	0.02 (-0.01 , 0.05)
Parks (ha)	0.02 (-0.02 , 0.06)	0.01 (-0.03 , 0.05)	0.01 (-0.01 , 0.03)	0.00 (-0.01 , 0.02)
Sport grounds (ha)	0.04 (0.01 , 0.08)[‡]	0.04 (0.01 , 0.07)[‡]	0.02 (0.01 , 0.03)[‡]	0.01 (0.00 , 0.03)
Allotments (ha)	-0.04 (-0.22 , 0.14)	-0.04 (-0.22 , 0.13)	0.04 (-0.04 , 0.13)	0.04 (-0.05 , 0.13)
Day trip grounds (ha)	0.04 (-0.04 , 0.13)	0.04 (-0.04 , 0.12)	0.02 (-0.01 , 0.05)	0.02 (-0.01 , 0.05)

[†]β represents the number of hours per week of extra activity corresponding with an increase of one hectare in the particular environmental factor, [‡] $p<0.05$

Table 4.4: Associations (β (95%CI))[†] between walking and bicycling for commuting purposes and square area of green and recreational space.

	Neighbourhoods with a 300 meter radius		**Neighbourhoods with a 500 meter radius**	
	Crude analyses	**Adjusted for age, gender and educational level**	**Crude analyses**	**Adjusted for age, gender and educational level**
Walking (hours per week)				
Woods (ha)	-0.01 (-0.05 , 0.03)	-0.01 (-0.06 , 0.03)	-0.01 (-0.02 , 0.01)	-0.01 (-0.02 , 0.01)
Parks (ha)	0.00 (-0.01 , 0.02)	0.01 (-0.01 , 0.02)	-0.00 (-0.01 , 0.01)	-0.00 (-0.01 , 0.01)
Sport grounds (ha)	-0.01 (-0.02 , 0.01)	-0.01 (-0.03 , 0.01)	-0.00 (-0.01 , 0.01)	-0.01 (-0.01 , 0.01)
Allotments (ha)	0.00 (-0.08 , 0.08)	-0.01 (-0.09 , 0.07)	-0.00 (-0.04 , 0.04)	-0.01 (-0.05 , 0.03)
Day trip grounds (ha)	-0.02 (-0.05 , 0.02)	-0.01 (-0.05 , 0.02)	-0.01 (-0.02 , 0.01)	-0.01 (-0.02 , 0.01)
Bicycling (hours per week)				
Woods (ha)	0.02 (-0.03 , 0.07)	0.01 (-0.04 , 0.06)	0.01 (-0.01 , 0.02)	0.00 (-0.01 , 0.02)
Parks (ha)	0.02 (-0.01 , 0.04)	0.02 (0.01 , 0.04)[‡]	0.00 (-0.01 , 0.01)	0.01 (-0.01 , 0.02)
Sport grounds (ha)	0.02 (-0.01 , 0.04)	0.02 (0.01 , 0.04)[‡]	0.00 (-0.01 , 0.01)	0.00 (-0.01 , 0.01)
Allotments (ha)	-0.05 (-0.16 , 0.05)	-0.07 (-0.16 , 0.03)	-0.01 (-0.06 , 0.04)	-0.02 (-0.07 , 0.03)
Day trip grounds (ha)	-0.01 (-0.06 , 0.04)	-0.00 (-0.05 , 0.04)	-0.00 (-0.02 , 0.01)	-0.00 (-0.02 , 0.01)

[†]β represents the number of hours per week of extra activity corresponding with an increase of one hectare in the particular environmental factor, [‡] $p<0.05$

In the neighbourhoods with a 500-meter radius crude analyses did show a significant association between time spent on walking and the square area of sport grounds. However, this association was no longer present when adjustments were made for gender, age and educational level. The association with the square area of sport grounds in neighbourhoods with a 300-meter radius was consistently present for bicycling during leisure time (β=0.04; Table 4.3), for commuting purposes (β=0.02; Table 4.4) as well as total time spent on bicycling (β=0.06; Table 4.5) and was independent of gender, age and educational level. For bicycling during leisure time this association was also present in neighbourhoods with a 500-meter radius. However, this association was not independent of gender, age and educational level. Only in neighbourhoods with a 300-meter radius the square area of parks was associated with bicycling for commuting purposes (β=0.02; Table 4.4) independent of gender, age and educational level.

Discussion

In this study, physical environmental factors associated with walking and bicycling were investigated. In a neighbourhood defined as a circle with a 300-meter radius around the postal codes of the participants, time spent on bicycling was associated with the square area of sport grounds in that neighbourhood independent of gender, age, educational level and domain of physical activity. Bicycling for commuting purposes was associated, independent of gender, age and educational level, with the square area of parks in neighbourhoods with a 300-meter radius.

In general, using GIS databases to study physical environmental factors in relation to physical activity has some distinct advantages compared to relying on only the perception of the physical environment. Firstly, these databases give an objective measure of for example the amount of green areas, recreational facilities and sports facilities in the neighbourhood, which makes it easier to compare neighbourhoods across towns. Secondly, the use of existing information is cost saving for the study.

Table 4.5: Associations (β (95%CI))[†] between walking and bicycling during leisure time and for commuting purposes combined square area of green and recreational space.

	Neighbourhoods with a 300 meter radius		Neighbourhoods with a 500 meter radius	
	Crude analyses	**Adjusted for age, gender and educational level**	**Crude analyses**	**Adjusted for age, gender and educational level**
Walking (hours per week)				
Woods (ha)	0.05 (-0.08 , 0.18)	0.07 (-0.06 , 0.20)	-0.01 (-0.05 , 0.03)	-0.00 (-0.04 , 0.04)
Parks (ha)	0.03 (-0.02 , 0.09)	0.02 (-0.03 , 0.08)	0.01 (-0.02 , 0.03)	-0.00 (-0.03 , 0.02)
Sport grounds (ha)	0.02 (-0.03 , 0.07)	0.01 (-0.04 , 0.06)	0.01 (-0.01 , 0.03)	0.01 (-0.01 , 0.03)
Allotments (ha)	0.11 (-0.15 , 0.36)	0.09 (-0.16 , 0.34)	-0.02 (-0.14 , 0.11)	-0.03 (-0.15 , 0.09)
Day trip grounds (ha)	-0.07 (-0.19 , 0.05)	-0.08 (-0.20 , 0.04)	-0.00 (-0.04 , 0.04)	-0.01 (-0.04 , 0.04)
Bicycling (hours per week)				
Woods (ha)	0.03 (-0.08 , 0.15)	0.03 (-0.09 , 0.14)	0.02 (-0.01 , 0.06)	0.02 (-0.01 , 0.06)
Parks (ha)	0.04 (-0.01 , 0.08)	0.03 (-0.01 , 0.08)	0.01 (-0.01 , 0.03)	0.01 (-0.01 , 0.03)
Sport grounds (ha)	0.06 (0.02 , 0.10)[‡]	0.06 (0.01 , 0.10)[‡]	0.02 (-0.00 , 0.03)	0.01 (-0.00 , 0.03)
Allotments (ha)	-0.09 (-0.31 , 0.13)	-0.11 (-0.33 , 0.11)	0.03 (-0.08 , 0.14)	0.02 (-0.09 , 0.13)
Day trip grounds (ha)	0.03 (-0.07 , 0.14)	0.04 (-0.07 , 0.14)	0.02 (-0.02 , 0.05)	0.02 (-0.02 , 0.05)

[†]β represents the number of hours per week of extra activity corresponding with an increase of one hectare in the particular environmental factor, [‡] $p<0.05$

Therefore, geographic databases seem to be a promising source of information in order to study the association between physical activity and physical environmental factors.
A disadvantage of GIS databases is that they are not sufficient to fully describe the association under study. To do this, objectively measured factors of the physical environment (such as features of GIS databases) will have to be combined with measurement of safety aspects as well as measurement of the perception that people have of their physical environment. In our analyses we did not take these aspects into account because such data was not available to us at the time of this study. Modest to high crime rates and the lack of safe bicycle paths and sidewalks may however very likely pose as a barrier to physical activity in the sense that people take the car to work or the shopping centre in stead of going by bike or walk to these places. It is also very likely that even when in theory a physical environment invites people to take a walk in the neighbourhood, they hesitate to do so because of the safety aspects.

Several methodological aspects of the present study need to be addressed. First, the Maastricht region did not include a wide range of types of green and recreational space. Only parks and sport grounds were reasonably represented. Therefore, we were unlikely to find associations for other types of green and recreational space. In addition, the between person variance was much larger than the between postal code variance, indicating a high degree of independence between individuals and postal codes and therefore indicating an increased power to find statistically significant results. However, this was not reflected in the associations found between physical activity and green and recreational space. This was probably due to the very small effects we were looking for, which would need a larger population in order to find statistically significant results. Also, the information in the GIS databases was probably aggregated to a higher level than needed for our purpose. For example, the item ‘parks’ included not only the parks, but also centre strips between roads and other green belts in the city irrespective of their sizes. Although green strips between road lanes do contribute to the aesthetics of green spaces, these features are unlikely to be a destination for physical activity. For the purpose of linking the average level of physical activity to these kinds of aspects of the neighbourhood, less aggregated (e.g. separate data on centre strips and parks) information will probably be more appropriate. Therefore, to fully examine the possibilities of geographical databases to study physical environmental factors associated with physical activity, our analyses should be repeated with the use of databases that are less aggregated. These databases should probably target specific environmental aspects of interest, for example the amount of bicycle paths, the amount of parks in the neighbourhood and the distance to facilities, such as health clubs, schools and shopping centres in the neighbourhood. In case of a study on the distance to facilities in relation to the use of these facilities and/or how people transport themselves (e.g. car, bicycle, walking) to these facilities it would be of great importance to include the presence of physical barriers (e.g. ring way, railroad, rivers and canals). In other words, aspects of the physical environment that are possibly linked to physical activity are diverse and together they constitute a complex model that is difficult to grasp within one study.

Studies that used self-reported environmental factors to study the association between physical activity and the physical environment, generally found access to recreational facilities, neighbourhood safety, and enjoyable scenery to be related to physical activity levels and/or physical activity participation.[81;85-92]
Only few studies addressed objective measures of the physical environment. Bauman et al. investigated the relationship between proximity to the coast and physical activity among a stratified sample of adults from households in New South Wales. Participants were classified as either ‘coastal’ or ‘inland’ based on their postal code of residence. Living near the coast was found to be associated with higher levels of physical activity independently of sex, age, country of birth, level of education and employment status.[93] Sallis et al. studied the association between the frequency of exercise and the distance between homes and exercise facilities among a random sample of adults living in San Diego. The distance between homes and exercise facilities was calculated using a street map of San Diego that included the geographical co-ordinates of both the homes of the participants and the exercise facilities. Density of exercise facilities around one’s house was found to be associated with exercise habits independent of demographic variables such as age, education and income.[90]

The Study on Environmental and Individual Determinants of physical activity (the SEID project) showed that recreational facilities located near home were used more often than facilities located elsewhere among healthy workers and homemakers in Western Australia. The distances between the homes and exercise facilities were calculated using data derived from GIS databases. Most frequently used facilities were the streets (by 45.6% of the respondents), public open space (28.8%) and the beach (22.7%). It was concluded from this study that accessible facilities determined whether or not they were used and in this way, support and enhance physical activity by providing opportunities.[(94)] Troped et al. studied the association between self-reported and objective physical environment factors and use of a community rail-trail among a random sample of adults living in Arlington, Middle America. Three objective environmental variables were defined based on GIS databases: distance to the bikeway, steep hill barrier, and a busy street barrier. The steep hill barrier and greater distance to the bikeway were associated with non-use of the bikeway.[(95)]

In the present study, inhabitants of the Dutch town Maastricht living in a neighbourhood with a larger square area of sport grounds close to home spent more time on bicycling in general. Individuals living in a neighbourhood with a larger square area of parks close to home spent more time on bicycling for commuting purposes. GIS-data of the present study showed that the largest amounts of sport grounds as well as parks were mostly situated in the outskirts of the town. Therefore, it is likely that our results are a reflection of the results that we would have found if the aim of the study would have been to study the association between the location of the home (e.g. centre versus outskirts) and time spent on walking and bicycling. Concerning leisure time bicycling, a possible explanation could be that people living in neighbourhoods with a larger square area of sport grounds (e.g. people living in the outskirts of town) spent more time on bicycling because for them it is relatively easy to reach non-urban surroundings that are more attractive for bicycling than it is for people living in the centre parts of town. Theoretically it would be possible that these people use their bikes for transportation to the sport grounds. However, the square area of sport grounds would have to be associated with time spent on sports and secondary analyses showed that this was not the case. Concerning bicycling for commuting purposes, a possible explanation could be that people living in neighbourhoods with a larger square area of sport grounds and/or parks (e.g. people living in the outskirts of town) also live close to one of the railway stations and therefore are more likely to use their bicycle for commuting purposes.

Despite of the adjustments made for educational level, it is possible that the associations found are influenced to some degree by the social economic status of the participants. Housing types in Dutch neighbourhoods are quite uniform, meaning that their inhabitants will have a more or less comparable social economic status. This means that we probably could not fully adjust for this factor in our analyses. In other words, the present study showed that living in a neighbourhood with sport grounds and or parks close to home is associated with time spent on bicycling. It is however very likely that these results reflect the association of living in the outskirts of town and time spent on bicycling. Moreover, this study showed that more research is necessary to fully examine the possibilities of geographical databases to study physical environmental factors associated with physical activity.

[5]

Physical activity and stroke: a meta-analysis of observational data*

Abstract

Purpose To quantify the relationship between physical activity and stroke morbidity and mortality and to explore sources of heterogeneity by means of meta-analysis of observational studies.

Methods In total, 31 relevant publications were included. Risk estimates and study characteristics were extracted from original studies and converted to a standard format for use in a central database.

Results Moderately intense physical activity compared to inactivity, showed a protective effect on total stroke for both occupational (RR: 0.64, 95%CI: 0.48-0.87) and leisure time physical activity (RR: 0.85, 95%CI: 0.78-0.93). High level occupational physical activity protected against ischemic stroke compared to both moderate (RR: 0.77, 95%CI: 0.60-0.98) and inactive occupational levels (RR: 0.57, 95%CI: 0.43-0.77). High level compared to low level leisure time physical activity protected against total stroke (RR: 0.78, 95%CI: 0.71-0.85), hemorrhagic stroke (RR: 0.74, 95%CI: 0.57-0.96) as well as ischemic stroke (RR: 0.79, 95%CI: 0.69-0.91). Studies conducted in Europe showed a stronger protective effect (RR: 0.47, 95%CI: 0.33-0.66) than studies conducted in the United States (RR: 0.82, 95%CI: 0.75-0.90).

Conclusions Lack of physical activity is a modifiable risk factor for both total stroke and stroke subtypes. Moderately intense physical activity is sufficient to achieve risk reduction.

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Introduction

It has been well established that physical activity plays an important role in preventing coronary heart disease and cardiovascular diseases in general.[4;25;96]

In 1999, Wannamethee and Shaper published a review including five cohort studies addressing the relationship between physical activity and stroke. They concluded that most of these studies had shown physical activity to be associated with a reduced risk of stroke and that moderate levels of physical activity may be sufficient to achieve a significant reduction in stroke risk.[26] However, no effort was made to present pooled risk estimates and to explain discrepant results of studies included in the review. Therefore, in the present meta-analysis we not only aimed to calculate pooled risk estimates. We specifically aimed to explore sources of heterogeneity that may have influenced the observed relationships between physical activity and stroke. Pooled risk estimates were calculated for total stroke, hemorrhagic and ischemic stroke, stratified by type of activity.

Methods

Data sources

The PUBMED database was searched for studies published in English until December 2001. We used various combinations of the keywords physical activity, exercise, cerebrovascular disease, stroke, ischemic stroke and hemorrhagic stroke. References from the publications obtained were searched for more references, new publications retrieved and again searched for more references. This process was repeated until no additional references could be identified. We reviewed all relevant papers and identified 36 published cohort or case-control studies on physical activity and stroke.

Study selection

Studies in which physical fitness was used as an estimate for physical activity were not considered eligible because physical fitness or aerobic power is a proxy-measure for vigorous activity and not for physical activity in general.(4) Consequently, one study was excluded from the analysis.(97) For some cohort studies, multiple publications were found.(98-105) As a rule, the publication with the longest follow-up time was included in the meta-analysis, resulting in exclusion of four studies.(98;100;102;104) Eventually, 31 relevant publications (24 cohort and seven case-control studies) were included in the meta-analysis.(99;101;103;105-132)

Data extraction

Risk estimates and study characteristics were extracted from original studies, double-checked and converted to a standard format for use in a central database. Risk estimates and the accompanying standard errors were extracted from the publications and converted to a log-scale for use in the meta-regression analysis. If p-values were reported as for example <0.05, we assumed a p-value of 0.05 in order to be able to calculate a maximum standard error. In some cases no p-value, standard error or confidence interval could be extracted from the publication. If possible, the authors of the particular publications were contacted and asked to provide us with the necessary information. Finally, part of the information was missing regarding two publications.(119;120) Some studies reported risk estimates for different subgroups of their population (e.g. gender or age). These subgroups were included in the meta-analysis as separate data units. Consequently, the 'N' column in Table 5.3, 5.4 and 5.5 represents data units and not publications.

In order to assess the extent of publication bias in this meta-analysis, we constructed funnel plots for total, hemorrhagic and ischemic stroke by plotting the natural logarithm of the effect measure against the inverse of the standard error of this measure. A deficit of negative imprecise studies in these funnel plots was assumed to indicate publication bias. In addition, we used Egger's method to test asymmetry in our funnel plots.(133) Publication bias was assumed to be present if, at $p<0.1$, the intercept significantly differed from zero.

Meta-regression analysis was performed as described by van Houwelingen et al. with use of the standard Wald confidence interval.[134] We performed a test of heterogeneity in order to decide between meta-regression analysis using a fixed-effects (no significant inter-study variation) or a random-effects approach (significant inter-study variation). Because of the small number of studies in the various strata, we chose a conservative approach and assumed heterogeneity up to a two-sided p-value of 0.5. In addition, we calculated the I^2 statistic for all random effect models as suggested by Higgins and Thompson.[135] This statistic can be interpreted as the proportion of total variation in study estimates that is due to heterogeneity. In contrast to the χ^2 statistic for heterogeneity, this statistic is not dependent on the number of studies in the meta-analysis.[135]

Stratified analyses were used to ensure that studies within strata would be similar in both outcome and physical activity measure. First, we stratified for type of physical activity (occupational and leisure time physical activity). Because occupational and leisure time physical activity may include different levels of physical activity and therefore could have different physiologic effects, we chose to separate these two general types of activity. Studies that reported on an integrated physical activity level of both occupational and leisure time physical activity (n = 3) were grouped with the studies reporting only on leisure time physical activity.

Within the strata for type of physical activity, further stratification was made for four combinations of reference and comparison categories: A) active versus inactive for studies that present risk estimates for more than two activity categories; B) active versus moderately active for studies that present risk estimates for more than two activity categories; C) moderately active versus inactive for studies that present risk estimates for more than two activity categories and D) active versus inactive for studies that present risk estimates for dichotomised activity categories. These separate analyses can be seen as an estimation of a dose-response relation between activity level and risk for stroke.[25] As a rule for this meta-analysis, the lowest category was defined as inactive, the highest as active. All categories in between were pooled to represent a moderately active category.

A third stratification was made for the outcome measure. The aetiology of ischemic stroke differs from the aetiology of hemorrhagic stroke.[136;137] Therefore, it may be possible that the mechanism by which physical activity affects ischemic and hemorrhagic stroke differs. Consequently, we will provide separate summary risk estimates for ischemic and hemorrhagic stroke. Because some studies did not report separate risk estimates for these subtypes of stroke, we also calculated a summary risk estimate for total stroke.

In addition to calculating pooled effect measures for different strata of physical activity and stroke, we performed meta-regression analysis to explore the influence of several factors on the pooled effect measure. Because of the generally small number of studies per stratum addressing occupational physical activity, these analyses were restricted to studies on leisure time physical activity. For the same reason analyses were further limited to studies in stratum A, i.e. active versus inactive for studies that present risk estimates for more than two activity categories.
The influence of study quality was investigated by calculating a pooled risk estimate weighted for this study characteristic. Study quality was determined using an adapted version of the scoring system proposed by Powell et al. and previously used by Berlin and Colditz.[25;96] The scoring system included three main aspects of study design: measurement of physical activity, measurement of disease status and epidemiological methods (Appendix B). Each component was rated according to its presence (no or uncertain, partly present, yes) in the individual studies. These ratings were coded as 0, 1 and 2, resulting in a total score (i.e. the sum of all sub-ratings) with a possible range from 0 to 32. The adaptation we made to the score concerned one of the characteristics of measurement of disease status. Powell et al. included an item on the diagnosis of coronary heart disease, whereas in the present meta-analyses an item on the diagnosis of stroke subtypes was admitted. We defined that diagnoses of stroke should preferably be made separately for ischemic and hemorrhagic stroke (Appendix B).

Table 5.1: Case-control studies on occupational or leisure time physical activity included in the present meta-analysis.

