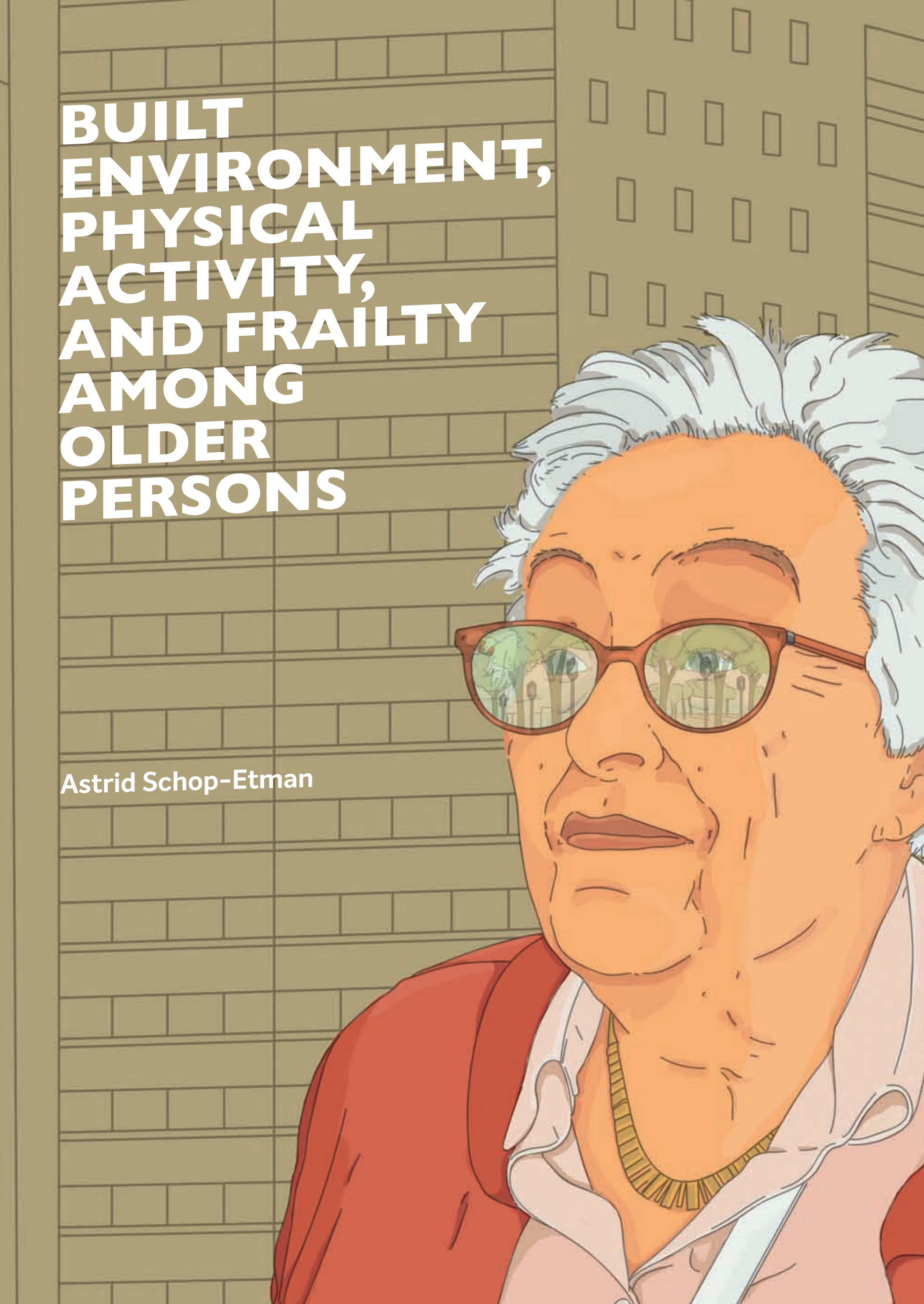
BUILT ENVIRONMENT, PHYSICAL ACTIVITY, AND FRAILTY AMONG OLDER PERSONS



Astrid Schop-Etman

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	Dr. J.M. Cramm

CONTENTS

‘Ik ben er voor iedereen, maar ik ben ook van iedereen. Ik leef, ik adem en ik beweeg. Ik ben overal, maar vooral in de harten. Ik ben oogverblindend, gezellig, historisch, een thuis. Ik ben kil en vies. Ik ben als mijn scheppers, ik ben als mijn gebruikers. Ik besta niet zonder de mensen. En elke keer als ze weer grote plannen maken, mij weer willen openrijten, verleggen, doorboren, dan gniffel ik om hun dure woorden. Mensen met plannen en dromen, mensen met behoeften. Ik geef ze alles wat ik heb. Daarna mogen ze languit rusten in mijn schoot, wegzakken in mijn aarde. Ik ben de stad, ik hou van de mensen, van hun rusteloosheid, van hun plannen, ambities en ideeën. Ze willen me onder controle houden. Alsof daar aan te beginnen is. Het moment waarop je het ene deel van mij op orde hebt, staat het volgende op instorten. Ik ben de stad en laat ze hun gang maar gaan. Ik ben de stad en ik zal altijd blijven.’

Een aangepast fragment uit ‘ik ben de stad’, Revka Bijl.

1

General introduction

1.1 BACKGROUND

Frailty

Worldwide populations are rapidly aging [1]. Globally, the number of older persons is expected to more than double, from 841 million in 2013 to more than 2 billion in 2050 [2]. Today, industrialized nations have the highest percentages of older persons in the world [3]. In the Netherlands, the proportion of adults aged 65 years and older is expected to increase from 16% (2.7 million) in 2012 to 25% (4.7 million) in 2050 [4]. Healthy aging plays a prominent role in international and national policies [5]. Besides maintaining good physical and mental health, there is a need to promote independent living while maintaining good quality of life and the ability to participate in society. Healthy and successful aging is not only about preventing and postponing diseases and mortality, but also about preventing frailty and loss of independent living.

Older persons can be either psychologically, socially, and/or physically frail [6]. This thesis focusses on physical frailty which is characterized by a low level of physical activity, muscle weakness, weight loss, exhaustion, and/or slowness [7]. Physical frailty hinders healthy aging [8] and has a negative effect on quality of life [9] since it may result in declines in balance, flexibility, reaction time, coordination, and muscular and cardiovascular endurance. Worldwide, 9.9% of those aged 65 years and older is physically frail and this proportion increases steadily with age up to 26% among those aged 85 years and older [10,11]. Among Dutch people aged 65 years and older, 6 to 11% is physically frail [12,13].

In figure 1, a conceptual framework is depicted with determinants and consequences of frailty for functioning, morbidity and mortality. This framework illustrates the associations addressed in this thesis, ranging from distal determinants such as built environment (block A), to more proximal determinants such as sociodemographic and lifestyle factors (block B). Although this framework allows for many associations to be studied, this thesis focuses primarily on determinants of frailty and disability.

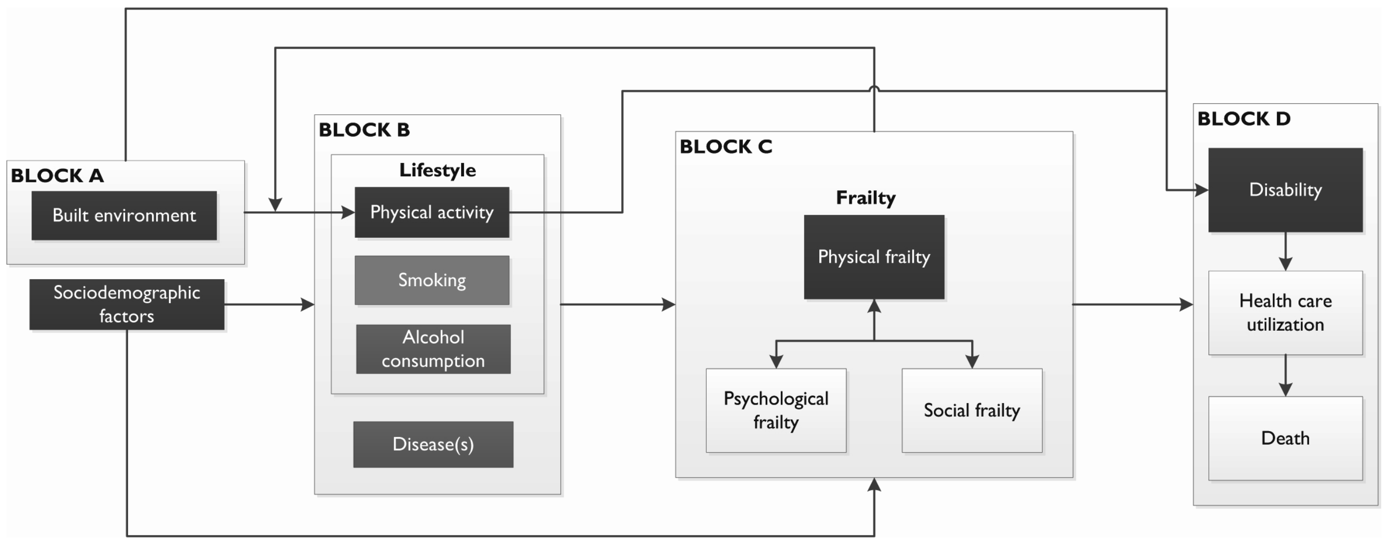

Figure 1 Conceptual model of determinants and consequences of frailty (adapted from Gobbens et al [44])
In dark grey: main factors under study in this thesis
In light grey: factors under study as mediators of the association between sociodemographic factors and physical frailty

Sociodemographic factors have been shown to be associated with frailty. Women, the older aged, and lower educated persons are at increased risk to become frail [14,15]. In the Netherlands, older persons with a low educational level have about three times higher risk of being frail compared to those with a high educational level which persists with increasing age [16]. Lifestyle factors such as smoking, alcohol consumption, and physical activity are suggested to be important target behaviors in the prevention of frailty [12,17]. However, although many studies have been conducted to get insight in determinants of frailty, less is known about determinants of frailty transitions. Better insight in determinants of frailty development, allows to define target groups for interventions aimed at preventing or decreasing frailty among older persons.

Disability

Frailty among older persons is highly predictive for disability (figure 1, block C and D) [18,19], and as such frailty is suggested to represent a transition phase between successful aging and disability [20]. Disability is highly prevalent among older persons: about 54% of people aged 65 years and older is dependent in one or more instrumental activities of daily living [21]. The proportion of Dutch older persons with functional limitations is expected to remain stable in the upcoming years as was found for the period 1990-2007 [22] which will, as the number of older persons is expected to increase, result in an increase in the absolute number of older persons with functional limitations. Consequences of disability are long-term care including homecare, assisted living, and long stays in hospitals (figure 1, block D) [23]. These consequences not only affect older persons themselves, as it also leads to increased health and social care expenditure affecting whole societies [1,24]. Therefore, the Dutch government finds it of importance that older persons live independently as long as possible [23].

Physical activity

Physical activity (PA) may help to prevent or delay frailty, and as a consequence reduce the risk of disability (figure 1, block B). Observational studies strongly suggest that compared to less physically active individuals, persons who are more physically active have lower rates of numerous health complaints [25,26]. WHO recommendations for older persons prescribe at least 150 minutes of moderate-intensity aerobic PA throughout the week *or* at least 75 minutes of vigorous-intensity aerobic PA throughout the week *or* an equivalent combination of moderate and vigorous intensity PA [19]. European older persons show large variation in the proportion meeting recommendations for PA to obtain health benefits (28-62%). In the Netherlands, this proportion is about a third [27].

Intervention studies show that older persons with different levels of abilities can improve their functional performance by regular PA training [28]. Domains of PA are transport-related PA and leisure-time PA. Transport-related PA is related to activities in daily living, such as walking to a shop or cycling to visit friends or family. Leisure-time PA includes recreational walking, participating in sports, and gardening. Transport-related PA greatly decreases after retirement - currently already close to the age of 66 years in the Netherlands - which is not compensated by increased leisure-time PA [29].

People can either be physically active in an unorganised setting, e.g. walking for transport or go for an individual run, or in an organised setting such as PA in a group setting at a certain time and place (in other words: PA programs). Many PA programs are offered, however, in order to increase PA levels at a population level these PA programs should have a sufficient participation. Little is known about participation levels of effective PA programs for older persons, and what components of PA programs are most effective to increase PA levels, and on the long term decrease disability among participating older persons.