First author	Year	Country	Study size	Outcome type	Cases	Relative risk	Quality score
Occupational physical activity							
-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
Leisure time physical activity							
Herman [128]	1983	Europe	371 men and women	Total stroke	132	AvsI: 0.24 (0.10 , 0.59)	22
						MvsI: 0.49 (0.31 , 0.77)	
Shinton[130]	1993	Europe	171 men	Total stroke	73	AvsI: 0.30 (0.10 , 0.60)	23
			152 women	Total stroke	52	AvsI: 0.37 (0.20 , 0.80)	
You[126]	1995	U.S.	406 men and women	Ischemic stroke	203	AvsI: 0.30 (0.10 , 0.70)	27
						MvsI: 1.00 (0.40 , 2.30)	
You[132]	1997	Australia	402 men and women	Ischemic stroke	201	AvsI: 0.60 (0.30 , 1.30)	22
						MvsI: 1.40 (0.60 , 3.30)	
Sacco[129]	1998	U.S.	1,047 men and women	Ischemic stroke	369	AvsI: 0.23 (0.10 , 0.54)	26
						MvsI: 0.39 (0.26 , 0.58)	
Fann[127]	2000	U.S.	447 men and women	Hemorrhagic stroke	149	AvsI: 0.70 (0.40 , 1.10)	17
						MvsI: 0.80 (0.40 , 1.30)	
Thrift[131]	2002	Australia	396 men	Hemorrhagic stroke	198	AvsI: 0.57 (0.28 , 1.14)	27
						MvsI: 0.57 (0.26 , 1.23)	
			266 women	Hemorrhagic stroke	133	AvsI: 1.26 (0.43 , 3.70)	
						MvsI: 0.57 (0.11 , 2.99)	

For the present meta-analysis, the various components were scored separately by three persons (GW, AS and EF) using blinded versions of the publication (i.e. without source, title, authors, results, discussion and references). If the scores given did not agree (5 out of 28 publications), consensus on a score was reached by discussion.

The influence of type of study-design, gender of the study population, country under study and year of publication was investigated by adjusting the meta-regression model for these variables. Dummy variables were created for type of study, gender of the study population and country under study. Year of publication was added to the model as continuous variable. These analyses were restricted to studies that reported separate risk estimates for men and women, excluding three studies on total stroke, one study on hemorrhagic stroke and three studies on ischemic stroke.

Results

The characteristics and estimated effect measures of the 31 retrieved cohort and case-control studies are chronologically summarised in Table 5.1 (case-control studies), Table 5.2a (cohort studies on occupational physical activity) and Table 5.2b (cohort studies on leisure time physical activity). Case-control studies did not report on occupational physical activity (Table 5.1). Among cohort studies, a clear shift over time was noted for the type of physical activity under study. Older publications more frequently reported on occupational activity, whereas more recent publications tended to report on leisure time physical activity (Table 5.2a and Table 5.2b). Approximately 70% of the case-control studies and 50% of the cohort studies reported an effect measure for either or both ischemic and hemorrhagic stroke (Table5.1, Table 5.2a and Table 5.2b). Generally, recent publications more often reported on subtypes of stroke. Case-control studies generally failed to report an odds-ratio separately for men and women (Table 5.1), whereas more than 75% of the cohort studies did report an effect measure for men and women separately (Table 5.2a and Table 5.2b).

Table 5.2a: Cohort studies on occupational physical activity included in the present meta-analysis.

First author	Year	Country	Study size	Outcome type	Cases	Relative risk	Quality score
Okada[120]	1976	Japan	4,186 men and women	Hemorrhagic stroke	143	AvsM: 0.79 (….. , …..)†	19
						AvsI: 0.31 (0.13 , 0.76)	
				Ischemic stroke	109	AvsM: 0.44 (….. , …..)†	
						AvsI: 0.44 (….. , …..)†	
Paffenbarger[101]	1978	U.S.	3,686 men	Total stroke	112	AvsI: 0.62 (0.34 , 1.14)	17
				Hemorrhagic stroke	60	AvsI: 0.58 (0.25 , 1.34)	
				Ischemic stroke	52	AvsI: 0.67 (0.27 , 1.67)	
Salonen[122]	1982	Europe	3,978 men	Total stroke	71	AvsI: 0.63 (0.40 , 0.91)	18
			3,688 women	Total stroke	56	AvsI: 0.59 (0.37 , 0.91)	
Menotti[118]	1985	Europe	99,029 men	Total stroke	187	AvsI: 1.00 (0.75 , 1.35)	15
						MvsI: 0.65 (0.45 , 0.93)	
						AvsM: 1.53 (1.08 , 2.16)	
Lapidus[114]	1986	Europe	1,351 women	Total stroke	13	AvsI: 7.80 (2.70 , 23.00)	21
Harmsen[112]	1990	Europe	7,495 men	Total stroke	148	AvsI: 0.91 (0.67 , 1.43)	21
				Hemorrhagic stroke	31	AvsI: 0.75 (0.00 , 2.07)	
				Ischemic stroke	69	AvsI: 1.11 (0.67 , 1.67)	

Table 5.2a: continued (I)

First author	**Year**	**Country**	**Study size**	**Outcome type**	**Cases**	**Relative risk**	**Quality score**
Menotti[99]	1990	U.S/Eur	8,287 men	Total stroke	353	AvsI: 0.99 (0.86 , 1.14)	15
Haheim[111]	1993	Europe	14, 403 men	Total stroke	81	AvsI: 1.62 (0.95 , 2.75)	19
						MvsI: 0.66 (0.34 , 1.23)	
Gillum[110]	1996	U.S.	2,713 men	Total stroke	69[§]	AvsM: 0.57 (0.34 , 0.96)	23
						AvsI: 0.93 (0.35 , 2.50)	
					201[§§]	AvsM: 0.83 (0.61 , 1.14)	
						AvsI: 0.55 (0.35 , 0.87)	
				Ischemic stroke	60[§]	AvsM: 0.54 (0.31 , 0.95)	
						AvsI: 0.76 (0.28 , 2.04)	
					186[§§]	AvsM: 0.85 (0.62 , 1.19)	
						AvsI: 0.59 (0.36 , 0.95)	
			2,368 women	Total stroke	53[§]	AvsM: 0.93 (0.50 , 1.75)	
						AvsI: 0.28 (0.13 , 0.60)	
					196[§§]	AvsM: 0.70 (0.50 , 0.99)	
						AvsI: 0.55 (0.33 , 0.91)	
				Ischemic stroke	48[§]	AvsM: 0.85 (0.43 , 1.64)	
						AvsI: 0.22 (0.10 , 0.49)	

Table 5.2a: continued (II)

First author	Year	Country	Study size	Outcome type	Cases	Relative risk	Quality score
					179[§§]	AvsM: 0.70 (0.49 , 1.00)	
						AvsI: 0.57 (0.34 , 0.98)	
Nakayama(119)	1997	Japan	961 men	Total stroke	64	AvsM: 1.88 (0.72 , 4.88)	22
						MvsI: 0.72 (0.40 , 1.30)	
				Hemorrhagic stroke	8	AvsM: 3.36 (0.36 , 31.57)	
						MvsI: 0.72 (0.14 , 3.70)	
				Ischemic stroke	37	AvsM: 2.09 (0.61 , 7.19)	
						MvsI: 0.90 (0.42 , 1.92)	
			1,341 women	Total stroke	78	AvsM: …... (….. , …..)[‡]	
						MvsI: 0.54 (0.30 , 0.97)	
				Hemorrhagic stroke	19	AvsM: …... (….. , …..)[‡]	
						MvsI: 0.35 (0.11 , 1.14)	
				Ischemic stroke	39	AvsM: …... (….. , …..)[‡]	
						MvsI: 0.48 (0.20 , 1.12)	
Evenson(109)	1999	U.S.	14,575 men and women	Ischemic stroke	189	AvsI: 0.69 (0.46 , 1.02)	
						MvsI: 0.59 (0.03 , 1.14)	

[†]No p-value or confidence interval was reported, [‡]Not reported in the original paper due to biased distribution of variables or small number of events, [§]aged 45-64 years, [§§]aged 65-74 years.

Table 5.2b: Cohort studies on leisure time physical activity included in the present meta-analysis.†

First author	Year	Country	Study size	Outcome type	Cases	Relative risk	Quality score
Salonen[122]	1982	Europe	3,978 men	Total stroke	71	AvsI: 1.00 (0.67 , 1.43)	18
			3,688 women	Total stroke	56	AvsI: 0.77 (0.50 , 1.25)	
Lapidus[114]	1986	Europe	1,351 women	Total stroke	13	AvsI: 10.1 (3.80 , 27.10)	21
Folsom[124]	1990	U.S.	41,837 women	Total stroke	218	AvsI: 0.60 (0.40 , 0.90)	9
						MvsI: 0.80 (0.50 , 1.10)	
Harmsen[112]	1990	Europe	7,495 men	Total stroke	148	AvsI: 0.83 (0.56 , 1.25)	21
				Hemorrhagic stroke	31	AvsI: 0.77 (0.00 , 2.18)	
				Ischemic stroke	69	AvsI: 0.83 (0.50 , 1.43)	
Lindsted[117]	1991	U.S.	9,484 men	Total stroke	410	AvsI: 0.94 (0.65 , 1.36)	18
						MvsI: 0.78 (0.61 , 1.00)	
Wannamethee[123]	1992	Europe	7,735 men	Total stroke	128	AvsI: 0.20 (0.10 , 0.90)	21
						MvsI (0.65 (0.00 , 1.37)	
Haheim[111]	1993	Europe	14,403 men	Total stroke	81	AvsI; 0.36 (0.15 , 0.80)	19
						MvsI: 0.64 (0.38 , 1.08)	
Lindenstrom[116]	1993	Europe	7,060 women	Total stroke	265	AvsI: 1.45 (1.01 , 2.08)	17
Simonsick[125]	1993	U.S.	5,177 men and women	Total stroke	161	AvsI: 0.86 (0.06 , 1.67)	17
						MvsI: 1.25 (0.64 , 1.86)	

Table 5.2b: continued (I)

First author	Year	Country	Study size	Outcome type	Cases	Relative risk	Quality score
Abbott[106]	1994	Asia	7,530 men	Hemorrhagic stroke	62[£]	AvsI: 0.50 (0.20 , 1.30)	24
						MvsI: 0.90 (0.30 , 2.50)	
				Hemorrhagic stroke	67[££]	AvsI: 0.30 (0.10 , 0.80)	
						MvsI: 0.50 (0.20 , 1.30)	
Kiely[105]	1994	U.S.	1,897 men	Total stroke	188	AvsI: 0.84 (0.59 , 1.18)	18
						MvsI: 0.90 (0.62 , 1.31)	
			2,299 women	Total stroke	214	AvsI: 0.89 (0.60 , 1.31)	
						MvsI: 1.21 (0.89 , 1.63)	
Gillum[110]	1996	U.S.	2,713 men	Total stroke	69[§]	AvsM: 0.85 (0.44 , 1.64)	23
						AvsI: 0.81 (0.41 , 1.59)	
				Total stroke	201[§§]	AvsM: 1.16 (0.78 , 1.72)	
						AvsI: 0.78 (0.53 , 1.14)	
				Ischemic stroke	60[§]	AvsM: 0.86 (0.43 , 1.72)	
						AvsI: 0.91 (0.45 , 1.85)	
				Ischemic stroke	186[§§]	AvsM: 1.12 (0.74 , 1.69)	
						AvsI: 0.75 (0.50 , 1.11)	

Table 5.2b: continued (III)

First author	**Year**	**Country**	**Study size**	**Outcome type**	**Cases**	**Relative risk**	**Quality score**
Evenson[109]	1999	U.S.	14,575 men and women	Ischemic stroke	189	AvsI: 0.82 (0.51 , 1.32)	27
						MvsI: 0.77 (0.30 , 1.24)	
Agnarsson[107]	1999	Europe	4,484 men	Total stroke	249	AvsI: 0.69 (0.47 , 1.01)	22
		.		Ischemic stroke	158	AvsI: 0.62 (0.40 , 0.97)	
Hu[113]	2000	U.S.	72,488 women	Total stroke	407	AvsI: 0.66 (0.47 , 0.91)	27
						MvsI: 0.87 (0.52 , 1.21)	
				Hemorrhagic stroke	109	AvsI: 1.02 (0.58 , 1.82)	
						MvsI: 0.85 (0.15 , 1.55)	
				Ischemisch stroke	258	AvsI: 0.52 (0.33 , 0.80)	
						MvsI: 0.83 (0.40 , 1.25)	
Ellekjaer[108]	2000	Europe	14,101 women	Total stroke	457	AvsI: 0.52 (0.38 , 0.72)	22
						MvsI: 0.77 (0.61 , 0.98)	
Paganini-Hill[121]	2001	U.S.	4,722 men	Total stroke	773	AvsI: 0.85 (0.72 , 1.01)	16
						MvsI: 0.91 (0.76 , 1.10)	
				Hemorrhagic stroke	69	AvsI: 0.69 (0.38 , 1.25)	
						MvsI: 1.06 (0.59 , 1.92)	

Table 5.2b: continued (II)

First author	Year	Country	Study size	Outcome type	Cases	Relative risk	Quality score
			2,368 women	Total stroke	53[§]	AvsM: 0.56 (0.16 , 1.92)	
						AvsI: 0.32 (0.10 , 1.05)	
				Total stroke	196[§§]	AvsM: 0.79 (0.47 , 1.32)	
						AvsI: 0.65 (0.40 , 1.05)	
				Ischemic stroke	48[§]	AvsM: 0.65 (0.18 , 2.27)	
						AvsI: 0.35 (0.10 , 1.15)	
				Ischemic stroke	179[§§]	AvsM: 0.81 (0.48 , 1.39)	
						AvsI: 0.68 (0.41 , 1.14)	
Lee[103]	1998	U.S.	11,130 men	Total stroke	378	AvsI: 0.82 (0.58 , 1.14)	21
						MvsI: 0.69 (0.30 , 1.09)	
Lee[115]	1999	U.S.	21,823 men	Total stroke	533	AvsI: 0.86 (0.65 , 1.13)	26
						MvsI: 0.86 (0.56 , 1.15)	
				Hemorrhagic stroke	84	AvsI: 0.54 (0.26 , 1.15)	
						MvsI: 0.65 (0.00 , 1.40)	
				Ischemic stroke	437	AvsI: 0.97 (0.71 , 1.32)	
						MvsI: 0.93 (0.61 , 1.26)	

Table 5.2b: continued (IV)

First author	**Year**	**Country**	**Study size**	**Outcome type**	**Cases**	**Relative risk**	**Quality score**
				Ischemic stroke	351	AvsI: 0.96 (0.74 , 1.24)	
						MvsI: 1.04 (0.79 , 1.39)	
			8,532 women	Total stroke	1,211	AvsI: 0.83 (0.73 , 0.95)	
						MvsI: 0.88 (0.76 , 1.01)	
				Hemorrhagic stroke	105	AvsI: 1.00 (0.64 , 1.56)	
						MvsI: 0.71 (0.42 , 1.20)	
				Ischemic stroke	508	AvsI: 0.81 (0.66 , 1.00)	
						MvsI: 0.95 (0.76 , 1.18)	

[†]No p-value or confidence interval was reported, [‡]Not reported in the original paper due to biased distribution of variables or small number of events, [£]aged 45-54 years, , [££]aged 55-68 years, [§]aged 45-64 years, [§§]aged 65-74 years.

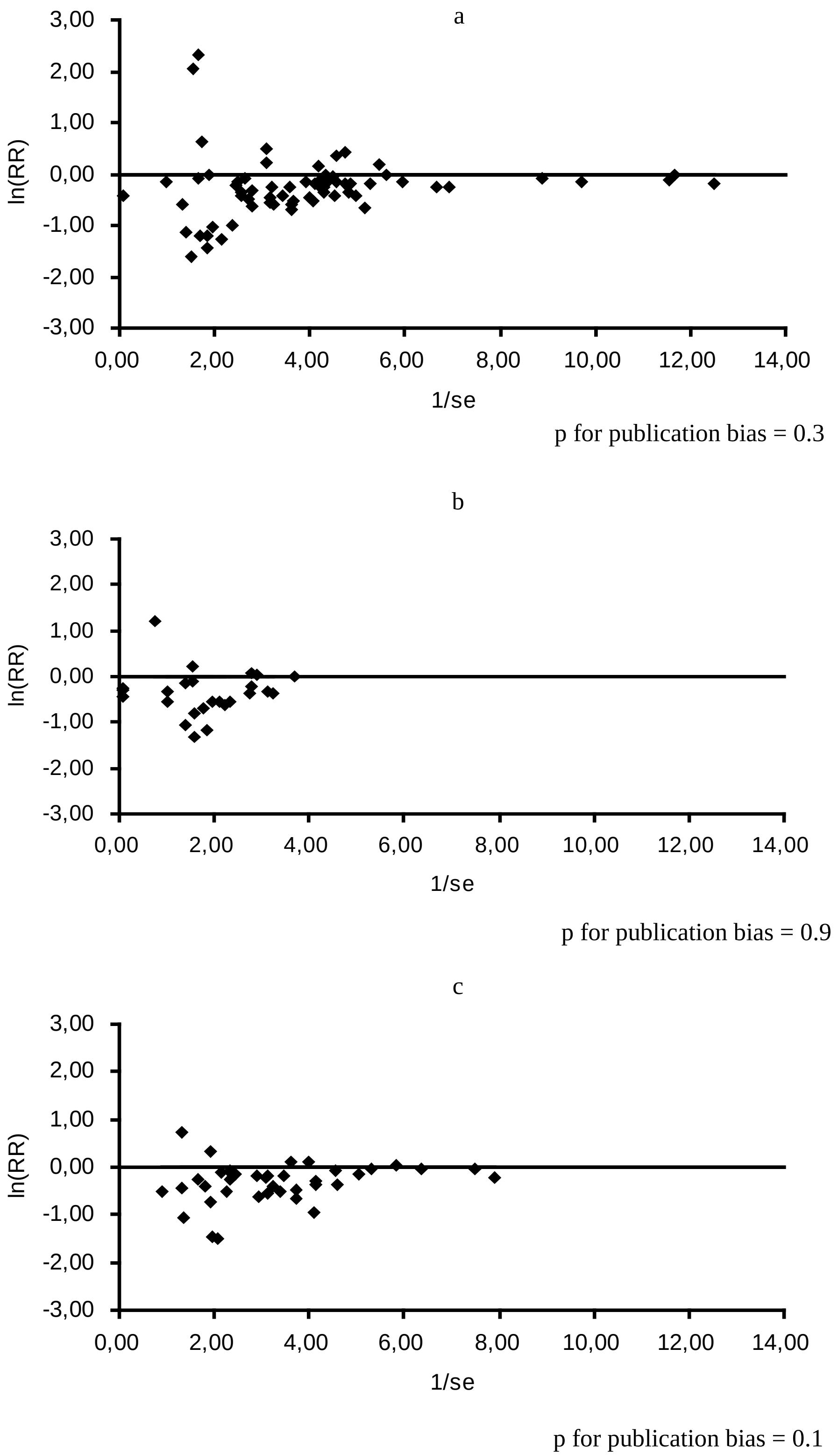

Figure 5.1: Funnel plots for total stroke (a), hemorrhagic stroke (b) and ischemic stroke (c).

The quality score of case-control studies was generally higher than the quality score of cohort studies (Table 5.1, Table 5.2a and Table 5.2b). Among cohort studies, the quality score of more recent studies tended to be higher than the score of earlier studies (Table 5.2a and Table 5.2b).

Funnel plots and Egger's test for asymmetry generally showed that publication bias in the present meta-analysis was limited (Figure 5.1). The results for ischemic stroke were however borderline significant (p=0.1; Figure 5.1)

Table 5.3: Pooled relative risks from studies of occupational activity and the risk of stroke.

	N	Relative risk (95%CI)	p-value for heterogeneity	I^2
A. Active – Inactive *for studies that present risk estimates for more than two activity categories*				
Total stroke	6	0.74 (0.49 , 1.12)	0.01	66%
Hemorrhagic stroke	1	0.31 (0.13 , 0.76)	--	--
Ischemic stroke	5	0.57 (0.43 , 0.77)	0.3	16%
B. Active – Moderately active *for studies that present risk estimates for more than two activity categories*				
Total stroke	6	0.92 (0.68 , 1.24)	0.04	57%
Hemorrhagic stroke	1	3.36 (0.36 , 31.57)	--	--
Ischemic stroke	5	0.77 (0.60 , 0.98)	0.5	--†
C. Moderately active – Inactive *for studies that present risk estimates for more than two activity categories*				
Total stroke	4	0.64 (0.48 , 0.87)	0.9	--†
Hemorrhagic stroke	2	0.45 (0.14 , 1.39)	0.6	--†
Ischemic stroke	3	0.67 (0.35 , 1.29)	0.7	--†
D. Physical activity dichotomised *(studies that present risk estimates for dichotomised physical activity categories)*				
Total stroke	6	0.87 (0.69 , 1.09)	0.004	72%
Hemorrhagic stroke	2	0.58 (0.21 , 1.58)	0.7	--†
Ischemic stroke	2	1.00 (0.62 , 1.63)	0.4	--†

†The I^2 statistic could not be calculated because the total variance was smaller than expected based on the within-study variance, i.e. studies included in this analysis were 'homogeneous'.

Table 5.4: Pooled relative risks from studies of leisure time activity and the risk of stroke.

	N	Relative risk (95%CI)	p-value for heterogeneity	I^2
A. Active – Inactive *for studies that present risk estimates for more than two activity categories*				
Total stroke	19	0.78 (0.71 , 0.85)	0.2	24%
Hemorrhagic stroke	9	0.74 (0.57 , 0.96)	0.6	--†
Ischemic stroke	11	0.79 (0.69 , 0.91)	0.2	23%
B. Active – Moderately active *for studies that present risk estimates for more than two activity categories*				
Total stroke	4	0.95 (0.68 , 1.32)	0.7	--†
Hemorrhagic stroke	0	--	--	--
Ischemic stroke	5	0.84 (0.63 , 1.11)	0.9	--†
C. Moderately active – Inactive *for studies that present risk estimates for more than two activity categories*				
Total stroke	15	0.85 (0.78 , 0.93)	0.5	--†
Hemorrhagic stroke	9	0.76 (0.55 , 1.05)	0.9	--†
Ischemic stroke	7	0.83 (0.64 , 1.09)	0.04	55%
D. Physical activity dichotomised *(studies that present risk estimates for dichotomised physical activity categories)*				
Total stroke	8	0.92 (0.54 , 1.58)	<0.001	78%
Hemorrhagic stroke	1	0.77 (0.00 , 2.18)	--	--
Ischemic stroke	1	0.83 (0.50 , 1.43)	--	--

†The I^2 statistic could not be calculated because the total variance was smaller than expected based on the within-study variance, i.e. studies included in this analysis were ‘homogeneous’.

Table 5.3 (occupational physical activity) and Table 5.4 (leisure time physical activity) present the results for three stroke outcomes (total, hemorrhagic and ischemic), stratified by the combination of reference and comparison groups of physical activity. In general, physical activity protected against stroke. People who were active at work were at lower risk of ischemic stroke compared to both inactive (RR (95%CI): 0.57 (0.43-0.77)) and moderately active (RR (95%CI): 0.77 (0.60-0.98)) persons at the workplace. In turn, moderately active people at the workplace were at lower risk of total stroke (RR (95%CI): 0.64 (0.48-0.87)) compared to persons who were inactive at the workplace (Table 5.3).

Table 5.5: Results from crude, weighted and adjusted analyses on sources of heterogeneity.*

		Crude analyses	Weighted analyses			
	N	RR (95%CI)	RR (95%CI)†	RR‡	RR§	RR£
Total stroke	16	0.79 (0.72 , 0.86)	0.78 (0.76 , 0.80)	0.78	0.79	0.77
Hemorrhagic stroke	8	0.75 (0.57 , 1.00)	0.74 (0.69 , 0.78)	0.74	0.74	0.72
Ischemic stroke	8	0.82 (0.71 , 0.96)	0.81 (0.78 , 0.83)	0.80	0.81	0.80

	N	p-value	Adjusted analyses RR (95%CI)
Total stroke			
Cohort studies	16	--	--
Male population	9	0.4	--
U.S.	13	0.008	0.82 (0.75 , 0.90)
Australia	0	--	--
Asia	0	--	--
Europe	3	0.008	0.47 (0.33 , 0.66)
Yr of publication	16	0.8101	--
Hemorrhagic stroke			
Cohort studies	6	0.9	--
Male population	5	0.07	0.54 (0.36 , 0.81)&
U.S.	4	0.2	--
Australia	2	0.9	--
Asia	2	0.1	--
Europe	0	--	--
Yr of publication	8	0.14	--
Ischemic stroke			
Cohort studies	8	--	--
Male population	4	0.2	--
U.S.	8	--	--
Australia	0	--	--
Asia	0	--	--
Europe	0	--	--
Yr of publication	8	0.5	--

* Restricted to stratum A of studies on leisure time physical activity and stroke risk excluding studies that did not report separate risk estimates for gender.† Weighted for the total quality score. ‡ Weighted for the quality score for measuring physical activity. §Weighted for the quality score for measuring disease status. £ Weighted for the quality score for epidemiological methodology. &RR (95%CI) for female population: 0.76 (0.67 , 0.86).

People who were active during leisure time were at lower risk of total stroke (RR (95%CI): 0.78 (0.71-0.85)), hemorrhagic stroke (RR (95%CI): 0.74 (0.57-0.96)) as well as ischemic stroke (RR (95%CI): 0.79 (0.69-0.91)), compared to those who were inactive during leisure time (Table 5.4). In addition, people who were moderately active during leisure time were at lower risk of total stroke (RR (95%CI): 0.85 (0.78-0.93)) compared to inactive persons (Table 5.4).

Results of the analyses conducted in order to study sources of heterogeneity are shown in Table 5.5. Analyses weighted for the quality score did not meaningfully change the risk estimate, but did tend to narrow the 95% confidence intervals (Table 5.5). The type of study design and the year of publication did not significantly contribute to the statistical explanation of the pooled risk estimate. A borderline significant effect ($p = 0.07$) was found for the gender of the study population among studies on hemorrhagic stroke. In male populations, being active during leisure time was associated with a 0.54 (95%CI: 0.36-0.81) risk of hemorrhagic stroke compared to being inactive during leisure time. In female populations, this risk was 0.76 (95%CI: 0.67-0.86; Table 5.5). For total stroke, a significant effect ($p = 0.008$) was found for the country under study (either U.S. or Europe). Among studies conducted in Europe, the pooled risk estimate for being active during leisure time was 0.47 (95%CI: 0.33-0.66) compared to being inactive during leisure time, for studies conducted in the U.S. this risk estimate was 0.82 (95%CI: 0.75-0.90; Table 5.5).

Discussion

The results of this meta-analysis indicate an association between physical activity and a lower risk of stroke. For occupational physical activity, being active was associated with a 43% and 23% lower risk of ischemic stroke compared to respectively being inactive and being moderately active. Being moderately active at work was associated with a 36% lower risk of total stroke compared to being inactive at work. For leisure time physical activity, being active was associated with a 20-25% lower risk compared with being inactive. Being moderately active during leisure time was associated with a 15% lower risk of total stroke compared to being inactive during leisure time. Gender was a borderline and country under study was a clear source of heterogeneity among studies on leisure time physical activity and total stroke risk.

As in all meta-analyses, we need to address publication bias. Based on funnel-plots and accompanying Egger tests, publication bias in the present meta-analysis seemed to be limited, although it could not be excluded. Only for ischemic stroke we detected possible publication bias (i.e. borderline significance in the Egger test). Therefore, the pooled risk estimate for ischemic stroke may be, to a small extent, biased. By restricting our search of the literature to English language papers we potentially introduced language bias into the meta-analysis. In 1997, Egger et al. published a study on language bias in randomised controlled trials and they concluded that the only study characteristic that predicted publication in an English-language journal was a significant result reported in the original study.(138) Therefore, if in the present meta-analysis language bias would have been present, this would probably have been reflected in our test for publication bias. Since publication bias was limited, language bias probably was limited too.

One limitation of our meta-analysis is that relatively few case-control studies were available, resulting in low power for testing the effect of study design on the pooled risk estimate. Within our analyses on sources of heterogeneity, only two case-control studies were available. Both studies were focussed on hemorrhagic stroke and the dummy variable for type of study was far from statistically significant (p=0.9). Therefore, we were not able to properly test the influence of study design on the pooled risk estimate.
In addition, pooled risk estimates from meta-regression models showed wider 95% confidence intervals for occupational physical activity than for leisure time physical activity. Probably, this was a result of the relatively few studies that were available on occupational physical activity and stroke risk. This likely contributed to the relatively high proportion of total variation in study estimates due to heterogeneity (I^2, calculated for the random effect meta-regression models) among studies on occupational physical activity. Consequently, results on leisure time physical activity generally seemed to be more reliable than results on occupational physical activity. Therefore, more studies on

occupational physical activity and stroke risk are needed to conclude whether or not this is a statistical artefact or a genuine characteristic of these studies.

Another limitation is the relatively small amount of studies addressing the relation between physical activity and hemorrhagic stroke, especially for occupational physical activity. More studies are needed to be able to make reliable quantitative statements about the relation of physical activity to hemorrhagic stroke.

We assumed that active participants were comparable across studies, as well as inactive and moderately active participants. This is probably not true, since the definitions of high, moderate and low levels of physical activity varied substantially across studies. This will have caused the contrasts between active and inactive physical activity categories to level off when calculating pooled risk estimates. Therefore, it is likely that the pooled risk estimates presented in the present meta-analysis give an underestimation of the true relationship of physical activity to stroke occurrence. Consequently, this phenomenon may be the explanation for the lack of significance of pooled risk estimates and high heterogeneity in results for studies that reported dichotomised activity categories. The variability in the definition of physical activity categories also makes it impossible to quantify the specific amount and intensity of physical activity needed to prevent stroke.

In the present meta-analysis also the degree of adjustment for confounding variables varied from study to study. Some studies presented risk estimates adjusted for only age and others included a wide variety of risk factors for stroke. In addition, by performing a meta-analysis we were limited in adjusting the pooled risk estimate for confounders that were reported in the original papers. Therefore, the pooled risk estimates calculated in the present meta-analysis will include some confounding of the true relationship between physical activity and stroke occurrence.

Overall, the small number of data-units within strata limited our meta-analysis. This led to a lack of power for conducting analyses to study sources of heterogeneity. We explored study quality, type of study design, gender of the study population, country under study and year of publication as sources of heterogeneity that could have influenced the results of separate studies. With the exception of the (borderline) significant effect of gender and country, none of these factors significantly contributed to the pooled risk estimate. Other interesting features would have been the average age of the population and adjustment for risk factors in individual studies. In the future, when more studies on the relationship between physical activity and stroke will have been published, it might be possible to take these factors into account.

In the present meta-analysis, country under study was identified as a significant source of heterogeneity among studies on leisure time physical activity and total stroke. From the 16 data units included in this analysis, 13 came from 8 different American studies, the other three came from three different European studies. In American studies, the protective effect of physical activity was lower (RR (95%CI): 0.82 (0.75-0.90)) than in European studies (RR (95%CI): 0.47 (0.33-0.66)). Forty six percent of the American studies reported on women, whereas among the European studies one third reported on women. In order to exclude an effect of gender of the study population, we repeated our analyses with adjustment for this variable. Pooled relative risks did not meaningfully change and the difference between American and European studies remained (RR (95%CI): U.S.: 0.81 (0.71-0.92), Europe: 0.46 (0.33-0.65)).
Possibly, the American studies contained smaller contrasts between active and inactive groups than European ones. This lack of contrast might be due to a generally lower level of physical activity in the United States compared to Europe. In surveys, the category most comparable between countries is the category of inactivity since it is generally defined as not being engaged in any or any meaningful physical activity. Data from the 1997-1998 National Health Interview Survey showed that in the United States 38.3% of all adults was never engaged in any light, moderate or vigorous leisure time physical activity.(139) In the Netherlands only 12% of the population aged 16 years and older is inactive.(41) This would mean that especially in the United States improving the level of physical activity is an important measure in preventing a disabling disease as stroke.

Recently, Lee et al. published another meta-analysis on physical activity and stroke risk.(140) For the most part, our meta-analysis was based on the same studies. However, our research of the literature included four studies that were not identified by Lee et al..(101;120;127;131) Also, our meta-analysis included studies with dichotomous physical activity categories, whereas Lee et al. excluded these studies from their analysis. In the end, our meta-analysis included two more case-control and six additional cohort studies.

The meta-analysis of Lee et al. included two studies that we excluded (one because it included physical fitness and one because of multiple publications).[98;141] Among cohort studies, Lee et al. calculated a pooled risk estimate for ischemic stroke of 0.79 (95%CI: 0.69-0.91) for high compared with low physical activity levels. For hemorrhagic stroke their pooled risk estimate was 0.66 (95%CI: 0.48-0.91). When comparing moderate with low physical activity levels, they calculated risk estimates of 0.91 (95%CI: 0.80-1.05) and 0.85 (95%CI: 0.64-1.13) for ischemic and hemorrhagic stroke respectively. In our meta-analysis, we found similar results and in case of ischemic stroke the results were identical for high versus low physical activity levels (i.e. 0.79 (95%CI: 0.69-0.91)). Lee et al. stratified for type of study design, type of stroke and reference and comparison categories. In the present meta-analysis however, we further stratified for leisure time and occupational physical activity. Moreover, we explored several sources of heterogeneity, such as year of publication and country under study.

The present study summarised the results of various studies on the association between physical activity and stroke. An earlier meta-analysis by Berlin and Colditz addressed the association between physical activity and coronary heart disease.[25] They reported a pooled relative risk of 1.4 (95%CI: 1.0 – 1.8) for coronary heart disease incidence and 1.9 (95%CI: 1.6-2.2) for coronary heart disease mortality for sedentary occupations compared to high occupational activity.[25] In our meta-analysis, these comparison groups showed a pooled risk estimate of 1.4 (95%CI: 0.9 – 2.0) for total stroke, 3.2 (95%CI: 1.3 – 7.7) for hemorrhagic stroke and 1.8 (95%CI: 1.3 – 2.3) for ischemic stroke. Therefore, the protective effect of occupational physical activity on the incidence of stroke seems to be at least comparable to and maybe even greater than the protective effect on coronary heart disease incidence. For leisure time physical activity, Berlin and Colditz reported pooled relative risks varying from 1.3 (95%CI: 1.0-1.7) to 1.9 (95%CI: 1.0-3.4) for coronary heart disease incidence and mortality.[25] In the present meta-analysis, low leisure time physical activity levels compared to high leisure time physical activity levels showed pooled risk estimates of 1.3 (95%CI: 1.2-1.4) for total stroke, 1.4 (95%CI: 1.0-1.8) for hemorrhagic stroke and 1.3 (95%CI: 1.1-1.4) for ischemic stroke. Consequently, the protective effect of leisure time physical activity on the incidence of stroke seems to be comparable to the protective effect on coronary heart disease incidence.

If physical activity could be successfully increased at the population level, the public health impact is large. Firstly, because coronary heart disease and stroke, which are responsible for about 75% of all cardiovascular diseases, have been identified as the first and second causes of death worldwide.[142-144] Secondly, it has been predicted that annual mortality from non-communicable diseases such as coronary heart disease and stroke will increase from an estimated 28.1 million deaths in 1990 to 49.7 million deaths in 2020 and that coronary heart disease and stroke will remain the most important causes of death in the years to come.[145] Thirdly, these diseases are relatively expensive to the Health Care System. In the Netherlands for example, it has been estimated that the costs of coronary heart disease and stroke are 0.9 and 1.0 billion Euro respectively and that these diseases are responsible for approximately 5.5% of all health care costs in the Netherlands.[146]

In conclusion, this meta-analysis provides quantitative evidence that physical activity is an important modifiable risk factor for stroke. Compared to inactivity, the largest risk reduction is obtained for moderately intense physical activity. The protective effect of physical activity on the incidence of stroke needs more emphasis in the prevention of this important public health problem.

Appendix B

Scoring list to assess study quality adapted from Powell et al..[96]

	No, or uncertain (0 points)	Partly present (1 point)	Yes (2 points)
Measurement of physical activity			
1. the operational definition of physical activity should be stated and understandable			
2. The reliability and validity of the measurement instrument should be determined			
3. The activity measure should be based on the activities reported specifically for each participant rather than on presumed activities based on membership in a group			
4. The measure should include information about the frequency, duration and intensity of the activities encompassed			
5. The level of physical activity during earlier periods of life should be determined			
6. For cohort studies, adherence to the original physical activity classification should be determined			
7. The information about the physical activity measure should be systematically collected with specified standard methods.			
Measurement of stroke			
1. The criteria for the diagnosis of stroke should be clearly specified and applied consistently throughout the study.			
2. The information about the diagnosis of stroke should be systematically collected by using specified, standard sources and methods			
3. The diagnosis should be made separately for ischemic and hemorrhagic stroke			
4. The identification of persons with stroke should be independent of their activity status			
Epidemiological methods			
1. The physical activity status should be determined for a period that precedes the onset of stroke			
2. Analyses should be adjusted for age, sex, blood pressure, cardiovascular diseases, diabetes, smoking status and alcohol consumption			
3. For cohort studies, the original group of participants should be typical of the population from which they are drawn For case-control studies, both cases and controls should come from the same population			
4. For cohort studies, few participants should be lost to follow-up, or it should be established that the original activity status is similar for those who are lost and those who remain			
5. For case-control studies, cases and controls should be chosen and the data collected according to a predetermined protocol			
6. For case-control studies, both data collectors and respondents should be unaware of the hypothesis under consideration			
7. For case-control studies, any constraint should apply equally to cases and controls			

[6]

Physical inactivity and obesity are differently related to 12-year coronary heart disease and stroke mortality

Abstract

Purpose To study physical activity, BMI and their interaction in relation to CHD, stroke and CVD mortality.

Methods The study population consisted of 35,650 healthy Dutch men and women aged 20-59 years at baseline. Vital status was checked after 12-years of follow-up and the underlying cause of death was ascertained using death certificates. During this follow-up period 1,288 people died, 313 of which of CVD. In data analyses, Cox proportional hazard models were used.

Results Physical inactivity and obesity were independent risk factors for CHD, stroke and CVD mortality. Inactive, obese individuals were at higher risk of CHD (HR (95%CI): 3.1 (1.3-7.6)), stroke (HR (95%CI): 4.9 (1.1-20.8)) as well as CVD mortality (HR (95%CI): 3.2 (1.7-5.9)), compared to very active, normal weight individuals. Among obese individuals (BMI ≥ 30 kg/m^2), a clear dose-response relationship was found between total physical activity and CHD mortality. Among (very) active individuals, a clear dose-response relationship was found between BMI and stroke mortality.

Conclusions The present study showed that physical inactivity and obesity were independent risk factors and that especially the combination of these risk factors was strongly related to CVD mortality. In addition, we concluded that among obese individuals physical activity protected against CHD mortality and among (very) active individuals BMI was strongly related to stroke mortality.

Introduction

Both a sedentary lifestyle and obesity have been identified as independent risk factors for cardiovascular mortality.[4;25;27;147-149] In 1999, Blair and Brodney published a review on the combined effects of these factors on morbidity and mortality. They concluded that physical activity attenuated the health risks of overweight and obesity, and that active obese individuals actually had lower morbidity and mortality rates than normal weight individuals who were inactive.[33] However, most of the studies in this review were conducted solely in men, addressed merely one outcome measure and about two thirds of these publications were based on the same prospective study (the Aerobics Centre Longitudinal Study).

Several published studies reported on the association between physical activity and mortality from cardiovascular diseases (CVD) within strata of body mass index.[3;150-157] This is very helpful in answering the question whether or not physical activity attenuates the health risk of overweight and obese individuals, but does not provide the possibility to directly compare relative risks for cardiovascular mortality between active obese and inactive normal weight persons. To our knowledge, no study has addressed the interaction between physical activity and body mass index in relation to stroke mortality. Since both factors were found to be associated with stroke mortality, the interaction issue is also relevant in relation to stroke mortality.[29;30;140;158]

In the Dutch Monitoring Project on Cardiovascular Disease Risk Factors we collected data on physical activity (both occupational and leisure time) and body mass index, as well as 12-year cause-specific mortality among men and women aged 20-59 at baseline.[61] This provided us with the opportunity to extend the data on populations and types of outcome for which the association between physical activity, both job-related and in leisure time, body mass index and mortality has been described. The aim of the present study was to address the independent associations of physical activity and body mass index as well as their interaction in association with mortality from coronary heart disease (CHD), stroke and CVD.

Methods

Study population

Between 1987 and 1992 40,431 men and women participated in 'the Monitoring Project on Cardiovascular Disease Risk Factors' in the Netherlands.[61] Each year, a new random sample of men and women aged 20-59 years was selected from the municipal registries of three Dutch towns (Amsterdam, Doetinchem and Maastricht). The overall response rate was 50% for men and 57% for women. The measurement included a short physical examination at the Municipal Health Service and a self-administered questionnaire. The questionnaire dealt with demographic factors, history of cardiovascular diseases and diabetes, medication, contraceptive use and lifestyle factors. The Medical Ethical Committee of Leiden University approved the study and all participants signed an informed consent form.

Physical activity

Participants scored both leisure time and occupational physical activity at three levels: 1) inactive, i.e. little or no physical activity, 2) active, i.e. regular physical activity, and 3) very active, i.e. regular strenuous physical activity. Total physical activity was defined as 1) inactive, i.e. inactive during leisure time and at work, 2) active, i.e. active either during leisure time or at work and 3) very active, i.e. all other categories.

Reproducibility of the physical activity questions was tested in 1990 when a sample of 1440 participants from 1989 was invited for re-examination (response rate 64%).[159] Reproducibility for total physical activity had a kappa value of 0.47. Relative validity of the questionnaire was studied in 1998, in the Maastricht-cohort using the EPIC physical activity questionnaire.[38] This enabled us to calculate the average number of hours spent on at least moderately intense (≥4.0 MET) physical activity.[160] Inactive individuals spent an average of 3.3 hours per week on these activities, active individuals 6.7 hours and very active 19.6 hours per week. These results show that our questionnaire could distinguish between inactive, active and very active individuals with acceptable validity.