Built environment

Since 40% of all PA of older persons takes place outdoors [30], the built environment may play an important role in shaping PA behavior (figure 1, block A). Older persons are likely to be affected by the features of their local environment [31,32], and as people age, their dependency on neighborhood resources has been shown to increase [33]. Mobility and independency can be greatly limited by a poorly-designed community. Therefore, the immediate surroundings of residences may be a decisive factor for engaging in PA [34]. Studies have shown mixed findings concerning the association between the built environment and PA. Despite the use of similar study designs, some studies found positive associations between characteristics of the built environment and PA whereas others found no association or even negative associations [31]. Positive associations showed that those living in neighborhoods with supportive built environment features like proximal access to facilities, good aesthetics, and availability of infrastructures (e.g. presence of sidewalks) and recreational facilities are more physically active than those living in neighborhoods with unsupportive environmental features [35,36]. Inappropriate methodology of current studies is often mentioned as one potential explanation for the inconsistencies, including the use of inappropriate geographical units such as postcode areas or boroughs [37,38]. A one-size predefined area around a person's residence may not capture sufficient variation for all environmental characteristics [39], therefore, it is suggested to investigate residential areas of different sizes for the interplay between the physical environment and PA [40] which can be easily determined by using Geographical Information Systems [41].

Local policymakers are increasingly responsible for the care of the elderly [42] who are expected to grow in numbers in urban environments in the Netherlands in the upcoming years [43]. At least in theory, cities can offer unique opportunities for the promotion of healthy aging by facilitating both transport-related PA and leisure-time PA. Using the local (built) environment as an entry point for interventions and policies to facilitate PA for older persons, requires good insights in which and how characteristics of the built environment are related to PA and disability.

1.2 THIS THESIS

Research questions

This thesis aimed to investigate how the built environment and PA influence disability among community-dwelling older persons. Three research questions will be answered:

1. Which groups of older persons are at increased risk of worsening in frailty?
2. Which characteristics of the built environment are important for PA and disability among older persons?
3. Which characteristics of PA programs can increase PA and decrease disability among older persons?

Outline

The three research questions correspond with Part I (chapters 2 and 3), Part II (chapters 4 and 5), and Part III (chapters 6 and 7). In chapter 2 it is examined which socio-demographic groups of older persons are at increased risk of worsening in frailty. Whether socio-economic inequalities in frailty worsening can be explained by lifestyle, health, and social participation is examined in chapter 3. Chapter 4 focusses on the role of the built environment for PA among older persons. Whether increases in PA by changing the built environment would also lead to improvements in physical functioning in daily living is investigated in chapter 5. The role of PA intensity for decreasing disability is addressed in chapter 6. Participation levels and characteristics of PA programs with high participation levels are addressed in chapter 7.

1.3 STUDIES USED

For this thesis, two different studies were used: the Survey of Health, Ageing and Retirement in Europe (SHARE), and the ELderly And their NEighborhood study (ELANE). SHARE data were used for Chapters 2 and 3. ELANE data were used for Chapters 4 through 6. Chapter 7 is a systematic review of the scientific literature.

SHARE study

The SHARE study is a multidisciplinary and cross-national panel database which is designed to investigate population-aging processes by looking at changes in health, economic situations, and social networks of persons aged ≥50 years. Over the years, more than 60000 individuals were interviewed face-to-face (computer-assisted). The SHARE study provides open access to its data collection on anonymous basis. At baseline (2004, wave 1), nationally representative samples of 11 European countries (Sweden, Denmark, Germany, the Netherlands, Belgium, Switzerland, Austria, France, Italy, Spain, and Greece) were drawn. In 2006 (wave 2) the Czech Republic, Poland, and Ireland joined SHARE. SHARELIFE (wave 3) has collected detailed retrospective life histories in 2008-2009. Wave 4 (2010-2011) and wave 5 (2012) also included Estonia, Hungary, Portugal, and Slovenia [45]. For chapters 2 and 3, data on frailty, socio-demographics, lifestyle, health, and participation of wave 1 and wave 2 were used.

ELANE study

The ELANE study aimed at investigating associations between the built environment and PA, independent living, and quality of life of older persons. Based on the study results, the study also aimed at recommending policymakers how to improve the built environment for the purpose of increasing PA levels, promoting independent living, and improving quality of life of older persons. The ELANE study was conducted by the Erasmus MC and TNO (the Netherlands Organisation for Applied Scientific Research) in 2011-2013 in Spijkenisse -a middle-sized town of about 72000 inhabitants in the Rotterdam area, the Netherlands- among two samples: dismissed hospitalized older persons who participated in the Prevention and Reactivation Care Program (PreCaP) [46], and a sample of randomly selected community-dwelling older persons. In 2011, a sample of 2017 persons of 65 years and older was randomly drawn from the municipal register of Spijkenisse. Participants had to be non-institutionalized, not bedridden, not wheelchair or scooter-bounded, and fluent in Dutch. Of the 972 persons eligible for inclusion, 430 were willing to participate (response 44%). Interviews at home were carried out between September 2011 and July 2012; winter months in between were excluded to avoid seasonal variation in PA. Of the 430 participants interviewed face-to-face at baseline (T0), 277 were again interviewed by telephone nine months later (T1; response 64%).Of the 430 participants at baseline, 150 had worn an accelerometer and GPS device for seven days, additionally to the interview (at baseline only).

Information about area characteristics was retrieved from street audits. Between June and October 2012, 88.8% (n= 918) of all streets in Spijkenisse were audited, and 214 additional street segments (as part of 143 streets), 8 parks, and 357 walking paths as identified by Google maps. When the physical lay-out of one part of a street was clearly different from other part(s) of the same street (e.g. big differences in aesthetics), it was split in two or more segments, which were audited separately. The audit instrument consisted of 41 items (11 on aesthetics, 7 on functional features, 8 on safety, and 15 on facilities).

In order to capture sufficient variation in area characteristics, geographical areas of different sizes were created. Around each participant's residence, walking path network buffers were created by using ArcGIS (Geographical Information System software package). Starting from the nearest starting point of streets to the participant's residence on the street network, all walking routes up to 400, 800, 1200, and 1600 meters were traced in every direction resulting in four buffers.

For chapter 4, baseline interview data on PA were used in combination with data on area characteristics. For chapter 5, both baseline and follow-up interview data on disability and PA, and data on area characteristics were used. Interview data on physical exercise and disability at both baseline and follow-up were used for chapter 6.

The ELANE study was financially supported by the Netherlands Organisation for Health Research and Development (ZonMw), project number 314030301.

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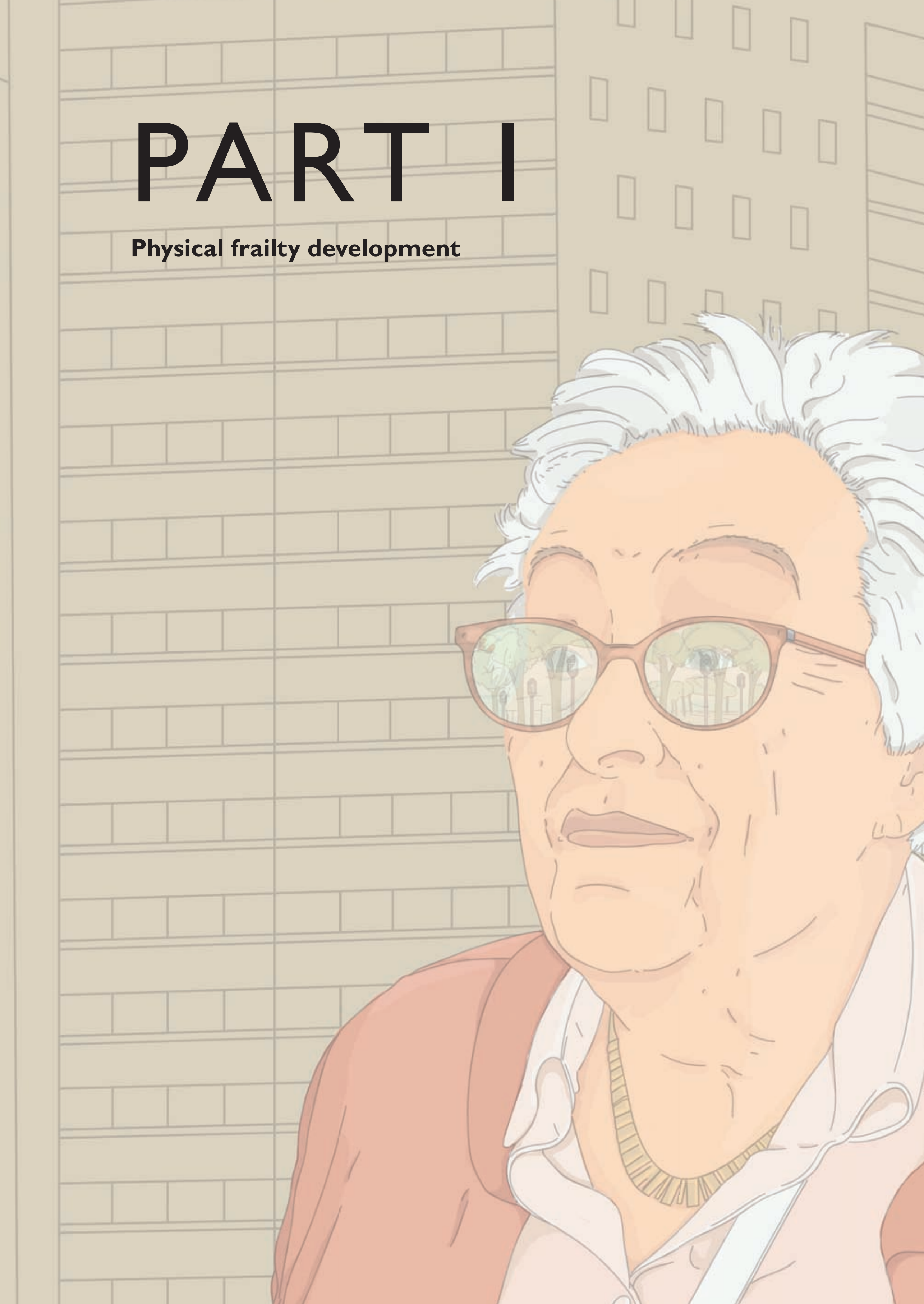
PART I

Physical frailty development



2

Socio-demographic determinants of worsening in frailty among community-dwelling older persons in 11 European countries

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ABSTRACT

Background The rapid increase of frail elderly worldwide will have a substantial impact on healthcare systems. The frailty process may be delayed, or even reversed, which makes it attractive for early interventions. However, little is known about the determinants of frailty state changes. The aim of this study is to compare socio-demographic determinants of worsening in frailty state in 11 European countries.
Methods Data of 14424 community-dwelling persons aged ≥55 years, enrolled in 2004 in the Survey of Health, Ageing and Retirement in Europe (SHARE), were analyzed. Three frailty states were identified (non-frail, pre-frail and frail) using Fried's criteria, and frailty state changes over a two-year period were determined. Multinomial regression analyses adjusted for baseline frailty state were conducted to investigate whether sex, age, marital status, and level of education determined a worsening in frailty state in the total and country-specific European population.
Results Of all individuals, 22.1% worsened, 61.8% showed no change and 16.1% improved in frailty state. Women, those aged ≥65 years, and lower educated persons showed an increased risk of worsening in frailty state. In Southern European countries, there was an earlier and larger increase in risk of worsening in frailty state in life which was more pronounced in women compared to men.
Conclusion In Europe, persons aged ≥65 years, women, and lower educated persons are at increased risk of worsening in frailty state. Differences between countries indicate that interventions aimed at delaying the frailty process in Southern European countries should start earlier with more attention towards women.

INTRODUCTION

Frailty among the elderly is a geriatric syndrome that results from a reduction in reserve capacity of multiple organs and functions and may be initiated by disease, inadequate nutritional intake, lack of physical activity, stress, and/or physiologic changes of ageing [1-3]. Frail elderly are at increased risk of disability, falls, dementia, hospitalisation, institutionalisation, healthcare utilization, and death [2,4-6]. The prevalence of frailty among community-dwelling elderly aged ≥65 years is reported to be 17.0% [7], increases with age and is about 25-40% among those aged ≥80 years [8,9]. With a worldwide ageing population, the number of frail elderly will increase rapidly, which will have a substantial impact on economic, social, and healthcare systems [1]. There is a clear need to further develop public health strategies to prevent frailty among the elderly.