Body mass index

During the physical examination, height was measured to the nearest 0.5 cm without shoes, while weight was measured to the nearest 0.5 kg in subjects wearing indoor clothing and no shoes. The body mass index (BMI) was calculated as weight in kilograms divided by the squared height in metres. Subsequently, BMI was categorised according to the WHO-guidelines as underweight (< 18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2) and obese (≥ 30 kg/m^2).[161]

Covariates

Educational level was classified as low (lower vocational training or primary school), medium (secondary school and intermediate vocational training) or high (higher vocational training or university). A history of cardiovascular diseases was defined as being medically treated by a physician or specialist for heart problems or having had a myocardial infarction, heart surgery or a cerebrovascular accident. A history of diabetes was defined if the respondent reported having diabetes. Use of medication was inquired by asking about current use of cholesterol lowering and anti-hypertensive medication and contraceptives among women. Family history was defined positive if one parent had experienced a myocardial infarction before the age of 60. Smoking status was categorised as never, ex or current smoker. Alcohol consumers were categorised as abstainers (0 glasses/week), moderate users (men: <3 glasses/week and women: <2 glasses/week) or high users (men: ≥3 glasses/week and women: ≥2 glasses/week), assuming that one glass contained approximately 10 grams of alcohol.

Mortality follow-up

Mortality follow-up lasted until January 1, 2002. Information on vital status was obtained from the National Population Registry in the town of residence. For 40,424 persons mortality follow-up was successfully completed (99.98%). In total, 1630 persons had died. For 1600 persons (98%), the primary cause of death was obtained from Statistics Netherlands. Among the 30 persons of whom the cause of death could not be obtained, 17 died in another country and 13 did not have a registered cause of death. Causes of death were coded according to the ninth revision of the International Classification of Diseases (ICD-9) until January 1, 1996 (36%) and to the 10th revision

(ICD-10) thereafter (64%). Coronary heart disease (CHD) was defined as ICD-9 codes 410-414 or ICD-10 codes I20-I25, stroke as ICD-9 codes 430-438 or ICD-10 codes I60-I69 and cardiovascular diseases (CVD) as ICD-9 codes 390-459 or ICD-10 codes I00-I99.

Statistical analysis

Participants with a history of CVD or diabetes mellitus (n = 2683), those categorised as underweight (n = 794), women who were pregnant at the time of examination (n = 323), participants with incomplete data on vital status (n = 7), physical activity (n = 766), height or weight (n = 17), demographic factors (n = 92), medication use (n = 56), smoking or alcohol consumption (n = 43) were excluded from analyses. Consequently, statistical analyses were performed on complete sets of information of 35,650 (88.2%) men and women, free from cardiovascular diseases and diabetes.

Cox proportional hazard survival analysis was used to study associations with the different outcome measures. We checked the proportional hazard assumption by testing the correlation between the Schoenfeld residuals and the rankings of survival times. For all models presented in the results section, the proportional hazard assumption was met.

All analyses were conducted in the total study population, in strata of gender and in strata of age (<40 and ≥40 years of age) at baseline. Analyses were repeated in the total study population, excluding those who died within two years of the examination in order to eliminate an effect of pre-existing disease.

For the associations between physical activity and mortality, the highest physical activity level was defined as reference category. In the analyses associating BMI with mortality, the normal weight category was defined as reference category. We tested the interaction between physical activity and BMI by including an interaction term of total physical activity and BMI in the proportional hazard model. Also, we constructed nine strata by cross-tabulating total physical activity and BMI and defined the combination of very active and normal weight as reference category.

Table 6.1: Baseline characteristics and 12-year mortality of the study population free from cardiovascular diseases and diabetes at baseline.

	Men N = 16,786	**Women** N = 18,864
Demographic factors		
Age (years)	40.4 (10.8)	40.6 (11.0)
Low educational level (%)	55.8	65.1
Medication use		
Cholesterol lowering medication (%)	0.2	0.2
Anti-hypertensive medication (%)	3.0	4.1
Contraceptive use (%)	--	24.2
Family history		
Mother or father experienced MI before age 60 (%)‡	11.1	11.3
Physical activity		
Occupational physical activity (% inactive)	70.6	66.9
Leisure time physical activity (% inactive)	33.8	36.9
Total physical activity (%)		
Inactive	24.4	25.4
Active	50.2	51.7
Very active	25.4	22.9
Body Mass Index		
Normal weight (18.5 – 24.9 kg/m^2, %)	53.9	63.9
Overweight (25.0 – 29.9 kg/m^2, %)	38.6	26.6
Obese (≥30.0 kg/m^2, %)	7.5	9.5
Smoking		
Current smoker (%)	39.9	39.1
Ex-smoker (%)	29.5	21.5
Never smoker (%)	30.6	39.4
Alcohol consumers†		
Abstainers (%)	22.4	49.3
Moderate alcohol consumers (%)	62.5	42.1
High alcohol consumers (%)	15.1	8.6
Mortality		
Years of follow-up	11.9 (2.2)	12.0 (2.0)
All-causes (number of events)	762	526
Cardiovascular diseases	205	108
Coronary heart disease	121	41
Cerebrovascular accidents	22	38
Other causes of death	500	395
Unknown causes of death§	57	23

† abstainers: 0 glasses/day; moderate alcohol consumption: up till 2 glasses/day for women and up till 3 glasses/day for men; high alcohol consumption: 2 glasses/day or higher for women and 3 glasses/day or higher for men. ‡ MI = myocardial infarction. § Including missing values among the causes of death

Multivariate analyses were carried out in two steps. In the basic model, analyses were adjusted for age, gender (if applicable) and place of residence. In the multivariate model, additional adjustments were made for educational level, family history, cholesterol lowering and anti-hypertensive medication, contraceptive use, smoking status, alcohol consumption, BMI (if applicable) and total physical activity (if applicable).

Results

The mean age of the study population was 40 years, approximately 60% had a low educational level and only a small proportion reported medication use (Table 6.1). Inactivity was less common during leisure time (35%) than during occupational hours (70%). In general, inactivity was more prevalent among women than among men. About a quarter of the population was categorised as physically inactive for total physical activity. Almost 40% of the men and 25% of the women were overweight, whereas obesity was more prevalent among women (9.5%) than among men (7.5%). The percentage of inactivity was 23.3% among individuals with a normal weight, 26.1% among overweight and 31.7% among obese individuals (not in Table). Approximately 40% of the population smoked cigarettes and about 50% of the women and 20% of the men did not use alcohol. During the 12 years of follow-up, 4.5% of the men and 2.8% of the women died. About a quarter of these deaths was due to CVD.

Overall, a lower physical activity level was associated with a higher risk of mortality (Table 6.2). Being inactive based on total physical activity was associated with a higher risk of stroke mortality (HR = 2.59) than of CHD mortality (HR = 1.18) and CVD mortality (HR = 1.38). In general, results did not differ between men and women and between different age categories. One exception was the strong association between leisure time physical activity and stroke mortality among participants aged less than 40 years (HR (95%CI): 4.04 (0.81-20.26)). Excluding the first two years of follow-up did not meaningfully alter results.

Table 6.2 Occupational, leisure time and total physical activity and hazard ratio (HR (95%CI)) for CHD, stroke and CVD mortality in the total study population.

		Crude model	Basic model†	Multivariate model‡
		CHD mortality		
Occupational physical activity				
Inactive	(120 / 24,466)	1.31	1.02 (0.72 , 1.45)	1.12 (0.78 , 1.61)
Active/Very active	(42 / 11,184)	1.00	1.00	1.00
Leisure time physical activity				
Inactive	(54 / 12,637)	0.92	1.16 (0.83 , 1.61)	0.99 (0.71 , 1.38)
Active/Very active	(108 / 23,013)	1.00	1.00	1.00
Total physical activity				
Inactive	(38 / 8,886)	1.28	1.25 (0.77 , 2.03)	1.18 (0.72 , 1.92)
Active	(95 / 18,184)	1.55	1.29 (0.85 , 1.95)	1.40 (0.92 , 2.13)
Very active	(29 / 8,580)	1.00	1.00	1.00
		Stroke mortality		
Occupational physical activity				
Inactive	(50 / 24,466)	2.30	1.99 (1.00 , 3.93)	1.85 (0.93 , 3.70)
Active/Very active	(10 / 11,184)	1.00	1.00	1.00
Leisure time physical activity				
Inactive	(30 / 12,637)	1.84	2.14 (1.28 , 3.56)	1.93 (1.15 , 3.24)
Active/Very active	(30 / 23,013)	1.00	1.00	1.00
Total physical activity				
Inactive	(27 / 8,886)	3.31	3.10 (1.41 , 6.84)	2.59 (1.17 , 5.74)
Active	(25 / 18,184)	1.48	1.24 (0.56 , 2.76)	1.16 (0.52 , 2.58)
Very active	(8 / 8,580)	1.00	1.00	1.00
		CVD mortality		
Occupational physical activity				
Inactive	(233 / 24,466)	1.34	1.06 (0.82 , 1.37)	1.10 (0.85 , 1.43)
Active/Very active	(80 / 11,184)	1.00	1.00	1.00
Leisure time physical activity				
Inactive	(119 / 12,637)	1.13	1.39 (1.10 , 1.75)	1.20 (0.95 , 1.51)
Active/Very active	(194 / 23,013)	1.00	1.00	1.00
Total physical activity				
Inactive	(90 / 8,886)	1.60	1.54 (1.10 , 2.16)	1.38 (0.98 , 1.94)
Active	(168 / 18,184)	1.45	1.21 (0.89 , 1.64)	1.24 (0.91 , 1.69)
Very active	(55 / 8,580)	1.00	1.00	1.00

† Basic model: adjusted for age, gender and place of residence. ‡Multivariate model: additional adjustments for educational level, family history of myocardial infarction, cholesterol lowering medication, anti-hypertensive medication, contraceptive use, smoking status, alcohol consumption and BMI.

Table 6.3: Categories of body mass index and hazard ratio (HR (95%CI)) for CHD, stroke and CVD mortality in the total study population.

		Crude model	Basic model†	Multivariate model‡
		CHD mortality		
Body mass index				
Obese	(21 / 3,035)	2.47	1.46 (0.89 , 2.40)	1.46 (0.87 , 2.42)
Overweight	(80 / 11,489)	2.43	1.32 (0.94 , 1.84)	1.38 (0.99 , 1.94)
Normal weight	(61 / 21,126)	1.00	1.00	1.00
		Stroke mortality		
Body mass index				
Obese	(12 / 3,035)	3.78	2.14 (1.05 , 4.33)	2.20 (1.04 , 4.64)
Overweight	(25 / 11,489)	2.02	1.35 (0.76 , 2.40)	1.44 (0.80 , 2.58)
Normal weight	(23 / 21,126)	1.00	1.00	1.00
		CVD mortality		
Body mass index				
Obese	(48 / 3,035)	2.93	1.71 (1.22 , 2.39)	1.76 (1.24 , 2.49)
Overweight	(147 / 11,489)	2.31	1.32 (1.03 , 1.69)	1.39 (1.09 , 1.78)
Normal weight	(118 / 21,126)	1.00	1.00	1.00

† Basic model: adjusted for age, gender and place of residence. ‡Multivariate model: additional adjustments for educational level, family history of myocardial infarction, cholesterol lowering medication, anti-hypertensive medication, contraceptive use, smoking status, alcohol consumption and total physical activity.

Overweight and obese individuals were at a higher risk of mortality than normal weight people (Table 6.3) were. Obesity was stronger associated with stroke (HR = 2.20) than with CHD (HR = 1.46) and CVD mortality (HR = 1.76). This was less outspoken for overweight. Results generally did not differ between men and women, between strata of age at baseline and after exclusion of the first two years of follow-up. Although the risk of CHD was not statistically significant among the obese in the total study population, this risk ratio was statistically significant among obese women (HR (95%CI): 2.43 (1.04-5.67)).

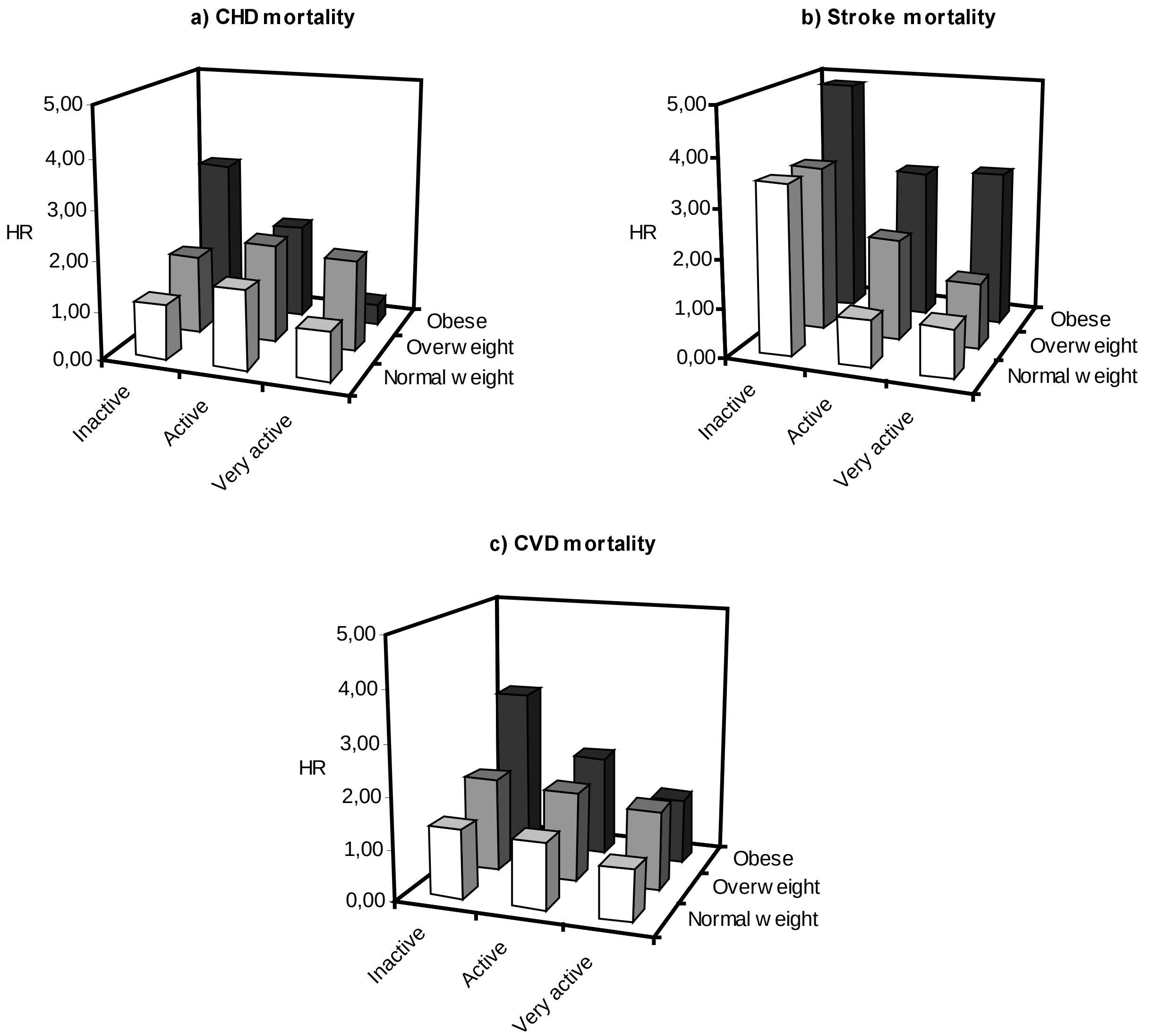

Figure 6.1: Multivariate relative risks of (a) CHD, (b) stroke and (c) CVD mortality for eight different combinations of physical activity and BMI with inactive and obese as reference category.

Figure 6.1 shows the hazard ratios for mortality from CHD, stroke and CVD for eight different combinations of physical activity and BMI compared with being very active in combination with having a normal weight. Consistently, the highest risk was found among those who were inactive and obese (HR (95%CI): CHD mortality: 3.14 (1.30-7.62), stroke mortality: 4.84 (1.13-20.73) and CVD mortality: 3.20 (1.72-5.95)). This risk gradually decreased with a higher physical activity level and lower BMI. The p-values for interaction between physical activity and BMI were 0.13 for CHD and stroke mortality and 0.40 for CVD mortality. Lower p-values were found in subgroups of the population, i.e. 0.10 for those aged 40 or over in relation to CHD mortality and 0.11 and 0.09 respectively for those aged 40 or over and women in relation to stroke mortality.

Among the obese, a clear dose-response relationship between physical activity and CHD mortality was observed (Figure 6.1). For CHD mortality, the risk dropped from 3.14 among inactive to 0.43 among very active individuals, resulting in a multivariate risk ratio of 7.39 (95%CI: 0.95-57.78). Such a dose-response relationship among the obese was not observed for stroke mortality. However, among active and very active individuals, a strong dose-response relationship was observed for BMI and stroke mortality. For these categories combined, the multivariate risk dropped from 3.12 among the obese to 0.97 among those with a normal weight, resulting in a risk ratio of 3.22 (95%CI: 1.21-8.56). Such a dose-response relationship among the active and very active was not observed for CHD mortality.

Discussion

In this prospective study we examined the associations between physical activity, BMI and CVD mortality in a relatively young cohort of Dutch men and women. We found that both physical activity and BMI were independently associated with CHD, stroke and CVD mortality. The combination of physical inactivity and obesity was strongly associated with CHD, stroke and CVD mortality. Among (very) active individuals a distinct dose-response relationship was found between BMI and stroke mortality and among the obese between physical activity and CHD mortality.

In the present study recall bias has played a role because of self-reported physical activity data. The reproducibility coefficient of 0.5 for total physical activity reflects fairly good agreement. Results of a study on the relative validity showed that a higher physical activity level was indeed associated with a greater amount of time spent on at least moderately intense physical activity. We conclude that our questionnaire was an adequate tool for distinguishing inactive and active groups within our population.

We had to rely on death certificates because information from hospital charts was not available. Therefore we could not distinguish causes of death on a detailed level. Moreover, our study population was relatively young and therefore, after 12 years of mortality follow-up only 313 cases of CVD mortality were present. The combination of these factors affected our ability to analyse associations in detail. For example we were not able to distinguish between ischemic and hemorrhagic stroke.

Numerous studies have addressed the relationships between physical activity or BMI and CHD and showed that especially inactive and obese individuals are at high risk.[4;25;27;162] It has also been shown that physical inactivity and obesity are risk factors for stroke.[29;30;140;158] The results of the present study are in accordance with these results.

To our knowledge, only four studies have addressed the question whether or not physical activity and BMI interact with each other in relation to mortality.[163-166] Three of these studies used cross-tabulation of physical activity and BMI categories, similarly to our analyses for figure 1.1, but did not test for statistical interaction.[163-165] The fourth study among 1,461 American men and women did not use cross-tabulation, but did test for interaction. This study found a statistical significant interaction ($p<0.01$) in relation to CHD mortality among men, but not among women.[166] The present study indicated that an interaction between physical activity and BMI in relation to CHD mortality would be especially present among those aged 40 or over ($p=0.10$) irrespective of gender.
Based on these results, no definite answer can be given as to whether or not physical activity and BMI interact in relation to CHD mortality.

Blair and Brodney stated that overweight and obese individuals who are active have lower death rates than overweight and obese individuals who are inactive. They also noted that this gradient across activity categories is often steeper in the higher categories of body habitus variables.[33] In the present study, also a steep gradient for physical activity and CHD mortality was observed among the obese. For stroke mortality, this gradient was steepest among those with normal weight. Blair and Brodney also stated that overweight and obese individuals who are active are less likely to die prematurely compared to normal weight persons who lead sedentary lives.[33] Results of the present study underline this statement for CHD mortality but not for stroke mortality. Finally, Blair and Brodney stated that at least in men, inactivity is as important as overweight and obesity as predictor of mortality.[33] The present study confirms this not only for men, but also for women.

The present study was, to our knowledge, the first to investigate the combination of physical activity and BMI in relation to stroke mortality. We observed a dose-response relationship between BMI and stroke mortality among active and very active, but not among inactive individuals. Furthermore, we found an interaction between physical activity and BMI in relation to stroke mortality among women. This study provides an indication that particularly the combination between physical inactivity and obesity is strongly related to stroke mortality. However, results from other studies are needed before definite statements can be made on the interaction between physical activity and BMI in relation to stroke mortality.

In summary, both physical activity and BMI are independent risk factors for cardiovascular mortality. Within BMI strata, the protective effect of physical activity on CHD was largest among obese individuals. Among (very) active individuals, a dose-response relationship was found between BMI and stroke mortality. We conclude therefore that physical inactivity and obesity are independent risk factors for CVD mortality and that physical inactivity and obesity interact differently with CHD and stroke mortality.

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[7]

Leisure time physical activity and health-related quality of life: cross-sectional and longitudinal associations*

Abstract

Purpose To study cross-sectional as well as longitudinal associations between leisure time physical activity and health-related quality of life in an apparently healthy population.
Methods Participants (1,871 men and women aged 26-65) were asked to fill in a questionnaire on physical activity and health-related quality of life.
Results Cross-sectionally, at least moderately intense leisure time physical activity was associated with general health perceptions, vitality, physical functioning and role limitations due to physical health problems. Change in leisure time physical activity was associated with change in social functioning in men as well as in women, irrespective of the intensity of physical activity. Only in men, change in leisure time physical activity was associated with change in vitality and general mental health.
Conclusion Cross-sectional associations were not confirmed by longitudinal analyses. Cross-sectional associations were mainly found for physical components of health-related quality of life, whereas longitudinal associations were predominantly observed for mental components of health-related quality of life. Confirmation of these results by those of other studies is needed in order to quantify health promotion messages.