Until recently, studies mainly focused on frailty as a non-dynamic entity. However, frailty can be understood as a continuum with intermediate states that can be modified [10]. Non-frail persons can become pre-frail, which can be seen as a precursor state of frailty. Of the community-dwelling elderly aged ≥65 years 52% are pre-frail [7]. Compared to non-frail persons, pre-frail persons are more likely to progress to frailty, which illustrates the downward spiral association of the frailty syndrome [9,11]. However, this is not a unidirectional process, i.e. there is a possibility to recover from a frail state to a pre-fail and potentially to a non-frail state [11]. It is thought that it is at the pre-frail state that the frailty process may still be reversed [1], which makes this state attractive for preventive strategies. As a first step towards such strategies, it is important to identify groups at increased risk of changing in frailty state. In this study, the phenotype of frailty as defined by Fried et al. (2001) is used to measure frailty. This measure has been validated and modified for use in numerous published reports and could currently be considered as a gold standard [10]. It is demonstrated that the construct of Fried's phenotype has a predictive validity for the adverse outcomes of frailty [9,12].

Risk factors, such as socio-demographic factors, are likely to contribute to differences between countries in onset and worsening in frailty. Therefore, the aim of this study is to search for socio-demographic determinants of worsening in frailty state among community-dwelling elderly in 11 European countries.

METHODS

Design

Data of subjects in the Survey of Health, Ageing and Retirement in Europe (SHARE) in 2004 (wave 1) were used. The SHARE study is designed to investigate population-ageing processes by looking at changes in health, economic situations, and social networks of individuals aged ≥50 years. For this purpose standardized computer-assisted face-to-face interviews were held. Nationally representative samples of 11 European countries (Sweden, Denmark, Germany, the Netherlands, Belgium, Switzerland, Austria, France, Italy, Spain, and Greece) were drawn with an overall pooled household response in wave 1 varying from 38.8% in Switzerland to 79.2% in France. A complete description of the SHARE survey design is described by Börsch-Supan et al. (2008, available online at http://www.share-project.org/).

Subjects

Data of community-dwelling persons aged ≥55 years at wave 1, who participated in wave 2 and with less than three missing Fried items at both waves were used for analyses. Of all subjects included in wave 1, 78.6% (n= 22414) were aged ≥55 years. Among these persons, a total of 7542 persons did not participate in the second wave. After further excluding 221 persons with three or more missing Fried items at one or both waves, and 227 persons institutionalised at either wave 1 or wave 2, data of 14424 individuals were eligible for analysis (appendix 1).

Frailty and frailty state changes

Frailty states were defined based on the five criteria of a phenotype described by Fried et al. [9], including weakness, weight loss, exhaustion, slowness, and low activity. Operationalisation of these criteria required adaptation to the SHARE survey contents for which the definition of Santos-Eggimann et al. [7] was used. Weakness was defined by using the highest of four measurements of hand grip strength. Cut-offs for grip strength stratified by sex and body mass index were applied, as set by Fried et al. [9]. One was positive for weight loss when answering 'less', or 'diminution in desire for food' to the question 'what has your appetite been like?' or when answering 'less' to the question 'So you have been eating more, or less than usual?'. Exhaustion was based on the question 'In the last month, have you had too little energy to do things you wanted to do?' with answering 'yes' as being positive for exhaustion. One was positive for slowness when mentioning having difficulty walking 100 meters or climbing one flight of stairs. At last, a participant was positive for low activity when answering 'one to three times a month', or 'hardly ever or never' to the question

‘How often do you engage in activities that require a low or moderate state of energy, such as walking, gardening, cleaning the car or going for a walk?’.

Frailty states were defined based on the total number of Fried criteria met (score ≥ 3= frail; score 1 or 2= pre-frail; score 0= non-frail). For our study, changes in frailty state within two years (from wave 1 to wave 2) were studied, which resulted in 3 groups: ‘worsening’, ‘no change’ and ‘improving’ in frailty state. Worsening was defined as changing from a non-frail, or pre-frail state at wave 1 to a higher frailty state at wave 2. Improving in frailty state was defined as changing from a frail or pre-frail state at wave 1 to a lower frailty state at wave 2.

Socio-demographic determinants

The following socio-demographic factors measured at wave 1 were used for analyses: sex, age, marital status, and level of education. Three variables were categorised: age (5 years groups), level of education (low=0-10 years, high=11-25 years), and marital status (married/registered partnership, never married, divorced, and widowed). For international comparisons of education, SHARE used the 1997 International Standard Classification of Education (ISCED-97).

Statistical analyses

When scores for one, or two of the five frailty criteria were missing, values were imputed through single random imputation, using software package R version 2.7.1. The scores of the population without missing values were used to replace missing values through a logistic regression model. Using this model the probability of scoring ‘positive for frailty’ on a frailty indicator for every individual (with one or more missing values) was predicted and a random draw from the binomial distribution with that probability was made. To check the influence of random imputation the procedure was repeated and no essential differences were found. Data for one, or twocriteria were imputed for respectively 2080 and 2312 individuals in wave 1 and 2 which completed the datasets (appendix 1).

As a first step, socio-demographic differences between the study population and the excluded sample were investigated using Chi-square tests for sex, marital status and level of education, and a t-test for mean age. In order to investigate which socio-demographic factors were associated with worsening in frailty state in the total study population, odds ratios with a 95% confidence interval (95% CI) for sex, age, level of education, and marital status were derived from multinomial logistic regression analyses, adjusted for baseline frailty state. Differences between countries in socio-demographic determinants of worsening (and improving) in frailty state were investigated by calculating odd ratios per country, adjusted for other determinants and baseline frailty state [13,14], using 'no change' in frailty state as a reference (p values <0.05 were considered significant). All analyses were conducted using SPSS 17.0.

RESULTS

Of the 14424 included individuals, 52.1% were non-frail, 29.1% pre-frail, and 8.8% frail at wave 1. After a two-year period, 22.1% had worsened, 61.8% showed no change, and 16.1% had improved in frailty state. Among those who worsened, more than two thirds (69.2%) showed a change from a non-frail state at wave 1 to a pre-frail state at wave 2. A proportion of 24.0% changed from a pre-frail to a frail state and 6.8% changed from a non-frail to a frail state. Of the persons who improved in frailty state, 76.9% changed from a pre-frail state to a non-frail state, 19.8% changed from a frail to a pre-frail state and 3.3% changed from a frail to a non-frail state. The distributions of frailty state changes per country showed that in Austria and Denmark most persons worsened in frailty state, i.e. 26.2% and 25.4%, respectively, while the least persons worsened in frailty state in Greece (16.3%) and Germany (19.2%) (table 1).

Table 1 Differences between countries in frailty state changes

	Total	Worsening		No change		Improving	
	N	N	(%)	N	(%)	N	(%)
Sweden	1638	348	(21.2)	1015	(62.0)	275	(16.8)
Denmark	919	233	(25.4)	556	(60.5)	130	(14.1)
Germany	1232	237	(19.2)	804	(65.3)	191	(15.5)
The Netherlands	1354	313	(23.1)	851	(62.9)	190	(14.0)
Belgium	2095	476	(22.7)	1276	(60.9)	343	(16.4)
Switzerland	522	113	(21.6)	329	(63.0)	80	(15.3)
Austria	1029	270	(26.2)	607	(59.0)	152	(14.8)
France	1441	347	(24.1)	859	(59.6)	235	(16.3)
Italy	1480	315	(21.3)	897	(60.6)	268	(18.1)
Spain	1117	277	(24.8)	566	(50.7)	274	(34.5)
Greece	1597	260	(16.3)	1154	(72.3)	183	(11.5)
Total	*14424*	*3188*	*(22.1)*	*8914*	*(61.8)*	*2322*	*(16.1)*

Socio-demographic determinants

Baseline socio-demographic characteristics showed that more participants were women, the majority of the participants were below 70 years of age, married (or with a registered partnership), and lower educated (table 2). The study participants who remained in the study and completed follow-up were younger ($p<0.001$), more often with a spouse ($p<0.001$), and higher educated ($p<0.001$) compared to the individuals lost-to-follow up. No sex differences were found between both samples.

Women showed a 1.26 fold (95% CI: 1.16-1.38) higher risk of worsening in frailty state compared to men. In addition, persons aged ≥65 years had a significantly increased risk of worsening in frailty state which increased with age up to a risk of 3.55 (95% CI: 2.97-4.25) for persons aged ≥80 years compared to persons aged 55-59 years of age. A significant higher risk of worsening in frailty state was also found for lower educated persons as compared to higher educated persons (OR=1.40, 95% CI: 1.28-1.54). No significant differences in risk of worsening in frailty state were found for marital status (table 2).

Table 2 Associations of socio-demographic factors with worsening in frailty state

		Study population (N=14424)		**Worsening**	
		N	(%)	OR[a]	(95% CI)
Sex	Men	6582	(45.6)	1.00	
	Women	7843	(54.4)	1.26*	(1.16,1.38)
Age	55-59	3447	(23.9)	1.00	
	60-64	3114	(21.6)	1.06	(0.93,1.21)
	65-69	2765	(19.2)	1.40*	(1.23,1.60)
	70-74	2158	(15.0)	1.80*	(1.56,2.07)
	75-79	1597	(11.1)	2.86*	(2.44,3.34)
	80+	1343	(9.3)	3.55*	(2.97,4.25)
Marital status	Married/reg. partnership	10370	(71.9)	1.00	
	Never married	716	(5.0)	1.14	(0.93,1.38)
	Divorced	811	(5.6)	0.97	(0.80,1.18)
	Widowed	2527	(17.5)	1.03	(0.91,1.16)
	Unknown	0	(0.0)		
Level of education	Higher	5790	(40.1)	1.00	
	Lower	8564	(59.4)	1.40*	(1.28,1.54)
	Unknown	70	(0.5)	n.a.	

[a] Mutually adjusted for each factor and for baseline frailty state; *$p<0.001$

Differences between countries were found in associations of sex, age, and level of education with worsening in frailty state. Figures 1-3 show these associations (adjusted OR's). All countries showed a significant increased risk for persons aged ≥75 years (appendix 2). In Greece, this increased risk started at the age of 60-64 years, where persons had a 1.85 fold (95% CI: 1.12-3.07) higher risk of worsening in frailty state

compared to persons aged 55-59 years. Persons had a significantly increased risk of worsening from the age of 65-69 years in Belgium (OR=1.64, 95% CI: 1.17-2.28) and Italy (OR=2.90, 95% CI: 1.87-4.49), and from 70-74 years in Austria (OR=2.00, 95% CI: 1.19-3.38) and France (OR=2.45, 95% CI: 1.58-3.80, p<.001). The risk of worsening in frailty state for persons aged 75-79 years ranged from 2.02 (95% CI: 1.37-2.98) in Belgium to 4.12 (95% CI: 2.26-7.49) in Greece compared to persons aged 55-59 years. For persons aged ≥80 years the risk of worsening ranged from 3.05 (95% CI: 1.98-4.72) in Belgium to 5.84 (95% CI: 2.39-14.30) in Switzerland. In general, Greece, Italy, and France showed higher risks per age category compared to the other European countries (figure 1 and appendix 2).
In Belgium, Italy, Spain, and Greece women had a significant higher risk of worsening in frailty state as compared to men with odds ratios for women ranging from 1.32 (p<0.05) in Belgium to 2.00 (p<0.001) in Italy. Seven countries did not show a significant difference between men and women in worsening in frailty state (figure 2 and appendix 2).

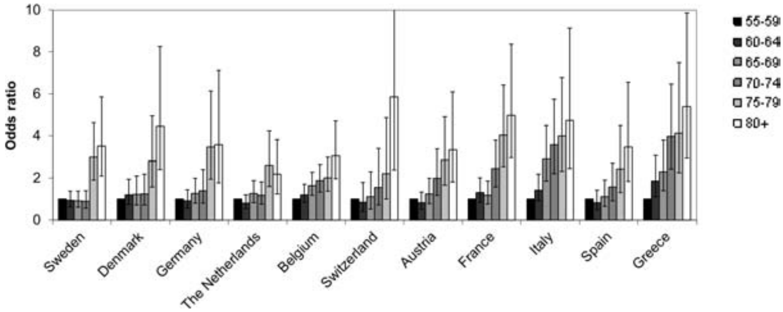

Figure 1 Differences between countries in worsening in frailty state by age: odds ratios (95% CI) adjusted for baseline frailty state, sex and level of education (n=14424)

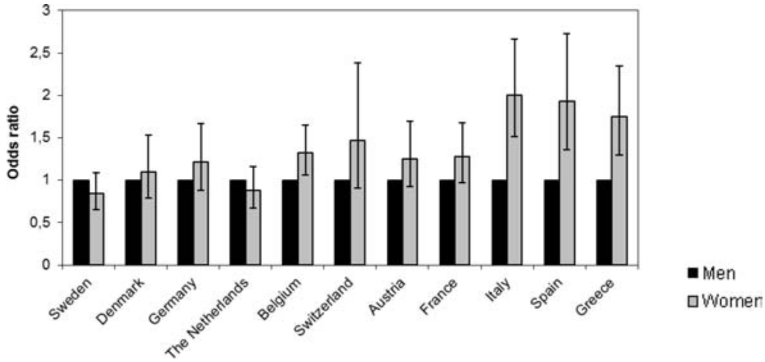

Figure 2 Differences between countries in worsening in frailty state by sex: odds ratios (95% CI) adjusted for baseline frailty state, age and level of education (n=14424)

An association of level of education with worsening in frailty state was found for six countries with a risk of lower educated persons ranging from 1.35 (95% CI: 1.08-1.70) in Belgium to 1.64 (95% CI: 1.03-2.63) in Spain as compared to higher educated persons. For Denmark, Switzerland, Austria, Italy, and Greece no association of level of education was found (figure 3 and appendix 2).

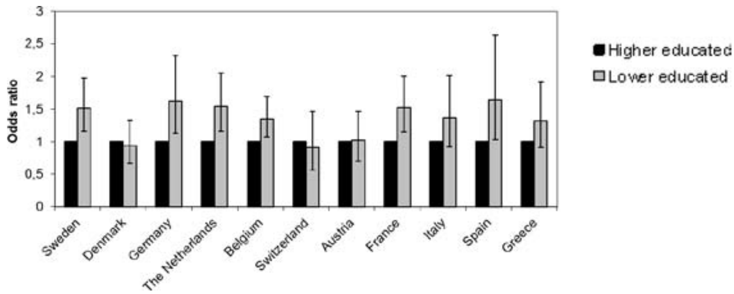

Figure 3 Differences between countries in worsening in frailty state by level of education: odds ratios (95% CI) adjusted for baseline frailty state, sex, and age (n=14424)

Improving in frailty state

Similar differences between countries as found for worsening in frailty state were found for improving in frailty state (appendix 3). In general, associations were found for age, sex, level of education, and marital status.

In Austria, Italy, and Greece, persons had a decreased probability of improving in frailty state from the age of 65 years onwards. Persons had a decreased probability of improving from ≥70 years in Spain and France. In Sweden, the Netherlands, Denmark, and Belgium, persons had a decreased probability from ≥75 years (OR ranging from 0.20 to 0.53). In Germany, persons had a decreased probability of improving from ≥80 years. No significant association with age was found for Switzerland. A significant association with sex was found for Denmark and Germany where women had a significant lower probability of improving in frailty state compared to men (OR=0.55, 95% CI: 0.34-0.88 and OR=0.53, 95% CI: 0.32-0.87 resp.). In Germany, Belgium, France, and Italy, lower educated persons had a lower probability of improving in frailty state compared to higher educated persons. In addition, four countries showed that persons without a spouse (never married or divorced) had a decreased probability of improving in frailty state compared to persons who were married, or had a registered partnership (OR ranging from 0.26 to 0.48). The complete results are shown in appendix 3.

DISCUSSION

In the European population we found women, those aged ≥65 years, and persons with ≤10 years of education were at increased risk of worsening in frailty state. Moreover, differences between countries were observed: persons in Southern European countries (France, Italy, and Greece) showed an increased risk of worsening at an earlier age compared to persons in Northern European countries (Sweden, Denmark, Germany, the Netherlands, and Switzerland). No sex differences were found in Northern European countries whereas in Southern European countries and in Belgium, women were at increased risk of worsening in frailty state as compared to men.

Some limitations of this study must be considered when interpreting these findings. Those lost-to-follow-up were significantly older, lower educated, and more often without a spouse, or registered partner. If health status determines who gets lost-to-follow-up, our results may underestimate 'real' associations. In the current study, Fried's phenotype as a measure of frailty is self-reported (four out of five criteria). Differential misclassification by socio-demographic factors may have introduced bias in our findings, but it is unclear in what direction and to what extent. For operationalising Fried's phenotype in the SHARE study, the definition of Santos-Eggimann (2009) was used which does not fully match the original criteria as defined by Fried et al. (2001). However, given that we studied changes in frailty state and that a potential measurement error would be equal at both waves of measurement, it is expected to be of minor influence to the reported changes. In this study we used the Fried's criteria to measure frailty. Although Fried's criteria are widely used, there is currently no general agreement on the best way to measure frailty. Other measures like the Tilburg Frailty Indicator [15] or the Sherbrooke Postal Questionnaire (SPQ) [16] differ from Fried's criteria by inclusion of other domains besides phyiscal frailty, e.g. social and cognitive frailty. There is an ongoing discussion about the inclusion of cognitive status in Fried's phenotype, which has been found to be associated with adverse outcomes of frailty [17]. These results raise some concerns about the validity of Fried's criteria and suggest that the inclusion of alternative criteria such as cognitive impairment might strengthen Fried's phenotype. It is currently unclear how inclusion of cognitive status or the use of another measure of frailty would have influenced our findings.

The findings contribute to the understanding of the frailty development process and can be related to outcomes of prior studies. The increased risk of women to worsen in frailty state is in accordance with the finding that considerably more women are frail compared to men [18,19]. Fried et al. (2001) and Walston et al.

(2002) found that the frailty prevalence is increasing with age, which is in line with our findings. In addition, the results showing that lower educated persons are at increased risk of worsening in frailty state is also found by Crimmins et al. (2010) [20]. Different studies did also found an association between level of education and frailty [21,22]. Differences between countries have also been reported by Santos-Eggimann (2009), who found that more persons in Southern European countries are pre-frail compared to persons in Northern European countries. For further understanding of the frailty process, it is of interest to search for (health- and behavior related) mediating factors which could explain the temporal relationship between age, sex ,and educational level and frailty changes.

Southern European populations have a higher healthy life expectancy compared to Northern European populations [23]. In this context, our finding of an earlier worsening in frailty state in Southern European countries seems a paradox. It might be explained by similar differences between countries in the delay of progress from (pre-) frailty to disability. The earlier onset of worsening in frailty state in Southern European countries may also be caused by lower rates of institutionalisation of (frail) elderly and women in Southern European countries compared to Northern European countries [7,24], as our study population consists of community-dwelling individuals (55-102 years). This may lead to more (frail) elderly in the community in Southern European countries with an increased risk of worsening in frailty state. Differences might also be present in healthcare access: Northern European elderly and women might visit healthcare professionals more often, because of better healthcare access compared to elderly and women in Southern European countries. Therefore, persons in Northern European countries might benefit more from healthcare advice. In addition, health-related behaviors might explain the cross-national age and sex differences in worsening in frailty state, e.g. in Northern European countries elderly are more physically active compared to Southern European countries and differences in physical activity between men and women are larger among Southern European elderly [25]. Whereas previous studies found a north-south gradient in health outcomes like self-rated health and mortality [26-28], socio-economic inequalities in worsening in frailty state appeared to be of similar magnitude in 11 European countries. Presumably causes of differences between countries in the size of socio-economic inequalities, such as differential healthcare access, or the stage of the epidemic of health behaviors apparently do not translate into differences in the size of educational inequalities in the worsening in frailty, or are buffered by other (currently unknown) factors. Further research on understanding differences between countries in socio-economic health inequalities should include this issue.

CONCLUSIONS

In conclusion, persons aged ≥65 years, women, and lower educated persons are at increased risk of worsening in frailty state in the European population. Because of the growing number of persons at risk of frailty, and the fact that frailty appears to be a dynamic process, delaying the frailty process is a major challenge in public health. Early interventions might delay the frailty development process and could even prevent pre-frail elderly to become frail. Public health interventions aimed at delaying the frailty process in Southern European countries should target persons earlier in life, and pay more attention to women than in Northern European countries.

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Appendix 1 Selection of the study population

	Household response rate (%)	N participants at w1	Born ≤ 1949 at w1	Non responders at w2	≥ 3 missings for Fried at both w1 and w2	≥ 3 missings for Fried score at w1 only	≥ 3 missings for Fried score at w2 only	Institutionalized at w1	Institutionalized at w2 (excl. institut. w1)	For analyses
Sweden	47.3	3053	2522	852	3	1	10	7	11	1638
Denmark	63.2	3193	1294	346	5	1	5	23	5	909
Germany	60.8	3008	2392	1133	6	0	3	8	10	1232
The Netherlands	60.6	2979	2320	918	17	3	7	12	9	1354
Belgium	39.7	3827	2894	760	6	2	2	9	9	2106
Switzerland	38.8	1004	773	234	4	1	0	0	9	525
Austria	55.6	1893	1601	548	8	0	4	7	5	1029
France	79.2	1707	2379	816	57	11	29	8	5	1453
Italy	52.8	2559	2181	677	9	0	1	26	2	1466
Spain	54.3	2396	1983	836	11	5	2	9	5	1115
Greece	63.4	2898	2075	422	4	2	2	7	41	1597
Total		*28517*	*22414*	*7542**	*130*	*26*	*65*	*116*	*111*	*14424*
		28517	*22414*				*7763 missing*		*227 institutionalized*	*14424*

*Including 533 individuals who had deceased after wave 1

2

Appendix 2 Differences between countries in worsening in frailty state by sex, age, and level of education: odds ratios (95% CI) (n=14424)

	Sex[a]		Age[b]						Level of education[c]	
	Men	**Women**	**55-59**	**60-64**	**65-69**	**70-74**	**75-79**	**80+**	**Higher educated**	**Lower educated**
Sweden	1.00	0.84 (0.65,1.09)	1.00	0.94 (0.64,1.38)	0.92 (0.61,1.38)	0.89 (0.56,1.41)	2.97*** (1.90,4.63)	3.51*** (2.11,5.85)	1.00	1.51** (1.16,1.98)
Denmark	1.00	1.10 (0.79,1.53)	1.00	1.20 (0.74,1.94)	1.23 (0.73,2.10)	1.25 (0.72,2.18)	2.80*** (1.58,4.96)	4.45*** (2.40,8.25)	1.00	0.94 (0.66,1.33)
Germany	1.00	1.21 (0.88,1.67)	1.00	0.91 (0.57,1.45)	1.26 (0.80,1.99)	1.39 (0.80,2.40)	3.45*** (1.95,6.13)	3.56*** (1.78,7.12)	1.00	1.62** (1.13,2.32)
The Netherlands	1.00	0.88 (0.67,1.16)	1.00	0.80 (0.54,1.20)	1.26 (0.84,1.88)	1.18 (0.76,1.82)	2.60*** (1.60,4.22)	2.18** (1.24,3.82)	1.00	1.54** (1.16,2.05)
Belgium	1.00	1.32* (1.06,1.65)	1.00	1.20 (0.85,1.70)	1.64** (1.17,2.28)	1.88*** (1.33,2.66)	2.02*** (1.37,2.98)	3.05*** (1.98,4.72)	1.00	1.35** (1.08,1.70)
Switzerland	1.00	1.47 (0.91,2.38)	1.00	0.86 (0.41,1.79)	1.11 (0.53,2.30)	1.55 (0.71,3.39)	2.21* (1.01,4.87)	5.84*** (2.39,14.30)	1.00	0.91 (0.56,1.47)
Austria	1.00	1.25 (0.92,1.69)	1.00	0.84 (0.52,1.34)	1.25 (0.78,2.00)	2.00** (1.19,3.38)	2.85*** (1.66,4.90)	3.32*** (1.81,6.08)	1.00	1.02 (0.70,1.47)
France	1.00	1.28 (0.97,1.68)	1.00	1.31 (0.85,2.01)	1.18 (0.76,1.85)	2.45*** (1.58,3.80)	4.03*** (2.53,6.43)	4.98*** (2.96,8.37)	1.00	1.52** (1.15,2.01)
Italy	1.00	2.00*** (1.51,2.66)	1.00	1.43 (0.92,2.20)	2.90*** (1.87,4.49)	3.56*** (2.22,5.73)	3.98*** (2.33,6.78)	4.74*** (2.46,9.14)	1.00	1.37 (0.92,2.02)
Spain	1.00	1.93*** (1.36,2.73)	1.00	0.84 (0.49,1.43)	1.12 (0.66,1.91)	1.58 (0.91,2.72)	2.42** (1.31,.4.48)	3.46*** (1.83,6.55)	1.00	1.64* (1.03,2.63)
Greece	1.00	1.75*** (1.30,2.35)	1.00	1.85* (1.12,3.07)	2.30** (1.40,3.78)	3.96*** (2.43,6.46)	4.12*** (2.26,7.49)	5.39*** (2.94,9.86)	1.00	1.32 (0.91,1.92)