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Introduction

As in many other Western countries, about half of the Dutch population is physically inactive according to the physical activity guideline, which states that every adult should accumulate 30 minutes or more of at least moderately intense physical activity on most, preferably all days of the week.[4;41;53;58] The association between physical activity and health has been well established.[4;102;105;167-172] In addition, cross-sectional studies have shown that physical activity may affect health-related quality of life by influencing its two main components: physical functioning and well-being.[4;34;173;174]

In light of the contribution of physical activity to public health it would be of particular interest to know whether or not longitudinal associations between change in physical activity and change in health-related quality of life could confirm the cross-sectional associations. From a health promotion point of view it would be of additional interest to know whether these associations differ between those who were inactive or active at baseline. To our knowledge, no previous studies have been published in which the association between change in physical activity and health-related quality of life has been described for the general, healthy population. Previous longitudinal studies on this issue were mostly (short term) intervention studies conducted in a clinical setting or among subgroups of the population.[175-182] For example, one study reported that after an eight-week strength training program among women aged 55 years and older, mental and physical health functioning tended to improve.[175] In another study the effect of endurance exercise on health related quality of life among 50-65 year old adults was studied. Over a 12-month period greater levels of endurance exercise participation were significantly associated with better ratings of physical functioning, role limitations due to physical health problems, pain and current health perceptions. Exercise participation levels were not significantly associated with well-being, fatigue and sleep problems.[181] Painter et al. studied a group of hemodialysis patients in their response to a 16-week exercise program. Significant improvements were found for physical functioning, role limitations due to physical health problems, general health and bodily pain.[179] Woodruff and Conway studied the impact of health/fitness status and health behaviour on perceived quality of life among U.S. Navy personnel at one-year and two-year intervals. They found a positive association between changes in health behaviour dimensions at 1-year and 2-year intervals and changes in quality of life in general.[182]

In the present study we used cohort data with a follow-up period of 5 years. In addition to cross-sectional analyses, the association between change in physical activity and change in health-related quality of life was studied. Longitudinal analyses were conducted in the total study population and separately for different baseline levels of physical activity.

Methods

Study population

The study population included individuals who participated in the Monitoring Project on Risk Factors for Chronic Diseases (MORGEN-project) that was carried out in The Netherlands from 1993 to 1997 at the municipal health services in three towns: Amsterdam, Doetinchem and Maastricht.[62] Each year, a new random sample of men and women aged 20-59 years was selected from the municipal registry of Amsterdam and Maastricht. In Doetinchem, the study population consisted of individuals ages 26-59 who had participated in the previous Monitoring Project on Cardiovascular Disease Risk Factors (1987-1992) and a new random sample of men and women aged 20-25 years from the municipal registry of Doetinchem to cover the whole age range of 20-59 years.[61] From 1998 onwards, the study continued only in Doetinchem (Doetinchem-cohort) including those individuals who participated in the MORGEN-project. Each year, the population of five years ago was asked to participate in the study.

For the present study, we used data from the MORGEN-project from the year 1995 onwards, because these years included identical measurement of physical activity as well as health-related quality of life. In order to study change in these factors we combined these data with data from the Doetinchem-cohort from the year 2000 onwards. At the present time, data from the Doetinchem-cohort was only available up to the year 2001. Therefore, the present study included data from the 1995 and 1996 MORGEN-study (first measurement; overall response rate 68.9%) and from the 2000 and 2001 Doetinchem-cohort (second measurement; overall response rate 73.9%). In total, 2,129 (75%) participants completed both measurements. For both measurements an identical questionnaire was used on demographic factors, medical history, lifestyle and health-related quality of life. In addition, a trained research assistant at the municipal health service measured height and weight. All respondents gave written informed consent.

Data collection

Demographic factors were age, gender and educational level. A low educational level was defined as lower vocational or primary school. Information about the medical history of chronic diseases was obtained by self-report for cardiovascular diseases, diabetes (type I and type II), asthma and cancer. Height was measured to the nearest 0.5 cm without shoes, while weight was measured to the nearest 0.5 kg in subjects wearing indoor clothing and no shoes, after they had emptied their pockets. The body mass index was calculated as height in centimetres divided by the squared weight in kilograms. These variables were used to characterise the study population and to adjust analyses for possible confounding effects.

The physical activity questionnaire used was designed for the ‘European prospective investigation into cancer and nutrition’ (EPIC) and was extended with a question on sports and other strenuous leisure time physical activities. Therefore, the questionnaire included questions on time spent on leisure time activities for summer and winter separately and questions on sports and activities at the place of work irrespective of season. Leisure time physical activity included walking, bicycling, odd jobs and gardening. The question on sports and other strenuous physical activities enabled the respondents to report on type, frequency and duration of three different activities. Activities at the place of work were measured in the following categories: ‘sitting’, ‘sitting and standing’, ‘walking regularly while carrying light objects’, ‘walking regularly while carrying heavy objects’.

The physical activity questionnaire (excluding the sport item) was validated with a 3-day activity diary in a population of 126 men and women aged between 20 and 70 years. Spearman correlation coefficients between the questionnaire and the diary were between 0.32 and 0.81 for men and between 0.28 and 0.72 for women.[38]

In the present study, physical activity data was limited to leisure time physical activity (including sports). Since leisure time physical activity is easier to modify than occupational physical activity it comprises a larger interest for public health promotion.[96] Total time spent on leisure time physical activity was based on hours per week spent on walking, bicycling (including commuting), odd-jobs and gardening for summer and winter separately and hours per week spent on sports and other strenuous leisure time activities irrespective of season. The average amount of time per week spent on walking, bicycling, odd jobs and gardening was estimated by taking the average of the reported hours per week of summer and winter. Activities were categorised according to their MET-value (i.e. metabolic equivalent or number of times resting metabolic rate) as reported by Ainsworth.[40] Cut-off points (4.0 and 6.5 MET) for the categories light, moderate and vigorous were derived from the Dutch physical activity guideline.[53]

Health-related quality of life was measured by the Dutch version of the standardised RAND-36 questionnaire, which was translated from the standardised SF-36 Health Survey.[183;184] The RAND-36 included 1 item on health change in the past year and 35 items on eight dimensions of health-related quality of life: physical functioning, role limitations due to physical health problems, bodily pain, general health perceptions, vitality, social functioning, role limitations due to emotional problems and general mental health. For each dimension, the crude score was linearly converted to a 0 to 100 scale, with higher scores indicating higher levels of functioning or well-being.[184] Ware et al. constructed two summary scores with factor analytic methods: the physical component summary scale and the mental component summary scale.[185]

Statistical analysis

The aim of this study was to investigate the association between leisure time physical activity and health-related quality of life in a general, apparently healthy population. Therefore, participants with self-reported chronic diseases (cardiovascular diseases, diabetes, asthma and cancer) at baseline or follow-up were excluded (n = 210). In addition, participants with missing values on physical activity or health-related quality of life (n = 48) were excluded. Consequently, 1871 men and women aged 26 to 65 years were available for data analyses. In our data, baseline values and change in health-related quality of life differed between men and women. Therefore, all analyses were conducted separately for men and women.

In general, health effects are expected from engagement in physical activity of at least a moderate intensity.[4;9;41;53;58] Therefore, we will focus on studying the association between leisure time physical activity of this intensity and health-related quality of life. However, in order not to oversee a possible association between total leisure time physical activity and health–related quality of life, all analyses were also executed for leisure time physical activity irrespective of intensity.

The cross-sectional association between leisure time physical activity and health-related quality of life was studied at baseline and after 5 years of follow-up by creating sex- and measurement-specific quintiles of the average amount of time spent on leisure time physical activity. Adjusted mean scores of health-related quality of life were calculated for each quintile of physical activity using the 'general linear models'-procedure in SAS (version 8.02). Adjustments were made for age and educational level. Trends across the quintiles were evaluated with linear regression in which the quintiles were modelled as continuous variables.

The 5-year change in time spent on leisure time physical activity and the 5-year change in scores of health-related quality of life were calculated for each participant by subtracting the measurement in 1995/1996 from 2000/2001. The association between change in leisure time physical activity and change in health-related quality of life was studied in the total study population with linear regression analyses. First, adjustments were made for age and educational level. In a second model, additional adjustments were made for the average value of both measurements for physical activity and health-related quality of life in order to adjust for regression to the mean.[186]

Because of the possible pronounced effect of extreme values on the slope of a regression line, the 5% most extreme values (i.e. the 2.5% maximum decrease (2.5^{th} percentile) and 2.5% maximum increase (97.5^{th} percentile)) of leisure time physical activity were excluded in a third model. The 2.5^{th} percentile of change in at least moderately intense leisure time physical activity was –14 hours per week in men and –13 hours per week in women, whereas the 97.5^{th} percentile of change was 14 hours per week in men and 11 hours per week in women. For total leisure time physical activity these cut-off points were –39.5 and 35 hours per week in men and –47 and 34 hours per week in women.

In order to see whether the association between change in leisure time physical activity and health-related quality of life concentrated on different dimensions of health-related quality of life depending on different levels of baseline physical activity, we also conducted linear regression analyses stratified by baseline quintiles. Because we wanted to focus on the possible difference between 'inactive' and 'active' participants, the middle three quintiles were grouped together. Again, the first model was adjusted for age and educational level, whereas in the second model additional adjustment was made for the average value of health-related quality of life. In the third model the 5% most extreme changes in leisure time physical activity were excluded within strata.

Table 7.1: Baseline characteristics of the study population.

	Men (n = 883)	**Women (n = 988)**
Age (years)	44.1 ± 9.2	43.3 ± 9.3
Height (m)	1.80 ± 0.68	1.67 ± 0.62
Weight (kg)	83.2 ± 10.3	70.0 ± 11.5
Body Mass Index (kg/m^2)	25.5 ± 2.9	24.8 ± 4.0
Educational level (% low †)	38.6	57.3
Walking (hours/week)	9.8 ± 10.4	9.5 ± 10.2
Odd-jobs (hours/week)	4.2 ± 5.3	1.0 ± 2.6
Bicycling (hours/week)	3.6 ± 4.0	4.8 ± 4.4
Gardening (hours/week)	2.1 ± 3.0	1.6 ± 2.0
Sports (hours/week)	1.8 ± 2.9	1.3 ± 2.5
Other leisure time activities (hours/week)	0.3 ± 1.9	0.2 ± 1.4

† A low educational level was defined as lower vocational or primary school.

Results

Table 7.1 shows baseline characteristics of the study population separately for men and women. The average age and body mass index was comparable between men and women. Women more often than men had a low educational level. Men spent more time on odd jobs, gardening and sports, whereas women spent more time on bicycling.

Table 7.2: Leisure time physical activity (mean ± sd) and health-related quality of life (mean ± sd) at baseline (1995/1996) and after 5 years of follow-up (2000/2001).

	Men n = 883		**Women n = 988**	
	1995/1996	**2000/2001**	**1995/1996**	**2000/2001**
Leisure time physical activity *(hours/week)*				
Light intensity[¶] (< 4.0 MET)	14.3 ± 12.7 [†]	12.6 ± 10.7 [‡,§]	10.8 ± 10.8	10.1 ± 9.7
Moderate intensity[¥] (4.0 – 6.5 MET)	6.4 ± 5.7 [†]	6.6 ± 5.8	7.2 ± 5.5	6.9 ± 4.9
Vigorous[&] (≥ 6.5 MET)	1.0 ± 2.1 [†]	0.8 ± 1.9 [‡,§]	0.4 ± 1.7	0.3 ± 1.0
Health-related quality of life *(score with range 0 -100)*				
Physical functioning	91.6 ±13.7 [†]	90.6 ±14.5 [‡,§]	88.3 ±15.7	86.9 ±16.7 [£]
Role limitations due to physical health problems	86.6 ±27.5 [†]	86.7 ±27.5 [‡]	81.5 ±32.8	79.2 ±35.1
Bodily pain	84.1 ±20.2 [†]	82.9 ±20.2 [‡,§]	78.4 ±22.0	76.2 ±22.3
General health perceptions	75.1 ± 16.8	72.9 ± 16.5 [§]	74.8 ± 16.8	72.5 ± 17.2 [£]
Vitality	70.0 ± 15.7 [†]	69.4 ± 16.7 [‡]	65.2 ± 16.4	64.7 ± 16.5
Social functioning	90.1 ±17.0 [†]	89.4 ±18.4 [‡]	84.3 ±20.3	84.0 ±20.6
Role limitations due to emotional health problems	89.9 ±24.5 [†]	88.6 ±27.6 [‡]	85.1 ±31.0	84.5 ±32.3
General mental health	78.8 ± 13.5 [†]	78.7 ± 14.0 [‡]	74.2 ± 14.7	74.6 ± 14.6
Physical component score	52.0 ±7.0 [†]	51.5 ±7.2 [‡,§]	50.9 ±8.3	49.8 ±8.6 [£]
Mental component score	51.5 ± 7.8 [†]	51.2 ± 8.9 [‡]	49.0 ± 9.5	49.2 ± 9.7

[†]In 1995/1996 men scored significantly different ($p<0.05$) than women, [‡]In 2000/2001 men scored significantly different ($p<0.05$) than women, [§]In men, the value in 2000/2001 differed significantly ($p<0.05$) from the value in 1995/1996, [£]In women, the value in 2000/2001 differed significantly ($p<0.05$) from the value in 1995/1996, [¶]Main activities were walking and odd-jobs, [¥]Main activities were bicycling, gardening and sports like fitness, swimming and dancing, [&]Main activities were sports like running, squash, soccer, tennis and hockey.

Table 7.2 presents mean values for leisure time physical activity and health-related quality of life at baseline and after 5 years of follow up, separately for men and women. At baseline and after 5 years of follow-up, women, compared to men, reported higher levels of light intense leisure time physical activity and lower levels of leisure time physical activity of a higher intensity. Average scores on all dimensions of health-related quality of life were lower in women than in men, with the exception of general health perceptions. Mean changes in both at least moderately intense physical activity (men: +10 minutes/week bicycling, +10 minutes/week gardening, -10 minutes/week sports; women: -15 minutes/week bicycling, gardening stable, -5 minutes/week sports; not in Table) and health-related quality of life (men: 0.1-2.4; women: 0.2-3.4; not in Table) were generally small and showed a decrease in physical activity as well as in health-related quality of life.

Cross-sectional associations

Adjusted mean baseline scores of health-related quality of life are shown in Table 7.3 for quintiles of hours per week spent on at least moderately intense physical activity. In both men and women, significant positive associations were found for physical functioning ($p=0.02$ and <0.0001 respectively), general health perceptions ($p=0.003$ and <0.0001 respectively), vitality ($p=0.0003$ and 0.003 respectively) and the physical component score ($p=0.05$ and 0.0002 respectively; Table 7.3). An additional significant trend was found for general mental health ($p=0.01$) in men and for role limitations due to physical health problems ($p=0.0009$) and social functioning ($p=0.04$) in women (Table 7.3). Cross-sectional analyses in the same study population 5 years later (not in Table) showed a significant trend for general health perceptions ($p=0.04$ and 0.03 respectively) and vitality ($p=0.02$ and 0.01 respectively) in both men and women. In women, additional significant trends were found for physical functioning ($p=0.004$), role limitations due to physical health problems ($p=0.05$) and the physical component score ($p=0.008$; not in Table). In men, no additional significant trends were found. Analyses for total leisure time physical activity (not in Table) showed no significant associations for both measurements and for any of the dimensions of health-related quality of life.

Table 7.3: Baseline (1995/1996) association between at least moderately intense leisure time physical activity (in quintiles of hours per week) and health-related quality of life (mean score), adjusted for age, educational level and body mass index.

	Q1	Q2	Q3	Q4	Q5	p for trend
Men	**0-3.0 hrs/wk n = 179**	**3.0-5.0 hrs/wk n = 158**	**5.0-7.5 hrs/wk n = 191**	**7.5-11.5 hrs/wk n = 182**	**>= 11.5 hrs/wk n = 173**	
Physical functioning	90.0	92.6	91.8	90.8	94.5	0.02
Role limitations due to physical health problems	85.3	87.3	87.1	87.0	87.7	0.5
Bodily pain	83.0	84.9	83.7	85.0	85.3	0.3
General health perceptions	72.9	74.6	75.1	76.1	77.9	0.003
Vitality	66.7	69.2	71.0	70.9	72.6	0.0003
Social functioning	90.0	90.4	90.1	90.2	90.5	0.8
Role limitations due to emotional problems	90.5	91.6	89.4	89.5	89.2	0.4
General mental health	77.3	78.3	78.8	79.8	80.6	0.01
Physical component score	51.3	52.3	52.1	52.1	53.0	0.05
Mental component score	50.9	51.3	51.5	51.8	51.8	0.2
Women	**0-3.5 hrs/wk n = 195**	**3.5-5.5 hrs/wk n = 195**	**5.5-7.5 hrs/wk n = 189**	**7.5-11.0 hrs/wk n = 203**	**>= 11.0 hrs/wk n = 206**	
Physical functioning	84.1	89.1	88.4	88.9	90.8	<0.0001
Role limitations due to physical health problems	77.1	77.8	77.0	81.8	86.9	0.0009
Bodily pain	75.7	78.2	80.2	79.1	79.0	0.1
General health perceptions	70.5	76.1	73.3	77.1	78.1	<0.0001
Vitality	62.4	65.5	65.4	65.7	67.7	0.003
Social functioning	81.9	84.7	84.4	83.6	86.6	0.04
Role limitations due to emotional health problems	81.6	86.3	80.9	85.9	87.5	0.08
General mental health	74.5	74.6	74.0	74.2	76.4	0.2
Physical component score	49.0	50.7	50.8	51.4	52.0	0.0002
Mental component score	48.6	49.3	48.5	48.9	50.0)	0.2

Longitudinal associations

Table 7.4 shows the associations between change in at least moderately intense leisure time physical activity and change in health-related quality of life as a result of linear regression analyses with and without exclusion of extreme values. We did not differentiate the models with and without adjustment for regression to the mean, because we found no real difference between the regression coefficients from these models. In both men and women change in leisure time physical activity was associated with change in social functioning irrespective of the model used. In men, an increase in leisure time physical activity of one hour per week was significantly associated (p = 0.01) with an increase in social functioning of 0.38 score points. In women, a similar association was found (β = 0.37; p = 0.04). In men only, change in leisure time physical activity was associated with change in bodily pain, general health perceptions and the physical component score. However, these associations disappeared when extreme values were excluded from the analyses.

Table 7.4: Change in health-related quality of life per one hour change in at least moderately intense leisure time physical activity.

	adjusted for age, educational level and regression to the mean		**additional adjustment for exclusion of extreme values**	
	β	**p-value**	β	**p-value**
Men				
Physical functioning	0.04	0.5	0.08	0.4
Role limitations due to physical health problems	0.20	0.3	-0.09	0.7
Bodily pain	0.31	0.006	0.25	0.1
General health perceptions	0.17	0.04	0.11	0.3
Vitality	0.11	0.2	0.14	0.2
Social functioning	0.22	0.05	0.38	0.01
Role limitations due to emotional health problems	-0.01	0.9	-0.03	0.9
General mental health	0.08	0.3	0.09	0.3
Physical component score	0.08	0.03	0.04	0.4
Mental component score	0.04	0.4	0.07	0.3
Women				
Physical functioning	0.15	0.07	0.09	0.4
Role limitations due to physical health problems	0.38	0.09	0.43	0.2
Bodily pain	0.08	0.5	0.01	0.9
General health perceptions	0.08	0.4	-0.05	0.7
Vitality	0.08	0.4	0.02	0.9
Social functioning	0.37	0.004	0.37	0.04
Role limitations due to emotional health problems	0.23	0.3	-0.18	0.5
General mental health	-0.02	0.8	-0.17	0.1
Physical component score	0.07	0.1	0.09	0.2
Mental component score	0.05	0.4	-0.05	0.5

Analyses for total leisure time physical activity (not in Table) showed a significant association in both men and women for social functioning (β = 0.16; p = 0.001 for men and β = 0.11; p = 0.02 for women). Only in men, additional significant associations were found for change in vitality (β = 0.11; p = 0.005), general mental health (β = 0.07; p = 0.04) and the mental component score (β = 0.06; p = 0.01).

Stratified analyses (not in Table) showed few differences between significant associations found among inactive (Q1) and active (Q5) men and women. In the analyses for at least moderately intense leisure time physical activity, active men showed a significant association with change in bodily pain (β = 0.55; p = 0.01) and change in the physical component score (β = 0.17; p = 0.01), whereas inactive men did not. However, when extreme values were excluded from the analyses these associations were no longer significant. In women, stratified analyses showed no different significant associations between the inactive and the active group for the association between at least moderately intense physical activity and health-related quality of life. In the analyses for total leisure time physical activity no different significant associations were found between inactive and active men and women.

Discussion

Results of this study suggest associations between leisure time physical activity and health-related quality of life in cross-sectional as well as in longitudinal analyses. Cross-sectional associations at baseline and follow-up showed a consistent positive association with at least moderately intense leisure time physical activity for general health perceptions and vitality in both men and women. In women alone, a consistent association was found for physical functioning, role limitations due to physical health problems and the physical component score. Longitudinal data showed a positive association between change in leisure time physical activity and change in health-related quality of life for social functioning in both men and women irrespective of the intensity of leisure time physical activity. Only in men, change in total leisure time physical activity was associated with change in vitality, general mental health and the mental component score.

Before discussing our results in light of other studies, some methodological issues need consideration. In this study we used questionnaires to assess physical activity and health-related quality of life. Self-report may have biased our results because of over or underreporting on both topics. However, it is unclear to what magnitude this bias has influenced our results. Furthermore, misclassification in the categories 'chronic illness' and 'no chronic illness' could have taken place. Firstly, exclusion of participants was based on self-report of chronic diseases (i.e. cardiovascular diseases, diabetes, asthma and cancer). Secondly, because we only had information on the chronic condition included in the questionnaire of the MORGEN-project, we could not control for all possible chronic conditions. The results of the longitudinal analyses may have been particularly affected by measurement error caused by self-report, because measurement error of both measurements influenced results of these analyses.

In our longitudinal analyses we adjusted for average values of leisure time physical activity and/or health-related quality of life in order to adjust for regression toward the mean. Another possibility would have been to adjust for baseline values instead of average values. However, it is known that this method suffers from complications in interpreting results. The main drawback of our method is that some overcorrecting will take place, leading to an underestimation of the effect.[(186)] Therefore, our results give a cautious estimate of the associations between leisure time physical activity and health related quality of life, particularly for the longitudinal analyses.

In both men and women, changes in at least moderately intense physical activities were small. Because we excluded participants with reported chronic illnesses, these changes are possibly smaller than in a population including participants with chronic illnesses. Particularly when people become chronically ill it would be expected that their physical activity level decreases. Changes in the dimensions of health-related quality of life varied from 0.1 to 2.4 in men and from 0.2 to 3.4 in women. The relevance of such small changes is under debate.[(187;188)] Changes that are important to patients, clinicians or policy makers probably differ. Developers of the SF-36 questionnaire suggested that a 5 to 10 point change along any of the eight dimensions measured is clinically meaningful.[(187;188)] However, even small changes in physical activity and in health-related quality of life could be relevant to public health because the overall societal impact of these changes can be large.[(189)]

Cross-sectional associations

Previous cross-sectional studies on the association between physical activity and health-related quality of life showed varying results. However, in general, associations between physical activity and one or more dimensions of health-related quality of life were found. For example, Brown et al. found that the physical component score of the SF-36 was significantly higher among participants with a higher physical activity score (based on the number of times that participants engage in leisure time physical activities) in young, middle-aged as well as older women. In this particular study, middle-aged women with the lowest physical activity level had a mean score of 48.1 (47.7-48.6), whereas middle-aged women with the highest physical activity level had a mean score of 51.4 (50.9-52.0). Similar, but not significant patterns were found for the mental component score.[(190)] In a study by Laforge et al. stage of readiness to exercise was significantly associated with physical functioning, general health perceptions and vitality in men and women aged 18 to 75. Generally, scores on these items increased over the categories precontemplation, contemplation, preparation, action and maintenance. For example, for general health perception the scores were 67.0, 69.4, 71.5, 75.5 and 78.7 respectively.[(191)] Our cross-sectional analyses showed a significant positive and consistent trend among physical activity quintiles in women alone for physical functioning, role limitations due to physical health problems and the physical component score and for general health perceptions and vitality in both men and women. The discrepancies in results between these studies may have been caused by the use of different study populations or differences in methodology. Because of the different associations in various studies, additional studies on the association between change in physical activity and change in health-related quality of life are needed in order to better understand the association between physical activity and health-related quality of life.

Longitudinal associations

Based on the results of the present study, no decisive answer can be given on the cause and effect question in the association between (change) in physical activity and health-related quality of life even though we used longitudinal data. It is not clear whether it is true that people who are physically active experience a better quality of life or that people with a better quality of life are more likely to be physically active. Both hypotheses may be correct and do not exclude one another. In case of the consistent association we found between change in leisure time physical activity and change in social functioning, however, it seems reasonable to assume that increasing leisure time physical activity causes an increase in social functioning. The associations we found among men between change in leisure time physical activity and bodily pain, general health perceptions as well as the physical component score were mainly caused by extreme changes in leisure time physical activity. This might be a reflection of either a bias in our study population or a genuine effect. When considering the pain dimension for example, it might be plausible that physical conditions, such as injuries biased our results.

Comparison of our data with other longitudinal studies on the association between change in physical activity and change in health-related quality of life is difficult. Most of these studies were clinical intervention studies in which the effect of a training program on well-being and/or physical functioning was measured in a population with a specific disease or disability.[176;179;180] To our knowledge, no other study reported on the association between change in physical activity and change in health-related quality of life in the general population. We found only one study in which change in physical activity was not based on an intervention. In that study, Woodruff and Conway reported a positive association in U.S. Navy personnel between changes in health behaviour dimensions at 1-year and 2-year intervals and changes in quality of life.[182] However, Woodruff and Conway used an overall measure for quality of life and only 1 questionnaire item on physical activity.

Cross-sectional associations versus longitudinal associations

Associations observed in our cross-sectional analyses were not confirmed in the longitudinal analyses. This may have been due to the methodological drawbacks of our study mentioned earlier. Another possibility is that in the cross-sectional analyses physical activity served as a proxy for, for example, a generally healthy lifestyle or health status, resulting in falsely attributing associations to physical activity. However, intervention studies indicate that physical activity can indeed improve health-related quality of life.[175-181] It is not clear to what extent these intervention studies might have been biased by a specific training effect and/or the so called Hawthorne-effect (the effect of the interest shown by the researcher in the respondents), leading to overestimation of the association between physical activity and health-related quality of life.[192;193]

In conclusion, cross-sectional associations were mainly found for physical components of health-related quality of life, whereas longitudinal associations were predominantly observed for mental components of health-related quality of life. Based on the results of the present study no conclusion can be drawn on cause and effect in the association between (change) in physical activity and health-related quality of life. Other studies, (long term) intervention studies included, aimed at the general population are needed to confirm the results found in our study, in order to be able to quantify health promotion messages regarding physical activity and health-related quality of life.

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[8]

General discussion

Physical inactivity has become a major public health threat because currently approximately 25% of the Dutch population is not engaged in any physical activity. It has been shown that a sedentary lifestyle is associated with an increased risk of for example cardiovascular diseases. The combination of a high prevalence of inactivity and its association with chronic diseases calls for public health action. Therefore, physical activity research has been focussing on developing physical activity guidelines that represent physical activity levels necessary to prevent these health-risks.
In order to be able to plan and execute physical activity interventions in the general population, we need knowledge on determinants of physical activity. Little is known about the behavioural determinants of adherence to the Dutch physical activity guideline and of specific domains and types of physical activity. Moreover, research on the association between the physical environment and engagement in physical activity is just emerging.

In this thesis we made an effort to address different public health aspects of physical activity in the Netherlands, taking into account its broad scope. We addressed physical activity methodology, behavioural, lifestyle and environmental determinants of physical activity and we studied the relationship between physical activity and outcome measures such as coronary heart disease, stroke and health-related quality of life.

Main findings

Table 8.1 summarises the main findings for each chapter described in this thesis. We studied reproducibility and relative validity of the SQUASH (chapter 2) in a population of 50 Dutch adults and found that the questionnaire was fairly reliable (overall reproducibility: r_s=0.58) and reasonably valid (overall validity: r_s = 0.45). We concluded that the SQUASH is a useful tool for monitoring physical activity levels in the Dutch population.

Table 8.1: Main findings of the chapters described in this thesis.

Ch	Aim	Study population	Conclusion
2	To determine reproducibility and relative validity of a short questionnaire to assess health enhancing physical activity (SQUASH) in an adult population.	n=50, aged 27-58 years	The SQUASH is a fairly reproducible (r_s=0.58) and reasonably valid (r_s=0.45) questionnaire.
3	To investigate demographic, psychosocial and lifestyle factors potentially related to moderate and vigorous physical activity and adherence to the physical activity guideline.	n=3,950, aged 23-70 years	Moderate physical activity is associated with the attitude towards increasing physical activity and with higher fruit consumption and a lower prevalence of smoking. Adherence to the physical activity guideline is associated with self-efficacy. Only vigorous physical activity is associated with the perception of sufficient affordable facilities in the neighbourhood.
4	To identify factors of the physical environment that may influence time spent on walking and bicycling.	n=11,541, aged 21-70 years	The surface of green and recreational space, especially sport grounds and parks, close to home is associated with time spent on bicycling.
5	To make quantitative statements on the association between physical activity and stroke and to explore sources of heterogeneity for this association.	31 observational studies on physical activity and stroke	Physical activity is associated with a 15-43% lower risk of stroke depending on the type and intensity of physical activity as well as stroke subtype. Studies among men tended to show stronger associations than those among women (RR 0.54 vs 0.76). Also, European studies showed stronger associations than American studies (RR 0.47 vs 0.82).
6	To study the independent associations of physical activity and body mass index as well as their interaction in relation to CHD, stroke, and CVD mortality.	n=35,650 , aged 20-59 years at baseline	Both physical activity and BMI are independently associated with CHD, stroke and CVD mortality. Physical activity is strongly associated with CHD mortality in the obese and BMI is related to stroke mortality in (very) active individuals.
7	To investigate cross-sectional as well as longitudinal associations between leisure time physical activity and health-related quality of life in an apparently healthy population.	n=1,871, aged 26-65 years at baseline	Cross-sectional associations were mainly found for physical components of health-related quality of life, whereas longitudinal associations were predominantly observed for mental components of health-related quality of life.

In our cross-sectional study among 3,950 Dutch adults on behavioural and lifestyle determinants of physical activity (chapter 3) we found moderately intense physical activity to be associated with the attitude towards increasing one's physical activity level, a higher fruit consumption and a lower prevalence of smoking. Adherence to the Dutch physical activity guideline was also associated with self-efficacy and vigorous physical activity was associated with the perception of sufficient affordable facilities in the neighbourhood. Results of this study emphasise the need for tailored intervention strategies.

Our multilevel study (chapter 4) among 11,541 adults was one of the first examining the association between physical activity and the environment. We found that the time people spent on bicycling was associated with the surface of sport grounds in the proximity of their homes.

Furthermore, our 12-year follow-up study among 35,650 adults (chapter 6) and our meta-analysis including 31 observational studies (chapter 5) showed that physical activity was strongly related to stroke. Based on our results, it seems that, at least in Europe, the association between physical activity and stroke is stronger than the association between physical activity and CHD.

Moreover, our follow-up study (chapter 6) showed that physical inactivity and obesity interact differently in relation to CHD and stroke mortality. Physical activity was strongly related to CHD mortality among obese individuals, whereas BMI was strongly related to stroke mortality among (very) active individuals.

Finally, our study among 1,871 adults (chapter 7) was one of the first studies among the general population to indicate an association between physical activity and health-related quality of life. Cross-sectionally, physical activity seemed to be related to the physical components of health-related quality of life, whereas longitudinally, associations were mainly found for the mental components.

Physical activity questionnaires

Epidemiological studies mostly use questionnaires to assess physical activity. However, the use of physical activity questionnaires introduces information bias.(194) When the presence of information bias leads to differential misclassification, it potentially over- or underestimates the association under study.(195) This type of bias is present when the

error of classification on one axis (exposure or outcome) is dependent on the classification on the other.[195] Examples of information bias are recall and self-favouring bias. Recall bias, in terms of this thesis, refers to the inability to correctly recollect one's physical activity pattern. Research has shown that recall bias may be larger for highly variable, light intense activities such as walking.[45] Self-favouring bias involves the tendency of persons to present themselves in a culturally appropriate light for self-esteem enhancement.[196] For example, this provides an explanation for the fact that overweight or obese people often tend to overestimate their physical activity level and at the same time tend to underestimate their food intake.[196-201]
The studies presented in this thesis have likely been influenced by information bias. Nevertheless, it is unknown to what extent this resulted in differential misclassification. If however, differential misclassification had been present to a large extent, most likely this would have caused underestimation of the associations under study.

The items included in a physical activity questionnaire play an important role in measuring physical activity. Questionnaires including a small number of different items (i.e. with low content validity) will often produce lower physical activity levels than questionnaires including a large number of items.[35;194] High content validity of a questionnaire has the advantage that more detailed information on physical activity patterns will be acquired. Depending on the aim of the study, a questionnaire with a high content validity is required or a questionnaire with a relatively low content validity may be sufficient.[14] For example, research designed to study physical activity as main exposure variable will need to include a physical activity questionnaire with relatively high content validity, whereas for studies in which physical activity is merely addressed as a possible confounding variable, a physical activity questionnaire with a relatively low content validity would suffice. Research designed to monitor physical activity levels will need a physical activity questionnaire with a high content validity in order to be able to register relatively small changes in physical activity in general or in specific domains or types of physical activity. [14;194]

In this thesis, we used three different physical activity questionnaires. Content validity increased from the oldest to the newest questionnaire. The oldest questionnaire (chapter 7) was designed for the Monitoring Project on Cardiovascular Disease Risk Factors of the National Institute for Public Health and the Environment in the Netherlands. In this project, physical activity was not considered a main exposure variable.[61] Therefore, the questionnaire included merely two questions: One on occupational physical activity and one on leisure time physical activity, both with predefined categories. Reproducibility for total physical activity had a kappa value of 0.47 and our calculations on relative validity showed that inactive individuals spent an average of 3.3 hours per week on at least moderately intense (≥4 MET) physical activity, active individuals 6.7 hours and very active 19.6 hours per week. In addition, physical activity based on this questionnaire was associated with CVD mortality, ensuring validity of the questionnaire (chapter 7). Therefore, we conclude that despite a low content validity, this questionnaire was able to distinguish inactive from active individuals with acceptable validity.

The next questionnaire (chapter 3 and 5) was an extended version of the EPIC physical activity questionnaire and was used in the Monitoring Project on Risk Factors for Chronic Diseases (MORGEN-project). This monitoring project succeeded the earlier mentioned project. In this project, physical activity was considered one of the main exposure variables.[62] The physical activity questionnaire included a similar question on occupational physical activity compared to the previous one and several other questions on the time spent on leisure time physical activity per week (i.e. walking, bicycling, gardening, household activities, doing odd jobs, sport and other strenuous activities). The physical activity questionnaire (excluding the sport item) was validated with a 3-day physical activity diary in a population of 126 men and women aged between 20 and 70 years.[38] Spearman correlation coefficients between the questionnaire and the diary were between 0.32 and 0.81 for men and between 0.28 and 0.72 for women.[38] Based on these results it was concluded that this questionnaire is suitable for ranking people according to their physical activity level.

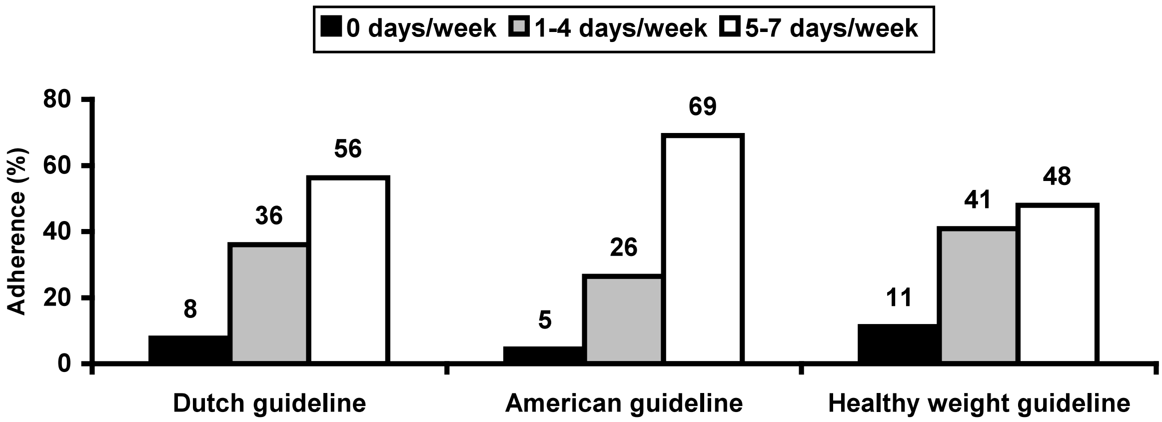
The most recently developed questionnaire (chapter 1 and 4, the SQUASH) included four domains of physical activity (i.e. commuting activities, household activities, occupational physical activity and leisure time physical activity (including sports)). Within these domains, for each activity, questions were asked about frequency, duration and intensity.[84] This questionnaire is currently used in the yearly national representative health interview survey by Statistics Netherlands and will be used in future monitoring studies of the National Institute for Public Health and the Environment. Reproducibility and relative validity of the SQUASH were studied in a population of 50 adults aged 27-58 years (chapter 2 of this thesis). Validity was studied by comparing results from the SQUASH with readings of the Computer Science and Applications (CSA) activity monitor. The Spearman correlation coefficient was 0.58 for overall reproducibility and 0.45 for overall validity.[84] Therefore, the SQUASH is a fairly reliable and reasonably valid questionnaire that can be used to order subjects according to their physical activity level. Moreover, due to the way the questionnaire was structured, it can be used to estimate adherence to the Dutch physical activity guideline.

Defining levels of physical activity

An important methodological issue in physical activity research is the definition of the physical activity level that is necessary to prevent health risks. Researchers agree that, for this purpose, moderate intense physical activity is required.[9;53] However, they have different opinions as to what metabolic equivalent corresponds with moderate intense physical activity. For example, Pate et al. defined moderate intensity for the adult U.S. population as an intensity of 3.0 to 6.0 MET.[9] The Dutch physical activity guideline for adults (18-55 years of age) defines moderate intensity as 4.0 to 6.5 MET.[53] In Ainsworth’s compendium of physical activities, walking for pleasure has been assigned an intensity of 3.5 MET.[40;66] Therefore, data from a physical activity questionnaire with questions about walking or similarly intense activities will contribute to moderately intense physical activity in the United States, but not in the Netherlands. This problem does not arise for individuals aged 55 or over, because in this age group the Dutch physical activity guideline also uses the cut-off point of 3.0 MET for moderate intense physical activity.[53]

Recently, a guideline for physical activity to prevent obesity was presented by Saris et al.. This healthy weight guideline states that individuals require approximately 45-60 minutes of moderate intense physical activity (defined as ≥ 3.5 MET) each day, to prevent transition to overweight or obesity.[3] However, to date, no published data is available concerning adherence to this guideline in the Netherlands.

To illustrate the importance of this definition issue, we have conducted a secondary analysis on the data that we used in chapter 4. Figure 8.1 shows the number of days per week on which individuals reported the required amount of moderate intense physical activity for three separate guidelines (the Dutch, the American and the healthy weight guideline).



Minutes/week	30	30	45
Moderate <55 years	4 MET	3 MET	3.5 MET
Moderate ≥55 years	3 MET	3 MET	3.5 MET

Figure 8.1: Compliance with different physical activity guidelines based on SQUASH-data from 12,984 Dutch individuals aged 21-70 years (chapter 4).

Compliance with a guideline was defined positive if an individual was categorised as being physically active (for the required amount and intensity) on 5-7 days per week, and inactivity as being physically active on 0 days per week. Using cut-off points of the Dutch guideline, 56% of the adults complied with the guideline, whereas cut-off points of the American guideline resulted in an adherence of 69%. According to the healthy weight guideline, 48% of the population showed adherence. For the category inactivity, these percentages were 8, 5 and 11% respectively. Compliance with the healthy weight guideline was 8% lower than compliance with the Dutch physical activity guideline and 21% lower than adherence to the American guideline. These figures point out that information about computation methods and cut-off points for intensity categories is very important when results on physical activity are compared between populations. If these details are omitted, comparison of results will lead to false conclusions.

Research that was presented in this thesis concerning moderately intense physical activity (chapter 3 and 7) always included the cut-off points of the Dutch physical activity guideline for adults under the age of 55 years (4.0-6.5 MET).[53] Naturally, we chose these cut-off points and not those mentioned in the American guideline since we used Dutch databases to study our research questions (Table 8.1). In our study on cross-sectional and longitudinal associations between leisure time physical activity and health-related quality of life (chapter 7) we found no evidence that our definition of moderately intense physical activity led to different results compared with those of American studies. However, in our study on psychosocial and lifestyle determinants of physical activity (chapter 3), we found an influence of physical activity intensity on the association with self-efficacy and perception of sufficient affordable facilities in the neighbourhood. Therefore, defining moderate intensity as 4.0-6.5 MET in stead of 3.0-6.0 MET could have resulted in different results compared to other studies. At the same time, this stringent definition will be more likely to discriminate determinants of truly vigorous physical activity from determinants of more moderately intense physical activity.

Prevalence and trends in physical activity in the Netherlands

The Dutch physical activity guideline states that every adult should accumulate 30 minutes of at least moderately intense (≥ 4.0 MET for those aged 18-55 and ≥ 3.0 MET for those aged 55 or over) on five but preferably all days of the week. For those aged under 18 years, one hour of at least moderately intense physical activity (≥ 5.0 MET) is recommended.[53] This guideline was formulated at an expert meeting in 1998 and was based on scientific publications on different age categories.[9;202-205] As discussed earlier, this guideline differs from the American guideline with respect to cut-off points of moderate intense physical activity being defined separately for different age groups.