*p<0.05; **p<0.01; ***p<0.001

[a] adjusted for baseline frailty state, age, and level of education

[b] adjusted for baseline frailty state, sex, and level of education

[c] adjusted for baseline frailty state, sex, and age

Appendix 3 Differences between countries in improving in frailty state by sex, age, marital status, and level of education: odds ratios (95% CI) (n=14424)

	Sex[a]		Age[b]						Marital status[c]				Level of education[d]	
	Men	**Women**	**55-59**	**60-64**	**65-69**	**70-74**	**75-79**	**80+**	**Married/reg. partnership**	**Never married**	**Divorced**	**widowed**	**Higher educated**	**Lower educated**
Sweden	1.00	1.17 (0.82,1.65)	1.00	1.00 (0.62,1.60)	0.90 (0.54,1.49)	0.62 (0.35,1.10)	0.48* (0.26,0.91)	0.19*** (0.09,0.40)	1.00	0.26** (0.10,0.71)	0.37** (0.19,0.75)	0.83 (0.47,1.45)	1.00	0.73 (0.52,1.02)
Denmark	1.00	0.55* (0.34,0.88)	1.00	0.60 (0.32,1.12)	0.68 (0.32,1.45)	0.60 (0.29,1.26)	0.20** (0.08,0.54)	0.31* (0.13,0.75)	1.00	0.58 (0.20,1.72)	1.41 (0.74,2.68)	0.65 (0.32,1.35)	1.00	0.76 (0.47,1.23)
Germany	1.00	0.53* (0.32,0.87)	1.00	1.28 (0.72,2.27)	1.19 (0.65,2.17)	0.65 (0.31,1.36)	0.61 (0.28,1.32)	0.16*** (0.06,0.45)	1.00	1.05 (0.47,2.37)	0.83 (0.34,2.04)	1.10 (0.58,2.11)	1.00	0.53* (0.32,0.87)
The Netherlands	1.00	1.04 (0.70,1.54)	1.00	1.19 (0.71,2.00)	0.61 (0.34,1.12)	0.94 (0.51,1.73)	0.36* (0.16,0.81)	0.18*** (0.07,0.43)	1.00	0.63 (0.23,1.69)	0.90 (0.42,1.92)	0.42* (0.21,0.81)	1.00	0.74 (0.50,1.09)
Belgium	1.00	1.13 (0.84,1.50)	1.00	1.17 (0.78,1.75)	0.87 (0.57,1.34)	0.68 (0.43,1.08)	0.53* (0.32,0.87)	0.32*** (0.19,0.57)	1.00	0.86 (0.46,1.60)	0.48* (0.25,0.93)	0.68 (0.46,1.00)	1.00	0.73* (0.55,0.98)
Switzerland	1.00	0.88 (0.46,1.67)	1.00	1.89 (0.75,4.75)	1.78 (0.70,4.52)	1.03 (0.35,3.06)	1.23 (0.44,3.49)	0.54 (0.16,1.84)	1.00	1.23 (0.32,4.66)	0.64 (0.22,1.88)	0.86 (0.38,1.93)	1.00	0.79 (0.43,1.44)
Austria	1.00	1.23 (0.76,1.96)	1.00	1.01 (0.56,1.84)	0.40** (0.20,0.79)	0.66 (0.31,1.37)	0.30** (0.14,0.67)	0.16*** (0.06,0.41)	1.00	0.66 (0.29,1.54)	0.34* (0.14,0.80)	0.82 (0.46,1.47)	1.00	0.76 (0.44,1.30)
France	1.00	0.72 (0.51,1.02)	1.00	0.71 (0.44,1.16)	1.07 (0.66,1.74)	0.56* (0.32,0.98)	0.34** (0.18,0.64)	0.25*** (0.13,0.48)	1.00	0.54 (0.26,1.09)	0.67 (0.36,1.25)	0.99 (0.63,1.54)	1.00	0.66* (0.47,0.93)
Italy	1.00	0.65 (0.47,0.90)	1.00	0.69 (0.45,1.06)	0.57* (0.36,0.92)	0.40** (0.24,0.67)	0.27*** (0.14,0.52)	0.24*** (0.12,0.47)	1.00	1.46 (0.73,2.91)	0.80 (0.24,3.72)	1.42 (0.90,2.27)	1.00	0.56** (0.38,0.83)
Spain	1.00	0.84 (0.60,1.19)	1.00	0.83 (0.50,1.38)	0.73 (0.44,1.22)	0.34*** (0.19,0.59)	0.28*** (0.15,0.52)	0.30*** (0.16,0.58)	1.00	0.81 (0.41,1.63)	1.06 (0.244.81	1.17 (0.73,1.89	1.00	0.68 (0.43,1.08)
Greece	1.00	1.23 (0.83,1.84)	1.00	0.84 (0.49,1.43)	0.55* (0.31,0.96)	0.36** (0.19,0.67)	0.22*** (0.11,0.44)	0.09** (0.04,0.19)	1.00	0.47 (0.18,1.24)	1.15 (0.48,2.74)	0.64 (0.39,1.04)	1.00	0.82 (0.52,1.28)

*p<0.05; **p<0.01; ***p<0.001

[a] adjusted for baseline frailty state, age, marital status, and level of education

[b] adjusted for baseline frailty state, sex, marital status, and level of education

[c] adjusted for baseline frailty state, sex, age, and level of education

[d] adjusted for baseline frailty state, sex, age, and marital status

3

Do lifestyle, health, and social participation mediate educational inequalities in frailty worsening?

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ABSTRACT

Background Lower educated older persons are at increased risk of becoming frail as compared to higher educated older persons. In order to reduce educational inequalities in the development of frailty, we investigated whether lifestyle, health, and social participation mediate this relationship.

Methods Longitudinal data of 14082 European community-dwelling persons aged 55 years and older participating in the Survey on Health, Ageing and Retirement in Europe (SHARE) in 2004 and 2006, were used. Associations of lifestyle (smoking behavior and alcohol consumption), health (depression, memory function, chronic diseases), and social participation, with educational level and frailty worsening were investigated using regression models. In multinomial logistic regression analysis, mediators were added to models in which educational level was associated with worsening in frailty over two years follow-up.

Results In all countries, frailty worsening was more prevalent among lower as compared to higher educated persons, although odds ratios were only statistically significant in five of the eleven countries included (ORs varying from 1.40 (95% CI: 1.06 to 1.84) to 1.61 (95% CI: 1.21 to 2.14)). Except for smoking behavior and memory function, the factors under study all showed associations with educational level and frailty worsening which met the conditions for mediation. After inclusion of the four relevant mediators, attenuation of odds ratios varied between 4.9% and 31.5%.

Conclusion While lifestyle, health, and social participation were associated with frailty worsening over two years among European community-dwelling older persons, only small to moderate parts of educational inequalities in frailty worsening were explained by these factors.

INTRODUCTION

Frailty develops as a consequence of age-related decline in many physiological systems, which collectively results in vulnerability to sudden health status changes [1]. Due to ageing in Western populations, an increased number of older persons will become frail in the upcoming years. According to the often used definition of Fried [2], currently, 37% of community-dwelling persons aged >55 years are pre-frail and about 4% are frail [3], with percentages increasing to 51% and 26% respectively for those aged >70 years [4]. Among those aged >55 years, almost one quarter of the population in Western countries worsened in frailty over a relatively short period of two years [5]. Because frailty can lead to falls, hospitalization, nursing home placement, and death [1], it is important to find out how the frailty process develops in order to prevent or slow down this process from onset. Moreover, since the development of frailty is found to be a reversible process, appropriate interventions may contribute to frail older persons becoming pre-frail or even non-frail [5,6].

Frailty is more prevalent among lower educated as compared to higher educated persons [7]. Two recent longitudinal studies suggested a causation mechanism as lower educated persons aged >55 years showed an increased risk to worsen in frailty over time, compared to higher educated persons [4,6]. Potential factors contributing to educational inequalities in worsening in frailty are largely unknown, but can be derived indirectly. There is evidence that an unhealthy lifestyle (e.g. smoking), limited social participation and health conditions are related to the frailty development process [2,8-11], although reverse causality cannot always be excluded. For example, frailty is associated with the onset of depression, but depression may also result in a worsening of frailty [12]. Because educational differences in lifestyle [13,14], health [15,16], and social participation [15,17] are well known, these factors may likely contribute to the educational inequalities in frailty worsening; a quantification of their contribution however, is currently lacking.

The Survey of Health, Ageing, and Retirement in Europe (SHARE) aims at investigating population ageing processes across European countries. Longitudinal data on frailty and underlying determinants make the study suitable for research aimed at improving the understanding of educational inequalities in the frailty process. When investigating the role of lifestyle, health, and social participation in educational inequalities in frailty worsening, possible differences between European countries in the extent to which potential mediators may contribute to inequalities in frailty worsening should be acknowledged. Therefore, this study adds knowledge by exploring whether lifestyle, health, and social participation mediate the relationship between educational level and frailty worsening among community dwelling elderly in 11 European countries.

METHODS

Design

Data of persons participating in the SHARE study in both 2004 (wave 1) and 2006 (wave 2) were used. Nationally representative samples of 11 European countries (Sweden, Denmark, Germany, the Netherlands, Belgium, Switzerland, Austria, France, Italy, Spain, and Greece) were interviewed face-to-face with structured computerized questionnaires. More detailed information can be found in chapters 1 and 2.

Subjects

Subjects were eligible for the analyses if they were community-dwelling, aged ≥55 years at wave 1, and participated in wave 2 as well. A total of 14477 European community-dwelling persons fulfilled these inclusion criteria, however 395 were excluded due to missing values for educational level, for ≥1 mediator(s), or because they had ≥3 missing Fried items at one or both waves. This resulted in a study population of 14082 persons.

Educational level

Educational level was measured at wave 1 and was defined as the number of years a person received full time education (i.e. receiving tuition, engaging in practical work or supervised study or taking examinations). For international comparisons of education, SHARE used the 1997 International Standard Classification of Education (ISCED-97). Educational level was dichotomized in zero to ten years (which corresponds with ISCED level 0-2; 'lower educated') and 11-25 years (which corresponds with ISCED level 3-6; 'higher educated').

Frailty worsening

Physical frailty was based on the Fried's criteria, i.e. weakness, slowness, low activity, weight loss, and exhaustion. To make optimal use of the data available in the SHARE survey, we measured frailty level with an adapted version of Fried's frailty scale as developed by Santos-Eggimann and colleagues [3]. Weakness was defined as being below cut-off points (stratified by sex and body mass index [2]) for the highest of four measurements of hand grip strength. Participants were classified positive for slowness when mentioning having difficulty walking 100 meter or climbing one flight of stairs. Participants were classified as positive for low activity when answering the question 'How often do you engage in activities that require a low or moderate state of energy, such as walking, gardening, cleaning the car, or doing a walk?' with 'one to three times a month' or 'hardly ever or never'. Unintentional weight loss was based on the answers 'less' or 'diminution in desire for food' to the question 'what has your appetite been like?' or the answer 'less' to the question 'So you have been eating more, or less than usual?'. Exhaustion was based on the question 'In the last month, have you had too little energy to do the things you wanted to do?'. Answering 'yes' was considered as being positive for exhaustion. Frailty states were based on the total number of criteria met: 'frail' (>3 criteria), 'pre-frail' (1-2 criteria), 'non-frail' (0 criteria). Worsening in frailty was defined as changing from a lower to a higher frailty state after two years (i.e. from non-frail to pre-frail or frail, or from pre-frail to frail) with 'no change in frailty' as the reference group. Additional analyses were performed for improving in frailty, which was defined as changing from a high to a low frailty state after two years (appendix 1).

Potential mediators: lifestyle, health, and social participation

Self-reported lifestyle (smoking and alcohol consumption), health (presence of chronic diseases, memory function, and depression), and social participation were measured at baseline. Smoking behavior was measured with the question "Do you smoke?" (current, former, or never smoker). Alcohol consumption was based on the number of days per week participants were drinking alcohol during the last six months (<1 day, 3-4 days, >5 days per week). Chronic diseases were measured by questioning 'Has a doctor ever told you that you have any of the following conditions?', followed by a list of 14 chronic conditions, e.g. hypertension, arthritis, osteoporosis' (none, >1 chronic diseases). Memory function was based on the maximum number of words (out of a ten-words list) a respondent was able to recall after a verbal and a numeric test ('impaired' (<4 words), 'good' (>4 words)). Depression was measured based on the EURO-D scale with 12 items on e.g. depression, pessimism, appetite, and fatigue ('not depressed' (0-4 items), 'probably depressed' (>5 items 'yes')) [18]. Social participation was measured with participating in social activities over the last month, e.g. voluntary work, cared for a sick person, participation at sports club ('none', 'one or more').