In 1999 and 2002 reports on physical activity and health in the Netherlands were published.[41;57] Both reports contained estimates of the proportion of the Dutch population that complied with the national physical activity guideline. In the first report, it was concluded that on average 40 to 55% of the Dutch population adhered to the guideline. This relatively large range was due to differences in study populations and physical activity questionnaires used to make this estimate.[41] None of the studies presented in this trend report used separate cut-off points for different age groups as stated in the Dutch physical activity guideline. In stead all studies applied the cut-off points for adults under 55 years of age (4.0 MET).[41] Therefore, this report did not give a strictly valid estimation of adherence to the Dutch physical activity guideline.
In the second report, again adherence to the guideline was presented. Based on results in this report it was estimated that 53% of the Dutch population (13 years or over) complied with the physical activity guideline.[57] Brisk walking (3.8 MET) was used as a cut-off point for moderate intense physical activity irrespective of age.[40;57;66] Therefore, this estimation did again not strictly represent the Dutch physical activity guideline.

Another data source for adherence to the Dutch physical activity guideline is the yearly, national representative health interview survey by Statistics Netherlands. This survey includes the SQUASH and uses computation methods with cut-off points for the various age categories as stated in the Dutch physical activity guideline. Based on these data, in the years 2001 and 2002 approximately 52% of the Dutch population (12 years or over) complied with the national physical activity guideline (Table 8.2). This percentage is lower among those with a primary school education (43%) and very low (23%) among those aged 12-17 years.

Table 8.2: Percentage of the Dutch population adhering to the Dutch physical activity guideline.†

	2001	2002
Total population	52	52
Gender		
Men	52	50
Women	52	53
Age		
12-17 years	23	24
18-54 years	49	48
≥55 years	60	61
Educational level		
Primary school	43	42
Lower general or vocational education	55	54
Higher general or vocational education or university	54	54

†Based on national representative health interview survey by Statistics Netherlands (data extracted from http://www.cbs.nl/nl/cijfers/statline/index.htm)

Because these figures were calculated using the age-specific cut-off points of the Dutch physical activity guideline they are the only valid estimation of adherence to the Dutch physical activity guideline to date. Based on the data presented here, it seems fair to conclude that currently, adherence to the Dutch physical activity guideline is approximately 25% among teenagers, 50% among adults under 55 years of age and 60% among those aged 55 or over.

The second report on physical activity and health also reported on the trend between 1975 and the year 2000 in adherence to the physical activity guideline among the Dutch population aged 12 years and over (Figure 8.2).[(57)] These data were based on the time use survey from the Dutch Social and Cultural Planning Office. Adherence to the physical activity guideline decreased from approximately 70% between 1975 and 1995 to 63% in the year 2000. This data included specific activities rather than cut-off points for intensity. Activities included in these estimates were sports, games, recreation, transportation by foot or bicycle and household work. Probably the main reason why this data source produces significantly higher estimates than the other data sources on adherence to the physical activity guideline is the inclusion of walking and household work irrespective of intensity level.

Within this time use survey, also the time spent on watching television was administered. Between 1975 and 2000 an increase from an average of 12 hours per week to 13 hours per week was reported. This underlines the trend in figure 8.2. Physical activity levels in the Netherlands seem to have been relatively stable in the past. Nevertheless, a decline was noted after 1995. In order to prevent disorders and diseases associated with sedentary lifestyles such as obesity and cardiovascular diseases we have to stop this decline.

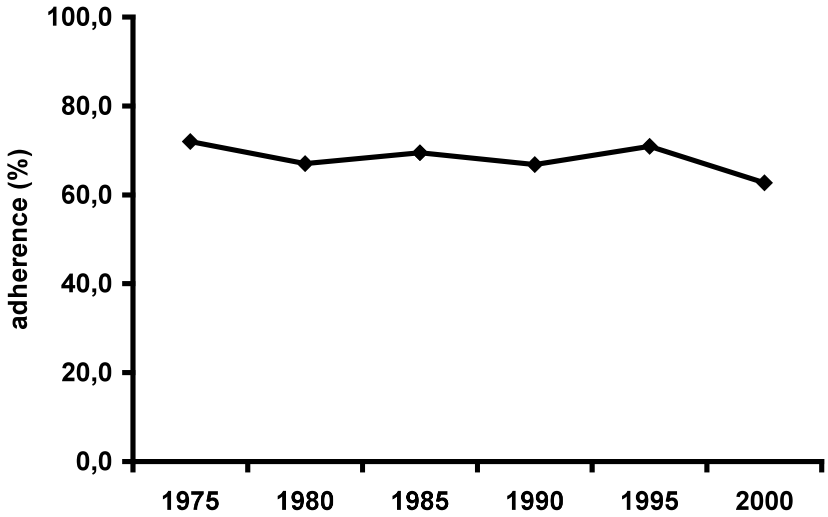


Figure 8.2: Trend in adherence to the Dutch physical activity guideline among the Dutch population aged 12 years and over between 1975 and 2000 based on the time use survey from the Dutch Social and Cultural Planning Office.[57]

Determinants of physical activity

One of the key questions of current physical activity research is how to motivate people to become and stay physically active, especially in the obesogenic environment that we live in today. Research on determinants of physical activity could help to decide which populations and factors to address in physical activity interventions. In their 2002 review, Trost et al. reviewed the literature on correlates of participation in physical activity by adults. Based on an earlier review of Bauman et al., they defined six classes of correlates: 1) demographic and biological factors, 2) psychological, cognitive and emotional factors, 3) behavioural attributes and skills, 4) social and cultural factors, 5) physical environment factors and 6) physical activity characteristics.[16;17]

Table 8.3: Summary of the results on correlates of physical activity reported by Trost et al..*

Determinant	**++†**	**--‡**	**00§**
Demographic and biological factors			
Older age		--	
Education	++		
Gender (male)	++		
Hereditary	++		
Income/socio-economic status	++		
Overweight/obesity		--	
Race/ethnicity (non-white)		--	
Psychological, cognitive and emotional factors			
Attitudes			00
Barriers to exercise		--	
Enjoyment of exercise	++		
Expect benefit	++		
Intention to exercise	++		
Knowledge of health and exercise			00
Lack of time		--	
Mood disturbance		--	
Normative beliefs			00
Perceived health or fitness	++		
Self-efficacy	++		
Self-motivation	++		
Self-schemata for exercises	++		
Stage of change	++		
Susceptibility to illness/seriousness of illness			00
Behavioural attributes and skills			
Activity history during adulthood	++		
Dietary habits (quality)	++		
Past exercise program	++		
Processes of change	++		
Social and cultural factors			
Physician influence	++		
Social support from friends/peers	++		
Social support from spouse/family	++		
Physical environment factors			
Climate/season		--	
Physical activity characteristics			
Perceived effort		--	

* Only those correlates with a repeatedly documented positive, negative or lack of association with physical activity.(17) † Repeatedly documented positive association, ‡ Repeatedly documented negative association, § Repeatedly documented lack of association.

Table 8.3 summarises the positive and inverse but also the lack of associations of these factors with physical activity as reported in their review.

Results described in this thesis covered all these classes of correlates and in general, our results were in line with the summary data reported in the review by Trost et al.. An exception is the association between attitude and physical activity. Trost et al. reported a repeatedly documented lack of association between attitude in general and physical activity.[(17)] In our study (chapter 3), we found an inverse association with the cognitive attitude towards *increasing* physical activity and a positive association with the affective attitude towards *increasing* physical activity. Since attitude towards *being* physically active and attitude towards *increasing* physically activity are conceptually different, this probably explains the difference in associations with physical activity.
The various associations found between demographic factors and physical activity point out that correlates of physical activity may differ or may be ranked differently in importance for different subgroups of the population.[(16-18;81)] In our research (chapter 3) we indeed found some variation in strength and in some cases the direction of the associations between subgroups of the population (gender, age and educational level). This indicates that knowing and understanding the target population is a very important success factor for an intervention.

In the review of Trost et al., only one of the physical environment factors (climate/season) was repeatedly documented as being associated with physical activity. However, a relatively large number of the physical environment variables included in the review (actual and perceived access to facilities, enjoyable scenery, frequently observe other exercising, home equipment, hilly terrain, neighbourhood safety, satisfaction with facilities and urban location) were categorised as having a weak or mixed association with physical activity.[(17)]
Until now, only a small subset of possible physical environmental characteristics has been studied.[(21)] Moreover, the use of more or less objective measures of the physical environment is clearly staying behind compared to studying the perception of environmental factors.[(21)] The increasing obesogenicity of the environment makes it very important to study the physical environment in relation to physical activity.[(206)] As

pointed out by Saelens et al., constructs, methods and findings from the fields of transportation, urban design and planning may be applied to physical activity research to improve understanding of environmental influences on physical activity.[22]
In our multilevel study (chapter 4), we made an effort to investigate data from geographical information systems (GIS) on land use in relation to physical activity levels. We found that the surface of green and recreational space close to home was associated with the time people living in that environment spent on bicycling. We could however not rule out that this association was actually a proxy for the association between physical activity and aspects of urban planning. For example, it could be true that districts close to for example sport grounds have better bicycling facilities. At the same time it could also be true that these districts attract inhabitants who like to bicycle.
The scattered results among studies addressing the association between physical activity and factors of the physical environment emphasises the need for further research on this topic. Most importantly, we need to have a conceptual model that describes the aspects involved in this association. Furthermore, we need to think about how to put these concepts into practice and about how to measure them in an appropriate way.

Eventually, we will need insight into both behavioural and environmental correlates of physical activity in order to develop successful intervention programs targeted at the right populations and motivating them in the appropriate way.[19] Until now, relatively few results have been published on physical activity interventions including structural changes in the physical environment or policy level strategies.[19;20] Also, current intervention projects involving these strategies will take some time before their results can be published. Therefore, because of the only just emerging interest in the association between physical activity and factors of the physical environment it is possible that at this point in time we are not fully able to achieve maximum effectiveness in interventions.[18;20;81]

The dose-response relationship between physical activity and health

Despite relatively large measurement error inherent to the use of physical activity questionnaires, research has shown consistent associations for physical activity with several chronic diseases.[4;10] Therefore, the potential health gain for physical activity interventions is large. In 2001, a consensus statement was published about dose-response relationships between physical activity and health. It was concluded that there is an inverse and probably linear dose-response relationship between physical activity and cardiovascular diseases as well as coronary heart disease mortality. For stroke mortality a 'U'-shaped relationship was suggested with higher disease rates among those with the lowest and highest levels of physical activity.[24]

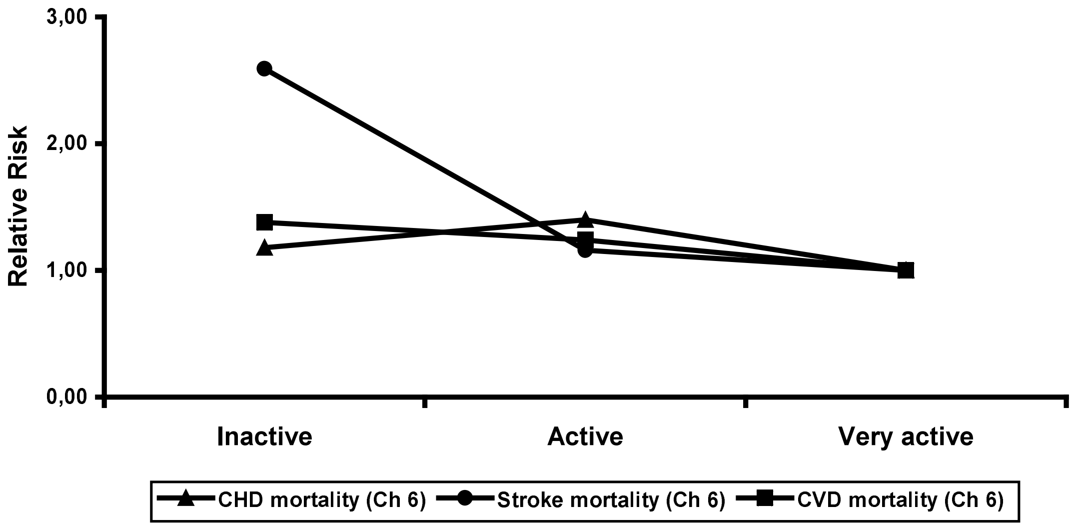


Figure 8.3: Results from chapter 6 of this thesis: The relationship between physical activity and CHD, stroke and CVD mortality.

Figure 8.3 shows the results of our follow-up study (chapter 6) in which we associated physical activity with the relative risk of CHD, stroke and total CVD mortality. For CVD mortality we found a modest linear dose-response relationship (HRs of 1.4 (inactive), 1.2 (active) and 1.0 (very active) respectively), but not for CHD (HRs of 1.2, 1.4 and 1.0 respectively). In the meta-analysis of Berlin and Colditz on the association between physical activity and CHD, pooled relative risks were reported separately for occupational (1.9, 1.4 and 1.0) and leisure time physical activity (1.6, 1.3 and 1.0).[25] Taking the confidence limits of these estimates into account, our results did not significantly differ from those of the meta-analysis conducted by Berlin and Colditz. We can conclude that a modest dose-response relationship exists between physical activity and CHD mortality.

For physical activity and stroke mortality we found an L-shaped relationship (HRs of 2.6, 1.2 and 1.0 respectively). In our meta-analysis (chapter 5), we observed a dose-response relationship between leisure time physical activity and ischemic stroke, particularly for studies conducted in Europe (RR = 2.1 for inactive versus active populations). These results suggest that physical inactivity is an especially strong risk factor for stroke mortality.

In conclusion, the relationship between physical activity and CHD mortality is a modest dose-response relationship.[24;25] Evidence is accumulating that the relationship between physical activity and stroke is stronger and that especially inactive persons are at a high risk for stroke.

Public health consequences of physical (in)activity

The potential health gain of physical activity interventions is large. Firstly, because physical inactivity is prevalent among half the Dutch population and secondly because of the relationship between physical activity and cardiovascular diseases. Bemelmans et al. used a mathematical model to estimate the health gain associated with the targets that were set in the policy document entitled Sports, Movement and Health from the Ministry of Health, Welfare and Sport.[207;208] These targets include a 10% increase in compliance with the Dutch physical activity guideline and a 4% decrease in prevalence of inactivity over a period of 10 years.[207] Bemelmans et al. calculated that if these targets were met, overall mortality would have decreased with 2.3% in the general population after 10 years, whereas the prevalence of myocardial infarction would have decreased with 1.3% among men and 1.5% among women. For stroke prevalence this would be 2.4% for both men and women. However, we have to question whether or not the targets that were set for this study are realistic. In order to decide on this issue, we have to take into account the effectiveness of actual physical activity interventions.

Table 8.4: Summary: the effectiveness of interventions to increase physical activity.[209]

Intervention	Effectiveness
Informational approaches	
– Point of decision prompts	Yes
– Community-wide campaigns	Yes
– Mass media campaigns	Insufficient evidence
– Classroom-based health education focused on information provision	Insufficient evidence
Behavioural and social approaches	
– School-based physical education	Yes
– College-based health education and physical education	Insufficient evidence
– Classroom-based health education focused on reducing television viewing and video game playing	Insufficient evidence
– Family-based social support	Insufficient evidence
– Social support interventions in community settings	Yes
– Individual-adapted health behaviour change programs	Yes
Environmental and policy approaches	
– Creation of or enhanced access to places for physical activity combined with informational outreach activities	Yes
– Transportation policies and infrastructure changes to promote non-motorised transit	Unknown, currently running
– Urban planning approaches – zoning and land use	Unknown, currently running

In 2002, Kahn et al. published a systematic review on the effectiveness of interventions that aimed to increase physical activity levels. Based on the approach used, the interventions were divided into 1) informational approaches, 2) behavioural and social approaches, and 3) environmental and policy approaches (Table 8.4). In light of this thesis, it is of particular interest to look at community-based CVD prevention programs. These kinds of prevention programs were included in Kahn's review under community-wide campaigns and informational approaches. Effectiveness of this approach was established.[209] However, no statement was made on the magnitude of this effect. Individual reports on intervention studies may give more information on the magnitude of the effect that may currently be expected from physical activity interventions.

In the Bootheel Heart Health Project, physical inactivity decreased over a period of four years. Physical inactivity was defined as report of no exercise, recreational, or other physical activities other than regular job duties during the last month. In communities where heart health coalitions were developed among health agencies, physical inactivity decreased with 6.8% compared to communities that did not develop health coalitions. Also, among individuals who were aware of these coalitions physical inactivity decreased with 6.4% compared with individuals who were not aware of these coalitions.[210]

In the Heartbeat Wales program, engagement in exercise (defined as engagement in moderate or strenuous activity on at least two days per week for at least 20 minutes) did not significantly change over a period of five years. In the intervention area the prevalence of exercise engagement increased with 2.1% compared with a 3.2% increase in the reference area.[211]

In the Dutch heart health community intervention 'Hartslag Limburg' there was no significant change over a period of three years in the proportion of the intervention population that met the target level of physical activity compared with the reference population. Individuals were classified as meeting the recommended target level if they had a physical activity score of at least 150 minutes per week and at least five sessions per week, and if they had indicated that they were physically active for at least 30 minutes a day on at least five days a week. The percentage of individuals not meeting the target showed an increase of 0.5% in the intervention area compared with a 1.1% decrease in the reference area.[212]

Taking the magnitude of the effects of these different community intervention projects into account, we have to conclude that the quantitative effect on physical activity levels was disappointing.[210-213] At the same time we have to conclude that the targets set in the Dutch policy document entitled Sports, Movement and Health (i.e. a 10% increase in adherence to the guideline and a 4% decrease in physical inactivity over a period of 10 years) seem too ambitious.

Conclusions

Can people be motivated to become active? Yes they can, but we are just learning how. We are able to identify subgroups that are at increased risk to be inactive and we have identified behavioural determinants of general inactivity. Especially when factors of the physical environment are concerned, we are only beginning to understand which factors in this environment are potentially associated with physical activity. More importantly, we are just starting to develop measurement tools to capture these factors in a for physical activity research appropriate way. Because the physical environment is a very important facilitator of physical activity, it is essential that we invest in this research area.

If we are able to increase physical activity levels in a population, the health impact is large. To begin with, half of the Dutch population is inactive according to the national physical activity guideline, which creates a large target population for physical activity interventions. Also, the strong relationship between physical activity and CHD and stroke indicates a substantial health gain. Moreover, an increase in physical activity may enhance health-related quality of life.

The negative trend in physical activity levels, the increasing prevalence of obesity and obesogenicity of environments make it crucial for researchers and policy makers to act now. In order to be able to successfully change our population's general physical activity level, we need to especially target those who are at high risk of inactivity and obesity (e.g. the young and the lowly educated) with physical activity interventions that combine community wide messages with individual counselling and environmental approaches.

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Summary

The overall aim of this thesis was to quantify three main public health aspects of physical activity in the Netherlands. We aimed to establish reproducibility and relative validity of a newly developed physical activity questionnaire. Also, we studied environmental, behavioural and lifestyle determinants of physical activity. Finally, we explored the association of physical activity with health outcomes such as stroke mortality and health-related quality of life.

Only in the last decade of the 20th century, physical activity recommendations adopted a lifestyle approach. Consequently, physical activity questionnaires needed to include items and domains of physical activity necessary to estimate adherence to this guideline. At the Dutch National Institute for Public Health and the Environment, we developed a physical activity questionnaire (the short questionnaire to assess health enhancing physical activity, the SQUASH). This questionnaire provides information on habitual activities with respect to occupation, leisure time, household, transportation means and other daily activities for estimating physical activity levels and on adherence to the new guideline in the general Dutch population.
Reproducibility of the SQUASH was established in a population of 50 individuals aged 27-58 years using a 5-week test-retest design (chapter 2). The questionnaire was validated with the Computer Science and Applications (CSA) physical activity monitor. The SQUASH proofed to be a fairly reliable (r_s = 0.58, 95%CI: 0.36-0.74) and reasonably valid (r_s = 0.45, 95%CI: 0.17-0.66) questionnaire and may be used to order subjects according to their level of physical activity in an adult population.

In order to successfully conduct physical activity intervention programs, knowledge on behavioural and environmental correlates of physical activity is required. We investigated factors potentially related to moderate and vigorous physical activity as well as factors associated with adherence to the Dutch physical activity guideline in a population of 3,950 individuals aged 23-70 years (chapter 3). Moderate to vigorous physical activity was inversely associated with the cognitive (*'physical activity is good for your health'*) attitude towards increasing physical activity and positively with the affective (*'physical activity is enjoyable'*) attitude towards increasing physical activity. The perception of sufficient affordable exercise facilities in the neighbourhood was positively associated with vigorous physical activity, but not with moderately intense physical activity. Participants who complied with the physical activity guideline were characterised as scoring lower on the cognitive attitude towards increasing physical activity and higher on self-efficacy. In addition, these participants more often perceived sufficient affordable exercise facilities in the neighbourhood. The results of this study emphasise the need for tailored intervention strategies taking into consideration the population's physical activity level, the attitude towards increasing physical activity, the level of self-efficacy and the perception of the physical environment.