Statistical analyses

When scores for one or two of the five frailty criteria were missing, values were imputed through single random imputation, using software package R V.2.7.1. The scores of the population without missing values were used to replace missing values through a logistic regression model. Using this model, the probability of scoring 'positive for frailty' on a frailty indicator for every individual (with one or more missing values) was predicted and a random draw from the binomial distribution with that probability was made. To check the influence of random imputation the procedure was repeated and no essential differences were found. Furthermore, a sensitivity analysis was conducted in which participants with missing outcome data were excluded (results available upon request). No substantial differences were found. Data were imputed for 2080 (14.8%) and 2312 (16.5%) individuals in waves 1 and 2, respectively.

Differences in sex, age, and educational level between the study population and the excluded sample were investigated using Chi-square tests (sex, educational level) and a t-test (mean age). The association of educational level and frailty worsening was based on odds ratios (ORs, 95% confidence interval (CI)) from multinomial logistic regression analyses. Following conventional rules of mediation analysis [19] the associations of educational level with the possible mediators, and of the possible mediators with frailty worsening were explored by binominal and or multinomial logistic regression analyses (depending on the number of categories of the mediating factor) among the total study sample. Finally, in multinomial logistic regression analyses, potential mediators were successively added to a model in which educational level was associated with frailty worsening, with 'no change in frailty' as the reference group, for each country separately. All analyses were adjusted for age and sex. Analyses concerning frailty changes were adjusted for baseline frailty state which has been found to be associated with subsequent changes in frailty [3,20]. In all analyses, p-values of <0.05 were considered significant using SPSS 20.0. In order to reduce potential selection bias generated by non-response, analyses were performed with individual longitudinal weights (SHARE Release guide 2.5.0).

RESULTS

The study sample was younger and higher educated than those excluded from the analyses ($p<0.01$, not tabulated). Within the study sample, most were women, in the younger age categories, and non-frail at wave 1 and wave 2. After two years of follow-up, 22.1% worsened, 16.0% improved, and 61.9% showed no change in frailty state. Lower educated persons (59.3%) were older, more often frail at both waves, and more often worsened in frailty after two years compared to higher educated persons. Among the higher educated persons 19.2% worsened compared to 24.0% among lower educated persons (table 1).

The absolute prevalence of worsening in frailty during a two year period was up to 9.5% higher among lower educated persons compared to those with higher education (Germany) (figure 1).

Table 1 Characteristics of the study population aged 55 years and older from 11 European countries participating in the SHARE study in both 2004 and 2006 (N=14082)

		Total (N=14082)	Higher educated (>10 years; N=5734)	Lower educated (0-10 years; N=8348)
		%	%	%
Sex (2004)	Female	54.3	48.9	58.0
	Male	45.7	51.1	42.0
Age (2004, in years)	55-64	45.9	56.0	38.9
	65-74	34.3	30.4	36.9
	75+	19.9	13.6	24.2
Frailty state (2004)	Non-frail	52.6	59.8	47.7
	Pre-frail	39.0	36.2	41.0
	Frail	8.4	4.0	11.3
Frailty state (2006)	Non-frail	48.7	58.0	42.4
	Pre-frail	39.8	36.3	42.2
	Frail	11.5	5.7	15.4
Frailty change (2004-2006)	Worsening	22.1	19.2	24.0
	Improving	16.0	16.3	15.9
	No change	61.9	64.5	60.1

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As shown in table 2, in the total study sample, lower educated persons had a lower probability to be a current or former smoker, to drink alcohol, or to participate in social activities as compared to higher educated persons. Furthermore, lower educated persons had a higher probability to be depressed, to have impaired

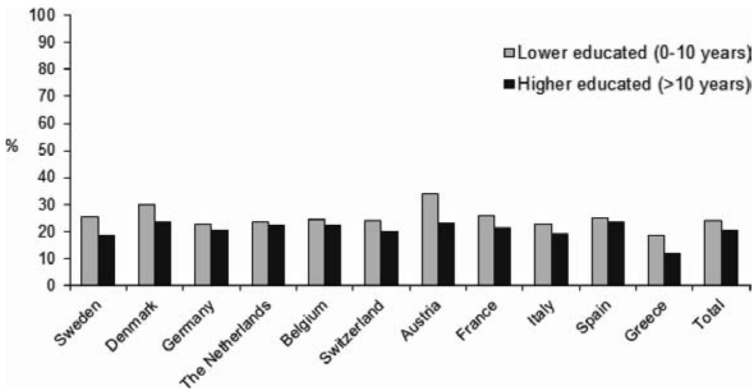

Figure 1 Frailty worsening prevalence (%) over two years follow-up by educational level for all countries and the total study population (N=14082)

memory, or have one or more chronic diseases (table 2). Cross-national differences in the pattern of inequalities were found for smoking behavior: in Sweden and the Netherlands, lower educated persons more often were current smokers (ORs 1.62 (95% CI: 1.19 to 2.22) to 2.00 (95% CI: 1.45 to 2.76)), whereas in France, Spain, and Greece, lower educated persons less often were current smokers compared to higher educated persons (ORs varying 0.65 (95% CI: 0.47 to 0.88) to 0.54 (95% CI: 0.35 to 0.84)) (appendix 2).

Being a current smoker, alcohol, having a depression, or one or more chronic diseases, and no social participation increased the likelihood of frailty worsening (table 3). Although not always significant for the separate countries, the direction of these associations was mostly comparable to that in the total study sample (appendix 3). Because alcohol consumption, chronic diseases, depression, and social participation

Table 2 Associations (odds ratios, 95% confidence intervals) between educational level and lifestyle, health, and social participation adjusted for age, sex, and country (N=14082)

			Higher educated (> 10 years)	**Lower educated (0-10 years)**	
			OR	**OR**	**(95% CI)**
Lifestyle	Smoking behavior	Never			
		Former	1.00	0.74**	(0.68 to 0.80)
		Current	1.00	0.84**	(0.76 to 0.93)
	Alcohol consumption	Hardly ever/never			
		1-2 days per week	1.00	0.52**	(0.47 to 0.58)
		3-4 days per week	1.00	0.38**	(0.32 to 0.44)
		5 days or more days per week	1.00	0.44**	(0.40 to 0.48)
Health	Depression	Not depressed			
		Probably depressed	1.00	1.74**	(1.60 to 1.89)
	Memory function	Good			
		Impaired	1.00	2.43**	(2.23 to 2.65)
	Chronic diseases	None			
		1 or more	1.00	1.31**	(1.20 to 1.43)
Social	Social participation	Yes			
		No	1.00	2.53**	(2.35 to 2.72)

**p<0.001

were associated with both educational level and frailty worsening, these factors were added as mediators to the explanatory models for educational inequalities in frailty worsening. Smoking was not added to the explanatory models, because smoking

Table 3 Associations (odds ratios, 95% confidence intervals) between lifestyle, health, and social participation and frailty worsening over two years follow-up, adjusted for age, sex, educational level, baseline frailty state, and country (N=14082)

			Frailty worsening[a]	
			OR	**(95% CI)**
Lifestyle	Smoking behaviour	Never	1.00	
		Former	1.07	(0.96 to 1.19)
		Current	1.16*	(1.02 to 1.32)
	Alcohol consumption	Hardly ever/never	1.00	
		1-2 days per week	0.84*	(0.73 to 0.96)
		3-4 days per week	0.88	(0.73 to 1.06)
		5 or more days per week	0.79**	(0.71 to 0.88)
Health	Depression	Not depressed	1.00	
		Probably depressed	1.27**	(1.12 to 1.43)
	Memory function	Good	1.00	
		Impaired	1.08	(0.96 to 1.20)
	Chronic diseases	None	1.00	
		1 or more	1.43**	(1.28 to 1.60)
Social	Social participation	Yes	1.00	
		No	1.18**	(1.08 to 1.30)

[a]Ref: no change; *p<0.05; **p<0.001

did increase the risk of worsening in frailty, but lower educated were doing better on this risk factor (i.e. less likely to be a current smoker) than higher educated.

An increased probability of worsening in frailty in lower as compared to higher educated persons was found in ten countries, but was only statistically significant in five countries (ORs varying from 1.40 (95% CI: 1.06 to 1.84) to 1.61 (95% CI: 1.21 to 2.14), table 4). Inclusion of lifestyle, health, and social participation separately resulted in only a minor attenuation of the odds ratios which varied between 4.9% in the Netherlands to 31.5% in Germany.

Table 4 Associations (odds ratios, 95% confidence intervals) between educational level and frailty worsening over two years follow-up, presented by models including lifestyle, health, and social participation (N=14082)

	Frailty worsening[a]						
	Higher educated (> 10 years)	Lower educated (0-10 years)					
		Model 1	Model 2	Model 3	Model 4	Model 5	
		sex, age, and baseline	sex, age, and baseline + Alcohol consumption	sex, age, and baseline + Health	sex, age, and baseline + Social participation	sex, age, and baseline + All mediators	
	OR	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	Attenuation in OR[c]
Sweden (N=1613)	1.00	1.51* (1.16 to 1.97)	1.44* (1.10 to 1.90)	1.47* (1.13 to 1.93)	1.48* (1.13 to 1.93)	1.38* (1.05to 1.82)	25.5%
Denmark (N=913)	1.00	0.95 (0.67 to 1.35)	0.93 (0.66 to 1.32)	0.96 (0.68 to 1.35)	0.95 (0.67 to 1.34)	0.93 (0.66 to 1.33)	n.a.
Germany (N=1217)	1.00	1.54* (1.09 to 2.17)	1.39 (0.98 to 1.98)	1.53* (1.08 to 2.17)	1.50* (1.06 to 2.13)	1.37 (0.96 to 1.95)	31.5%
The Netherlands (N=1332)	1.00	1.61* (1.21 to 2.14)	1.57* (1.18 to 2.10)	1.65* (1.24 to 2.20)	1.57* (1.18 to 2.08)	1.58* (1.18 to 2.12)	4.9%
Belgium (N=2067)	1.00	1.42* (1.13 to 1.77)	1.39* (1.11 to 1.75)	1.42* (1.13 to 1.78)	1.38* (1.10 to 1.73)	1.37* (1.09 to 1.72)	11.9%
Switzerland (N=519)	1.00	1.04 (0.64 to 1.67)	1.05 (0.65 to 1.70)	1.05 (0.65 to 1.69)	0.87 (0.53 to 1.43)	0.91 (0.55 to 1.50)	n.a.
Austria (N=1013)	1.00	0.96 (0.67 to 1.39)	0.96 (0.66 to 1.39)	0.93 (0.64 to 1.35)	0.96 (0.66 to 1.39)	0.92 (0.63 to 1.34)	n.a.
France (N=1383)	1.00	1.40* (1.06 to 1.84)	1.39* (1.05 to 1.84)	1.35* (1.02 to 1.79)	1.36* (1.03 to 1.80)	1.30 (0.98 to 1.73)	25.0%
Italy (N=1463)	1.00	1.31 (0.90 to 1.91)	1.33 (0.91 to 1.95)	1.31 (0.90 to 1.90)	1.27 (0.87 to 1.86)	1.28 (0.88 to 1.88)	n.a.

Spain (N=1072)	1.00	1.55 (0.99 to 2.42)	1.52 (0.98 to 2.37)	1.51 (0.96 to 2.37)	1.64* (1.04 to 2.58)	1.56 (0.98 to 2.49)	n.a.
Greece (N=1490)	1.00	1.38 (0.95 to 2.00)	1.38 (0.95 to 2.00)	1.38 (0.95 to 2.01)	1.39 (0.96 to 2.02)	1.40 (0.96 to 2.03)	n.a.
TOTAL[b] (N=14082)	1.00	1.39** (1.26 to 1.53)	1.36** (1.22 to 1.51)	1.37** (1.24 to 1.51)	1.36** (1.23 to 1.50)	1.31** (1.19 to 1.45)	20.5%

[a] Reference category: no change;
[b] Additionally adjusted for country;
[c] (OR model 1 – OR model 5)/(OR model 1 – 1)*100%
Model 1: Adjusted for sex, age, and baseline frailty state;
Model 2: model 1 + alcohol consumption;
Model 3: model 1 + depression and chronic diseases;
Model 4: model 1 + social participation;
Model 5: model 1 + all 5 mediators;
*p<0.05; **p<0.001.

DISCUSSION

Among European community-dwelling older persons aged >55 years, lower educated were found to be at an increased risk of worsening in frailty over a two-years follow-up. While low alcohol consumption, chronic diseases, depression, and less social participation increased the probability of frailty worsening and were more prevalent among the lower educated, only small to modest parts of the educational inequalities in frailty worsening were explained by these factors.

Our findings are in line with research in which lower educated older persons were found to be at an increased risk of worsening in frailty over an average 6.4 years period [7]. Lifestyle factors are reported to be on the pathway of educational inequalities in health [21-23], which is supported by our finding that alcohol consumption contribute to educational differences in frailty changes. Our finding that the presence of chronic diseases explained part of educational inequalities in frailty worsening is supported by findings of Gobbens et al. [24] who found that multimorbidity partly mediates the relationship between income and frailty. As mentioned, associations between health factors such as depression and frailty may be due to reverse causality [12]. Our longitudinal approach however, strengthens the evidence of the association between health factors and the development of frailty.

Our finding that alcohol consumption was associated with a lower probability of frailty worsening is supported by studies in which alcohol consumption was found to protect against coronary heart disease and dementia [25,26].

Smoking behavior is associated with both the onset [11,13] and worsening in frailty. Overall, associations with frailty worsening were found for certain health conditions, i.e. presence of depression and the presence of chronic diseases, which is supported by earlier research on the presence of frailty [2,8,13,27]. Furthermore, persons who were not socially participating showed an increased risk of worsening in frailty. These results fit well with the findings of Cramm et al. [28] who showed that the social environment (e.g. social cohesion, social support, contact with neighbors) plays an important role for the well-being of older persons.

There is a possibility that two years is too short to detect an effect of the possible mediators on the frailty worsening process. Future research in this field should focus on follow up periods longer than two years, and search for additional explanations for the educational inequalities in frailty worsening. Previous studies addressed the importance of material (e.g. financial situation, housing conditions), psychosocial (e.g. life events, external locus of control), and environmental factors (e.g. neighborhood characteristics) when studying educational inequalities in health [18,29-31]. It therefore seems legitimate to further investigate how and when differential exposure to material circumstances, psychosocial factors, and characteristics of the built environment over the life course between educational groups may translate into an increased risk of worsening in frailty among the lower educated.

Some limitations of this study should be mentioned. Firstly, frailty state was measured via self-report. Differential misclassification of frailty state by educational level may have led to incorrect associations. It is unknown, however, whether this would result in under- or overestimations of the educational inequalities in frailty development. Secondly, the self-reported nature of the mediators may have resulted in an underestimation of their contribution to educational inequalities in frailty worsening. There is evidence of larger under-reporting of chronic conditions [32] and over-reporting of a healthy lifestyle [33,34] among persons with lower as compared to higher educational levels. Furthermore, higher educated persons are more likely to participate in surveys as compared to lower educated persons which may also have resulted in an underestimation of educational inequalities in frailty worsening. Thirdly, alcohol consumption was measured by the number of days drinking alcohol per week, without asking for the number of glasses per day. Therefore, this measure does not allow to differentiate between binge drinkers and regular drinkers. This may have underestimated the contribution of alcohol consumption to inequalities in frailty worsening, since binge drinking increases the likelihood of unfavourable health outcomes (e.g. functional limitations and death) [35-37], and for example in Dutch persons, may be more common among lower than higher educated persons [38]. Fourthly, among the non-responses at wave 2, some passed away between wave 1 and 2 (exact number is unclear). As some deaths could have been due to worsening in frailty, this may have resulted in an underestimation of the prevalence of frailty worsening. As lower educated persons were more likely to worsen in frailty, it may also have resulted in an underestimation of the educational inequalities in frailty worsening.

CONCLUSION

In conclusion, our study showed that although lifestyle, health, and social participation were associated with the frailty development process, only small to moderate parts of educational inequalities in frailty worsening among older European persons were explained by these factors.

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APPENDIX 1

Improving in frailty

In additional analyses, we explored the role of potential mediators in educational inequalities in frailty improving. Four out of the 11 countries showed that lower educated persons had a lower probability to improve in frailty than higher educated persons, with ORs ranging from 0.72 (95% CI: 0.54 to 0.96) in Belgium to 0.55 in Spain (95% CI: 0.35 to 0.86).The same four mediators that we investigated for frailty worsening were included in explanatory models for frailty improving (adjusted for sex, age, and baseline frailty state) which led to an increase of 20.7% in the total population up to 58.4% in Italy of the observed inequalities in frailty improving (table 1).

3

Table 1 Associations (odds ratios, 95% confidence intervals) between educational level and frailty improving over two years follow-up, presented by models including lifestyle, health, and social participation (N=14082)

	Frailty improving[a]			
	Higher educated (>10 years)	**Lower educated (0-10 years)**		
		Model 1	**Model 2**	
		sex,age, and baseline	**sex,age, and baseline + All mediators**	**Increase in odds ratio[c]**
	OR	**OR (95% CI)**	**OR (95% CI)**	
Sweden (N=1613)	1.00	0.82 (0.58 to 1.15)	0.93 (0.65 to 1.33)	n.a.
Denmark (N=913)	1.00	0.79 (0.49 to 1.26)	0.72 (0.44 to 1.19)	n.a.
Germany (N=1217)	1.00	0.60* (0.38 to 0.94)	0.57* (0.36 to 0.92)	-13.2%
The Netherlands (N=1332)	1.00	0.76 (0.52 to 1.12)	0.75 (0.50 to 1.10)	n.a.
Belgium (N=2067)	1.00	0.72* (0.54 to 0.96)	0.74* (0.55 to 0.98)	14.3%
Switzerland (N=519)	1.00	0.88 (0.49 to 1.57)	0.85 (0.47 to 1.54)	n.a.
Austria (N=1013)	1.00	0.82 (0.48 to 1.37)	0.99 (0.57 to 1.71)	n.a.
France (N=1383)	1.00	0.71 (0.50 to 1.01)	0.75 (0.53 to 1.06)	n.a.
Italy (N=1463)	1.00	0.67* (0.45 to 0.97)	0.83 (0.56 to 1.25)	58.4%
Spain (N=1072)	1.00	0.55* (0.35 to 0.86)	0.62* (0.39 to 1.00)	25.1%

(continued) Associations (odds ratios, 95% confidence intervals) between educational level and frailty improving over two years follow-up, presented by models including lifestyle, health, and social participation (N=14082)

	Frailty improving[a]			
	Higher educated (>10 years)	Lower educated (0-10 years)		
		Model 1	Model 2	
		sex,age, and baseline	sex,age, and baseline + All mediators	Increase in odds ratio[c]
	OR	OR (95% CI)	OR (95% CI)	
Greece (N=1490)	1.00	0.88 (0.55 to 1.38)	0.89 (0.56 to 1.41)	n.a.
TOTAL[b] (N=14082)	1.00	0.66** (0.59 to 0.75)	0.71** (0.63 to 0.81)	20.7%

[a] Reference category: no change;
[b] Additionally adjusted for country;
[c] (1/OR model 1) – (1/OR model 2)/(1/OR model 1 – 1)*100%
Model 1: Adjusted for sex, age, and baseline frailty state;
Model 2: model 1 + all 4 mediators;
*p<0.05; **p<0.001.

APPENDIX 2

Associations (odds ratios, 95% confidence intervals) between educational level and lifestyle, health, and social participation adjusted for age and sex for all countries separately (N=14082)

			Lifestyle					Health			Social
	Education		Smoking behaviour		Alcohol consumption			Depression	Memory	Chronic diseases	Social participation
			Former	Current	1-2 days	3-4 days	5 days or more	Probably depressed	Impaired	1 or more	No
Sweden (N=1613)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	1.15 (0.92 to 1.43)	2.00** (1.45 to 2.76)	0.50** (0.39 to 0.63)	0.37** (0.26 to 0.54)	0.28** (0.18 to 0.41)	1.29 (0.97 to 1.70)	1.49** (1.20 to 1.85)	1.62** (1.27 to 2.07)	1.54** (1.24 to 1.91)
Denmark (N=913)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	0.85 (0.61 to 1.19)	0.89 (0.63 to 1.26)	0.51* (0.35 to 0.77)	0.36** (0.23 to 0.58)	0.52** (0.36 to 0.76)	1.21 (0.80 to 1.85)	1.15 (0.86 to 1.54)	0.83 (0.59 to 1.17)	1.28 (0.94 to 1.73)
Germany (N=1217)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	0.49** (0.34 to 0.71)	1.00 (0.67 to 1.49)	0.74 (0.51 to 1.05)	0.66 (0.40 to 1.08)	0.42** (0.27 to 0.63)	1.43* (1.04 to 1.99)	1.93** (1.42 to 2.63)	1.53* (1.07 to 2.19)	2.35** (1.79 to 3.09)
The Netherlands (N=1332)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	0.86 (0.66 to 1.12)	1.62* (1.19 to 2.22)	0.75 (0.53 to 1.05)	0.35** (0.23 to 0.52)	0.47** (0.36 to 0.62)	0.85 (0.64 to 1.13)	2.10** (1.65 to 2.66)	0.91 (0.71 to 1.16)	1.37* (1.08 to 1.73)
Belgium (N=2067)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	0.95 (0.76 to 1.18)	1.03 (0.77 to 1.37)	0.67* (0.53 to 0.86)	0.44** (0.31 to 0.63)	0.52** (0.42 to 0.65)	1.44** (1.17 to 1.79)	1.62** (1.29 to 2.04)	1.05 (0.83 to 1.32)	1.61** (1.35 to 1.93)
Switzerland (N=519)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	1.03 (0.66 to 1.61)	0.80 (0.49 to 1.30)	0.74 (0.45 to 1.21)	0.71 (0.39 to 1.29)	0.68 (0.43 to 1.07)	0.83 (0.51 to 1.36)	1.69* (1.15 to 2.49)	0.98 (0.67 to 1.44)	1.72* (1.18 to 2.49)

(continued) Associations (odds ratios, 95% confi dence intervals) between educational level and lifestyle, health, and social participation adjusted for age and sex for all countries separately

			Lifestyle					**Health**			**Social**
			Smoking behaviour		**Alcohol consumption**			**Depression**	**Memory**	**Chronic diseases**	**Social participation**
(N=14082)'			**Former**	**Current**	**1-2 days**	**3-4 days**	**5 days or more**	**Probably depressed**	**Impaired**	**1 or more**	**No**
Austria (N=1013)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	0.82 (0.55 to 1.23)	0.92 (0.59 to 1.44)	1.17 (0.74 to 1.87)	0.64 (0.37 to 1.08)	0.47** (0.31 to 0.71)	1.98* (1.24 to 3.16)	1.30 (0.94 to 1.80)	1.29 (0.91 to 1.82)	1.80** (1.31 to 2.48)
France (N=1383)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	0.67* (0.51 to 0.88)	0.59* (0.41 to 0.84)	0.54** (0.39 to 0.75)	0.54* (0.31 to 0.93)	0.60** (0.46 to 0.77)	1.31* (1.03 to 1.66)	2.83** (2.11 to 3.79)	1.56* (1.17 to 2.08)	1.83** (1.47 to 2.28)
Italy (N=1463)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	0.96 (0.70 to 1.30)	0.84 (0.58 to 1.22)	1.30 (0.82 to 2.08)	0.40* (0.16 to 1.00)	0.98 (0.49 to 1.94)	1.68* (1.23 to 2.28)	2.37** (1.68 to 3.36)	1.25 (0.91 to 1.73)	2.24** (1.70 to 2.97)
Spain (N=1072)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	1.20 (0.74 to 1.96)	0.54* (0.35 to 0.84)	0.62 (0.37 to 1.05)	0.64 (0.25 to 1.62)	0.72 (0.49 to 1.07)	3.06** (2.01 to 4.64)	2.01* (1.26 to 3.22)	1.51* (1.02 to 2.21)	3.85** (2.74 to 5.40)
Greece (N=1490)	Higher	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Lower	OR (95% CI)	0.61* (0.43 to 0.86)	0.65* (0.47 to 0.88)	0.99 (0.70 to 1.40)	0.81 (0.49 to 1.37)	1.33 (0.90 to 1.96)	1.25 (0.91 to 1.73)	2.28** (1.70 to 3.06)	1.10 (0.83 to 1.47)	0.81 (0.63 to 1.05)