Little is known about the association between factors in the physical environment and physical activity. We studied factors of the physical environment that may influence time spent on walking and bicycling in a population of 11,541 individuals aged 21-70 years (chapter 4). This study was one of the first examining the association between physical activity and objectively measured aspects of the physical environment. Demographic factors and time spent on walking and bicycling (during leisure time and for commuting purposes) were assessed with a self-administered questionnaire, whereas databases from geographical information systems (GIS) were used to objectively measure the surface of green and recreational space close to the home of our participants. Green and recreational space included woods, parks, sport grounds, allotments for vegetable gardens and grounds for day trips. We defined the physical environment as a circle around the postal code of a respondent with a radius of 300 and 500 metres. Multilevel regression analysis was used to study the association between walking and bicycling on the one hand and green and recreational space on the other hand. Analyses were adjusted for gender, age and educational level. In a neighbourhood defined as a circle with a 300-meter radius around the postal codes of the participants, time spent on bicycling (for commuting purposes and during leisure time combined) was associated with the surface of sport grounds in that neighbourhood. Bicycling for commuting purposes alone was associated with the surface of parks in neighbourhoods with a 300-meter radius. Because of the location of sport grounds and parks, i.e. in the outskirts of the town, it is possible that our results reflect an association between urban planning and time spent on bicycling rather than a true association of walking and bicycling with these factors of the physical environment. Another possibility is that these surroundings attract inhabitants who like to bicycle.

Although a dose-response relationship has been established between physical activity and several chronic diseases, the nature of the association between physical activity and stroke remains unresolved. The same is true for the combination of physical activity and BMI in relation to cardiovascular mortality.
We performed a meta-analysis on physical activity and stroke based on 31 observational studies in order to pool risk estimates and to explore sources of heterogeneity for the relationship between physical activity and stroke (chapter 5). Pooled risk estimates were calculated for total stroke, hemorrhagic and ischemic stroke, stratified by type of activity. The results of this meta-analysis indicate an inverse association between physical activity and stroke risk. Compared to inactivity and moderate activity, occupational physical activity at a high level showed a respectively 43% and 23% lower risk for ischemic stroke, but not for total stroke and hemorrhagic stroke. Leisure time physical activity at a high level compared to inactivity showed an approximately 25% lower risk for total stroke, hemorrhagic stroke as well as ischemic stroke. Studies conducted in Europe showed a stronger protective effect (0.47 95%CI: 0.33-0.66) than studies conducted in the United States (0.82 95%CI: 0.75-0.90). From this study we concluded that physical inactivity is a modifiable risk factor for both total stroke and stroke subtypes and that this relationship varies in strength across countries.

We also studied the association between physical activity, BMI and CHD, stroke and CVD mortality in a cohort of 35,650 healthy Dutch men and women aged 20-59 years at baseline (chapter 6). Vital status was checked and the underlying cause of death was ascertained using death certificates. During 12 years of follow-up, 1,288 people died, 313 of which of CVD. Statistical analyses were conducted using Cox proportional hazard survival analysis. Both physical inactivity and obesity were independent risk factors for CHD, stroke and CVD mortality. Especially inactive, obese individuals were at high risk of CHD (3.1 (1.3-7.6)), stroke (4.8 (1.1-20.7)) and CVD mortality (3.2 (1.7-6.0)), compared with very active, normal weight individuals. Among the obese (BMI ≥ 30 kg/m^2), a strong dose-response relationship was found between total physical activity and CHD mortality. Among the (very) active, a clear dose-response relationship was found between BMI and stroke mortality. We concluded that physical inactivity and obesity were independent risk factors and that especially the combination of these risk factors was strongly related to CVD mortality. In addition, we concluded that among obese individuals physical activity protected against CHD mortality and among (very) active individuals BMI was strongly related to stroke mortality.

Knowledge on the association between physical activity and health-related quality of life in the general population is scarce. Our study was one of the first including longitudinal analyses in the general population.
We used cohort data from 1,871 individuals aged 26-65 at baseline with a follow-up period of 5 years in order to study cross-sectional and longitudinal associations between (change in) physical activity and (change in) health-related quality of life. Cross-sectional associations at baseline and follow-up showed a consistent positive association with at least moderately intense leisure time physical activity for general health perceptions and vitality in both men and women. In women alone, a consistent association was found for physical functioning, role limitations due to physical health problems and the physical component score. Longitudinal analyses showed a positive association between change in leisure time physical activity and change in health-related quality of life for social functioning in both men and women irrespective of the intensity of leisure time physical activity. Only in men, change in total leisure time physical activity was associated with change in vitality, general mental health and the mental component score. Therefore, cross-sectional associations were not confirmed by longitudinal analyses. Cross-sectional associations were mainly found for physical components of health-related quality of life, whereas longitudinal associations were predominantly observed for mental components of health-related quality of life.

In our general discussion (Chapter 8) we addressed the issue of defining levels of physical activity. Based on secondary data analysis we showed the difference in adherence to three different physical activity guidelines (the Dutch, the American and the healthy weight guideline). Compliance with the healthy weight guideline was 8% lower than compliance with the Dutch physical activity guideline and 21% lower than adherence to the American guideline. Therefore, we concluded that it is very important to have information about computation methods and cut-off points for intensity categories to prevent that comparison of results on physical activity between populations will lead to false conclusions.

Also, we argued that, although various data sources are available, only one data source reports adherence to the Dutch physical activity guideline taking into account the different cut-off points that were defined for different age groups. This data source showed that current adherence to the physical activity guideline is approximately 50%.

Furthermore, we placed the potential health impact from physical activity interventions within the context of actual physical activity interventions. Potentially, the health impact of physical activity interventions is large. However, although physical activity intervention programs seem to be effective to some extent, the quantitative effect on physical activity levels was disappointing. Maximal effectiveness comprised a 7% decrease in inactivity and a 2% increase in engagement in physical activity. Therefore, we concluded that the targets that were set in the Dutch policy document entitled Sports, Movement and Health from the Ministry of Health, Welfare and Sport (i.e. a 10% increase in adherence to the guideline and a 4% decrease in physical inactivity over a period of 10 years) were too ambitious.

We concluded that the negative trend in physical activity levels, the increasing prevalence of obesity and obesogenicity of environments make it crucial for researchers and policy makers to act now. In order to be able to successfully change our population’s general physical activity level, we need to especially target those who are at high risk of inactivity and obesity (e.g. the young and the lowly educated) with physical activity interventions that combine community wide messages with individual counselling and environmental approaches.

Samenvatting

Dit proefschrift beschrijft drie aspecten van de relatie tussen lichamelijke activiteit en volksgezondheid. Als eerste is de reproduceerbaarheid en relatieve validiteit van een nieuwe vragenlijst over lichamelijke activiteit onderzocht. Daarnaast is aandacht besteed aan omgevings-, gedrags- en leefstijldeterminanten van lichamelijke activiteit. Tenslotte is de associatie bestudeerd tussen lichamelijke activiteit en gezondheidsmaten zoals sterfte aan cardiovasculaire ziekten en gezondheidsgerelateerde kwaliteit van leven.

Pas in de jaren negentig werd een richtlijn voor lichamelijke activiteit geformuleerd met daarin een zogenaamde leefstijlbenadering (de Nederlandse norm gezond bewegen). Om te kunnen vaststellen welk deel van de Nederlandse bevolking voldoet aan deze richtlijn, is het van belang te beschikken over gevalideerde vragenlijsten over lichamelijke activiteit met daarin de juiste items en domeinen van lichamelijke activiteit. Bij het Rijksinstituut voor Volksgezondheid en Milieu is een dergelijke vragenlijst (de 'short questionnaire to assess health-enhancing physical activity', de 'SQUASH') ontwikkeld om het monitoren van lichamelijke activiteit in Nederland mogelijk te maken.
In hoofdstuk 2 van dit proefschrift wordt het onderzoek beschreven naar de reproduceerbaarheid en relatieve validiteit van de SQUASH. De studiepopulatie bestond uit 50 mannen en vrouwen in de leeftijd van 27 tot 58 jaar. De deelnemers hebben de SQUASH twee keer ingevuld met een tussenliggende periode van vijf weken. Aansluitend op het invullen van de SQUASH (eerste keer) droegen zij gedurende twee weken een bewegingsmeter. De resultaten van dit onderzoek lieten zien dat de SQUASH een redelijk betrouwbare (r_s=0,58; 95%BI: 0,36-0,74) en relatief valide (r_s=0,45; 95%BI: 0,17-0,66) vragenlijst is die kan worden gebruikt voor het rangschikken van personen naar hun niveau van lichamelijke activiteit.

Om een succesvolle interventie te kunnen uitvoeren op lichamelijke activiteit is kennis nodig over de gedrags- en omgevingsfactoren die daarmee samenhangen. In hoofdstuk 3 van dit proefschrift bestudeerden we factoren die samenhangen met matig en zwaar intensieve lichamelijke activiteit alsmede factoren in samenhang met het voldoen aan de Nederlandse norm gezond bewegen. De studiepopulatie bestond uit 3.950 mannen en vrouwen in de leeftijd van 23 tot 70 jaar. Mensen die veel tijd besteedden aan matig tot zwaar intensieve lichamelijke activiteit hadden een negatievere cognitieve attitude (‘*lichamelijke activiteit is goed voor je gezondheid*’) en een positievere affectieve attitude (*‘lichamelijke activiteit is leuk’*) ten opzichte van meer gaan bewegen vergeleken met mensen die minder tijd besteedden aan deze activiteiten. Daarnaast hadden mensen die veel tijd besteedden aan zwaar intensieve lichamelijke activiteit vaker de perceptie dat er voldoende, betaalbare voorzieningen in de eigen woonwijk aanwezig zijn om actief te zijn dan mensen die minder tijd besteedden aan deze activiteiten. Dit verband werd niet gevonden voor matig intensieve lichamelijke activiteit. Mensen die voldeden aan de Nederlandse norm gezond bewegen scoorden lager op de cognitieve attitude ten opzichte van meer gaan bewegen en hoger op eigen effectiviteit vergeleken met diegenen die niet aan de norm voldeden. Daarnaast hadden deze mensen vaker de perceptie dat er voldoende, betaalbare voorzieningen in hun wijk aanwezig waren om lichamelijk actief te zijn. De resultaten van deze studie benadrukken de noodzaak van interventies op maat waarin rekening wordt gehouden met het huidige niveau van lichamelijke activiteit, de attitude die mensen hebben ten opzichte van meer gaan bewegen, de inschatting die mensen maken van hun eigen effectiviteit en de perceptie die mensen hebben van hun omgeving.

Er is weinig bekend over de associatie tussen factoren uit de fysieke omgeving en lichamelijke activiteit. Wij bestudeerden factoren in de fysieke omgeving die mogelijk van invloed zijn op de tijd die mensen besteden aan wandelen en fietsen (Hoofdstuk 4). Dit onderzoek was één van de eerste waarin werd gekeken naar de associatie tussen objectief gemeten kenmerken van de fysieke omgeving en lichamelijke activiteit. De studiepopulatie bestond uit 11.541 mannen en vrouwen in de leeftijd van 21 tot 70 jaar. Met behulp van een vragenlijst werd nagevraagd hoeveel tijd gemiddeld per week werd besteed aan wandelen en fietsen (vrije tijd en woon-werkverkeer). Daarnaast werden geografische informatie systemen (GIS) gebruikt voor het vaststellen van de oppervlakte aan groen en recreatief terrein in de naaste omgeving van de woning van de deelnemers aan dit onderzoek. Groen en recreatief terrein omvatte de onderdelen bos, parken, sportvelden, volkstuinen en dagrecreatief terrein. De fysieke omgeving werd gedefinieerd als een cirkel met een straal van 300 en 500 meter rondom de postcode van elke deelnemer. In een omgeving met een straal van 300 meter met een groter oppervlak aan *sportvelden* werd meer tijd besteed aan fietsen (zowel vrije tijd als woon-werkverkeer). In een omgeving met een straal van 300 meter met een groter oppervlak aan *parken* werd meer tijd besteed aan fietsen voor woon-werkverkeer. Omdat sportvelden en parken veelal in de buitenste ring van steden liggen, is het mogelijk dat onze resultaten een afspiegeling zijn van een associatie tussen ruimtelijke ordening en lichamelijke activiteit. Een alternatieve verklaring zou kunnen zijn dat de woonomgeving in de nabijheid van sportvelden en/of parken inwoners aantrekt die veel tijd besteden aan fietsen.

Ondanks de aangetoonde dosis-respons relatie tussen lichamelijke activiteit en verschillende chronische aandoeningen is er nog geen uitsluitsel over de mate waarin lichamelijke activiteit samenhangt met cerebrovasculaire accidenten (CVA) en in hoeverre de combinatie van lichamelijke activiteit en Quetelet index (QI) gerelateerd is aan sterfte aan hart- en vaatziekten.
Hoofdstuk 5 van dit proefschrift omvat een meta-analyse op 31 observationele studies met als doel een gepoolde risicoschatter te kunnen geven voor de associatie tussen lichamelijke activiteit en CVA en bronnen van heterogeniteit voor deze associatie te identificeren. De gepoolde risicoschatter werd uitgerekend voor CVA in het algemeen, ischemische CVA en hemorrhagische CVA. Daarnaast werden deze berekeningen apart uitgevoerd voor lichamelijke activiteit op het werk en in de vrije tijd. In het algemeen geven de resultaten van deze meta-analyse aan dat lichamelijke activiteit geassocieerd is met een lager risico op CVA. Een hoog niveau van lichamelijke activiteit op het werk was geassocieerd met een 43% lager risico op een ischemische CVA ten opzichte van een laag niveau en met een 23% lager risico op een ischemische CVA ten opzichte van een matig niveau van lichamelijke activiteit op het werk. Voor lichamelijke activiteit tijdens de vrije tijd vonden we een beschermend effect van 25% (hoog t.o.v. laag) op het optreden van een CVA (zowel ischemisch, hemorrhagisch als totaal). Studies die in Europa werden uitgevoerd rapporteerden een sterker beschermend effect (0,47; 95% BI: 0,33-0,66) tussen lichamelijke activiteit en CVA dan studies die werden uitgevoerd in de Verenigde Staten (0,82; 95% BI: 0,75-0,90). Op basis van deze meta-analyse concludeerden we dat lichamelijke inactiviteit een risicofactor is voor zowel CVA in het

algemeen als voor subtypen van CVA en dat deze relatie in sterkte varieert tussen landen.

In hoofdstuk 6 van dit proefschrift beschreven we de relatie tussen lichamelijke activiteit, Quetelet index (QI) en sterfte aan coronaire hartziekten (CHZ), CVA, en hart- en vaatziekten (HVZ). De studiepopulatie bestond uit 35.650 mannen en vrouwen in de leeftijd van 20 tot 59 jaar aan het begin van het onderzoek. Met behulp van overlijdensaktes werd na 12 jaar follow-up de vitale status vastgesteld. Tijdens deze periode stierven 1.288 mensen, waarvan 313 aan HVZ. Analyses werden uitgevoerd met de 'Cox proportional hazard'-methode. De resultaten van dit onderzoek lieten zien dat lichamelijke inactiviteit en QI onafhankelijke risicofactoren waren voor CHZ, CVA en HVZ-sterfte. Met name de combinatie van inactiviteit met obesitas (QI $\geq$ 30 kg/m^2) was geassocieerd met een verhoogde kans op sterfte aan CHZ (3,1; 95% BI: 1,3-7,6), CVA (4,8; 95% BI: 1,1-20,7) en HVZ (3,2; 95% BI: 1,7-6,0) vergeleken met de combinatie zeer actief en een normaal gewicht (18,5≤QI<25,0). Onder de deelnemers met obesitas werd een sterke dosis-respons relatie gevonden tussen lichamelijke activiteit en CHZ-sterfte. Onder de (zeer) actieven vonden we een dosis-respons relatie tussen QI en CVA-sterfte. We concludeerden dat lichamelijke inactiviteit en obesitas onafhankelijke risicofactoren zijn voor HVZ en dat met name de combinatie van deze factoren samenhangt met een verhoogde kans op sterfte aan HVZ. Daarnaast concludeerden we dat lichamelijke activiteit in het bijzonder beschermt tegen sterfte aan CHZ onder obese personen en dat een gezond gewicht met name beschermt tegen sterfte aan CVA onder (zeer) actieve personen.

Er is weinig bekend over de associatie tussen lichamelijke activiteit en gezondheidsgerelateerde kwaliteit van leven in de algemene bevolking. Ons onderzoek was één van de eerste die deze associatie in de algemene bevolking longitudinaal kon analyseren. We maakten gebruik van cohort-data van 1.871 mannen en vrouwen in de leeftijd van 26 tot 65 jaar aan het begin van het onderzoek met een follow-up periode van 5 jaar (Hoofdstuk 7).

Cross-sectioneel (begin en na 5 jaar) vonden we voor zowel mannen als vrouwen dat matig intensieve lichamelijke activiteit samenhangt met een betere ervaren gezondheid en een hogere vitaliteit. Alleen bij vrouwen vonden we een associatie met fysiek functioneren, rolbeperkingen ten gevolge van fysieke gezondheidsproblemen en de fysieke deelscore van gezondheidsgerelateerde kwaliteit van leven. Longitudinaal vonden we bij zowel mannen als vrouwen dat meer gaan bewegen in de vrije tijd samenhangt met een verbetering in sociaal functioneren, onafhankelijk van de intensiteit van lichamelijke activiteit. Alleen bij mannen was meer gaan bewegen in de vrije tijd geassocieerd met een verbetering in vitaliteit, algemene mentale gezondheid en de mentale deelscore van gezondheidsgerelateerde kwaliteit van leven. Cross-sectionele en longitudinale analyses gaven daarmee verschillende resultaten.

In de algemene discussie (Hoofdstuk 8) lieten we zien hoe verschillende definities van matig intensieve lichamelijke activiteit (4, 3,5 en 3 MET) leiden tot verschillende schattingen voor het percentage personen dat voldoet aan een richtlijn (ook wel norm-actieven) voor lichamelijke activiteit. Vergeleken met de Nederlandse norm gezond bewegen (56%) was het percentage norm-actieven 8% lager voor de richtlijn voor gezond gewicht (48%) en 21% lager voor de Amerikaanse norm bewegen (69%). We concludeerden dat standaardisatie van definities noodzakelijk is als niveaus van lichamelijke activiteit worden vergeleken tussen verschillende populaties.
Daarnaast concludeerden we in de algemene discussie dat, ondanks de aanwezigheid van meerdere bronnen voor het schatten van de prevalentie norm-actieven in de Nederlandse bevolking, er slechts één bron is die de Nederlandse norm gezond bewegen strikt heeft gevolgd en daarmee een *valide* schatting geeft. Op basis van deze bron voldoet op dit moment ongeveer 50% van de volwassen bevolking aan de Nederlandse norm gezond bewegen.
Bovendien werd in de algemene discussie de potentieel te behalen gezondheidswinst van interventies op lichamelijke activiteit vergeleken met de werkelijk behaalde resultaten van interventiestudies. In theorie is de impact van deze interventies groot. In de praktijk blijkt het kwantitatieve effect van deze interventies echter vooralsnog gering. Het maximaal behaalde effect bedroeg een daling van 7% in inactiviteit en een stijging van 2% in lichamelijke activiteit. We concludeerden daarom dat de doelen die werden gesteld in de nota “Sport, bewegen en gezondheid” van het Ministerie van Volksgezondheid, Welzijn en Sport (nl. 10% stijging in ‘voldoen aan de richtlijn’ en 4% daling in inactiviteit over een periode van 10 jaar) te ambitieus zijn.

Tenslotte concludeerden we dat het om de negatieve trend in lichamelijke activiteit, de stijgende prevalentie van obesitas en de obesogeniteit van onze omgeving om te buigen in een positieve richting van belang is dat onderzoekers en beleidsmakers *nu* stappen ondernemen. Interventies op lichamelijke activiteit zouden zich met name moeten richten op groepen in de bevolking die een verhoogd risico hebben op lichamelijke inactiviteit en obesitas (zoals personen met een laag opleidingsniveau en jongeren). Deze interventies zouden volgens de huidige inzichten gebaseerd moeten zijn op een community benadering, gecombineerd met individuele counseling en maatregelen die de fysieke omgeving beïnvloeden.

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About the author

Wanda Wendel-Vos was born on October 12th, 1972 in Assen, the Netherlands. In 1991, she completed secondary school (VWO) at the ‘Christelijke Scholengemeenschap Assen’ in Assen. From 1991 till 1995 she studied ‘Nutrition and Dietetics’ at the ‘Hanzehogeschool’ in Groningen. In 1995, she started the study ‘Human Nutrition’ at Wageningen University. As part of that study she conducted a research project on the bioavailability of carotenoids from spinach. In September 1997 she received her MSc degree.

In October 1997 she was appointed at the Department for Chronic Diseases Epidemiology of the National Institute for Public Health and the Environment in Bilthoven as research associate.

In April 1999, she started her PhD-project of which the results are described in this thesis. This project was conducted at the Centre for Prevention and Health Services Research of the National Institute for Public Health and the Environment in collaboration with the Division of Human Nutrition and Epidemiology of the Wageningen University. She participated in the educational program of the Graduate School VLAG. In 2000, she attended the annual Erasmus Summer Programme of the Erasmus University Medical School in Rotterdam. She joined the Public Health training for PhD students of the Netherlands School of Public Health.

In August 2003 she started her job as epidemiological researcher at the Centre for prevention and health services research of the National Institute for Public Health and the Environment.

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