*p<0.05; **p<0.001

APPENDIX 3

Associations (odds ratios, 95% confidence intervals) between lifestyle, health, and social participation and frailty worsening over two years follow-up adjusted for age and sex for all countries separately (N=14082)

		Lifestyle					Health			Social
		Smoking behaviour		Alcohol consumption			Depression	Memory	Chronic diseases	Social participation
		Former	Current	1-2 days	3-4 days	5 days or more	Probably depressed	Impaired	1 or more	No
Sweden (N=1613)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	0.99 (0.75 to 1.30)	1.39 (0.93 to 2.08)	0.74* (0.55 to 0.99)	0.65 (0.40 to 1.04)	0.97 (0.60 to 1.56)	1.88* (1.21 to 2.94)	1.11 (0.85 to 1.47)	1.39* (1.01 to 1.91)	1.24 (0.95 to 1.62)
Denmark (N=913)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	1.01 (0.68 to 1.50)	1.54* (1.02 to 2.31)	0.97 (0.61 to 1.54)	0.76 (0.44 to 1.33)	0.78 (0.51 to 1.19)	1.52 (0.83 to 2.80)	1.22 (0.86 to 1.73)	1.17 (0.78 to 1.75)	1.40 (0.99 to 1.98)
Germany (N=1217)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	1.08 (0.75 to 1.57)	1.01 (0.63 to 1.64)	0.68 (0.45 to 1.02)	0.85 (0.51 to 1.42)	0.37** (0.23 to 0.59)	0.97 (0.58 to 1.60)	1.18 (0.84 to 1.65)	1.32 (0.90 to 1.95)	1.16 (0.85 to 1.59)
The Netherlands (N=1332)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	1.01 (0.72 to 1.42)	2.23** (1.54 to 3.21)	0.55* (0.36 to 0.85)	0.67 (0.41 to 1.09)	0.80 (0.57 to 1.11)	1.34 (0.86 to 2.08)	1.23 (0.91 to 1.65)	1.53* (1.12 to 2.08)	1.35* (1.02 to 1.79)
Belgium (N=2067)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	1.51* (1.15 to 1.97)	1.30 (0.90 to 1.86)	0.87 (0.64 to 1.18)	1.04 (0.69 to 1.56)	0.81 (0.62 to 1.07)	1.82** (1.32 to 2.51)	1.23 (0.93 to 1.61)	1.44* (1.08 to 1.91)	1.36* (1.09 to 1.70)
Switzerland (N=519)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	1.59 (0.90 to 2.83)	1.53 (0.81 to 2.92)	1.43 (0.73 to 2.79)	1.31 (0.59 to 2.87)	1.24 (0.68 to 2.25)	2.16 (0.97 to 4.81)	1.96* (1.17 to 3.28)	1.59 (0.95 to 2.68)	3.02** (1.83 to 4.96)

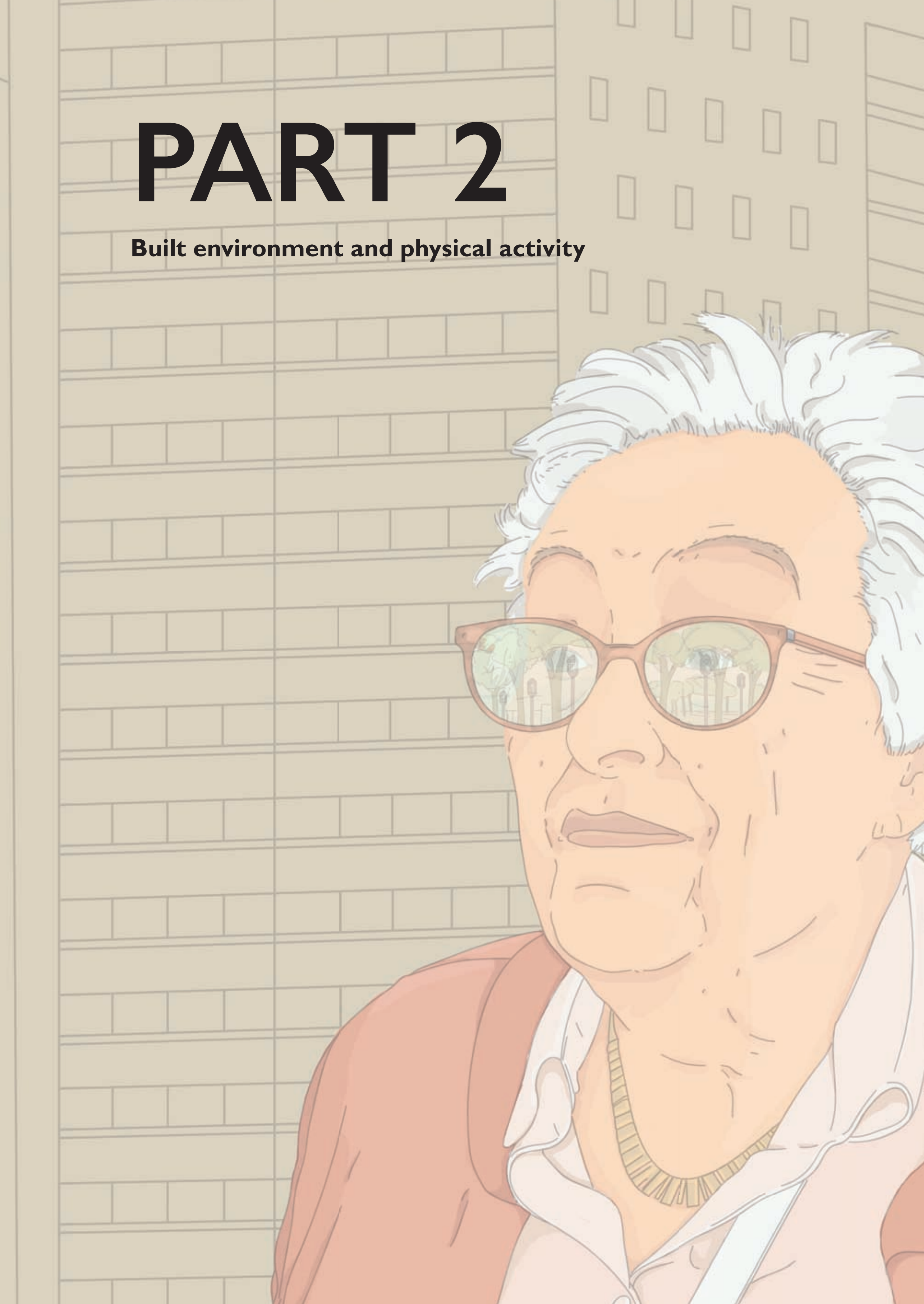
(continued) Associations (odds ratios, 95% confidence intervals) between lifestyle, health, and social participation and frailty worsening over two years follow-up adjusted for age and sex for all countries separately (N=14082)

		Lifestyle					Health			Social
		Smoking behaviour		Alcohol consumption			Depression	Memory	Chronic diseases	Social participation
		Former	Current	1-2 days	3-4 days	5 days or more	Probably depressed	Impaired	1 or more	No
Austria (N=1013)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	0.94 (0.63 to 1.42)	1.37 (0.88 to 2.12)	1.07 (0.71 to 1.61)	0.66 (0.37 to 1.17)	1.02 (0.67 to 1.57)	1.66* (1.04 to 2.66)	1.39 (1.00 to 1.94)	1.22 (0.86 to 1.74)	1.02 (0.75 to 1.39)
France (N=1383)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	0.92 (0.65 to 1.30)	1.10 (0.70 to 1.72)	0.96 (0.63 to 1.46)	0.84 (0.42 to 1.66)	1.03 (0.75 to 1.41)	1.66* (1.17 to 2.37)	0.63* (0.45 to 0.89)	1.58* (1.10 to 2.28)	1.22 (0.93 to 1.61)
Italy (N=1463)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	0.91 (0.66 to 1.26)	0.72 (0.48 to 1.10)	0.73 (0.44 to 2.12)	1.17 (0.39 to 3.58)	1.28 (0.66 to 2.46)	1.10 (0.77 to 1.58)	1.19 (0.75 to 1.89)	1.12 (0.79 to 1.59)	1.18 (0.85 to 1.63)
Spain (N=1072)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	1.61 (0.99 to 2.62)	1.96* (1.19 to 3.23)	0.72 (0.40 to 1.31)	0.71 (0.23 to 2.24)	0.86 (0.58 to 1.29)	1.19 (0.78 to 1.82)	0.83 (0.47 to 1.47)	2.30** (1.44 to 3.68)	0.81 (0.56 to 1.18)
Greece (N=1490)	No change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Worsening	1.41 (0.92 to 2.16)	1.17 (0.78 to 1.76)	1.07 (0.69 to 1.66)	0.88 (0.42 to 1.85)	0.98 (0.61 to 1.57)	0.80 (0.51 to 1.26)	1.39 (0.92 to 2.11)	1.93* (1.30 to 2.88)	1.08 (0.80 to 1.47)

*p<0.05; **p<0.001

PART 2

Built environment and physical activity



4

Characteristics of residential areas and transport-related walking among frail and non-frail Dutch older persons: does the size of the area matter?

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ABSTRACT

Background A residential area supportive for walking may facilitate elderly to live longer independently. However, current evidence on area characteristics potentially important for walking among older persons is mixed. This study hypothesized that the importance of area characteristics for transport-related walking depends on the size of the area characteristics are measured, and older person's frailty level.
Methods The study population consisted of 408 Dutch community-dwelling persons aged 65 years and older participating in the Elderly And their Neighborhood (ELANE) study in 2011-2012. Characteristics (aesthetics, functional features, safety, and facilities) of residential areas surrounding participants' homes ranging from a buffer of 400 meters up to 1600 meters (based on walking path networks) were linked with self-reported transport-related walking using linear regression analyses. In addition, interaction effects between frailty level and area characteristics were tested.
Results An increase in aesthetics (e.g. absence of litter and graffiti) within 800 and 1200 meter buffers, and an increase of one facility per buffer of 400 and 800 meters were associated with more transport-related walking, up to a 2.83-fold increase per two weeks (CI 1.12-7.28; $p<0.05$). Better functional features were associated with less transport-related walking. No differences were found between frail and non-frail elderly.
Conclusions More facilities within 400-800 meter buffers, and better aesthetics of 800-1200 meter buffers were associated with more transport-related walking among community-dwelling older persons. Better functional features were associated with less transport-related walking. The importance of area characteristics for transport-related walking differs by area size, but not by frailty level. Neighborhood improvements may affect transport-related walking among older persons, thereby perhaps contributing to living longer independently.

INTRODUCTION

In aging populations, the demand for and costs of institutionalised care may become unsustainable in many Western countries. Interestingly, policies aimed at limiting institutionalised care may be in line with the desire of many elderly to live longer independently [1]. Living longer independently however, requires a good functional health and it is for this reason that health promotion among elderly becomes increasingly important. Regular physical activity (PA), such as walking, may help to minimize the burden on health care and social care by extending years of active independent living, reducing disability, and improving the quality of life, and may increase life expectancy with several years [2,3]. Since up to 83% of the elderly worldwide do not meet recommendations for PA to obtain health benefits [2], PA promotion in this population should be an important part of preventive strategies. Improving transport-related walking, such as walking to a shop, seems an excellent strategy since two third of all walks of the elderly are for transport-related purposes [4], and elderly can easily make it part of their daily life.

It is increasingly recognized that living longer independently can be facilitated if the residential area around older persons' homes facilitates and inspires elderly to walk for daily activities, such as shopping. There is an increased interest in investigating the role of functional area characteristics (e.g. presence of sidewalks), aesthetics (e.g. presence of trees, absence of graffiti), the presence of facilities (e.g. shops), and safety [5], however studies showed mixed findings concerning the elderly [6]. Methodological shortcomings of current studies are often mentioned as one potential explanation for the inconsistencies, including the use of inappropriate geographical units [7,8]. Commonly used geographical units defined as a one-size predefined area around a person's residence may not capture sufficient variation for all environmental characteristics [9]. While very common characteristics (e.g. trees) can vary in small areas, larger areas are needed to capture variation in less common characteristics (e.g. parks). Therefore, it was suggested to investigate residential areas of different sizes for the interplay between the physical environment and PA [10]. As older adults are generally less functionally fit than their younger peers, they may use a smaller area around their residences. The ability to walk may differ between elderly. Aging may widen the variation between elderly in levels of frailty. Frail elderly, being at increased risk of dependent living [11,12], are likely to be bound to smaller areas around their house since they are characterized by lower levels of PA [13,14]. As a consequence, associations between area characteristics and walking may differ by frailty status.

This study aims at investigating whether the association between area characteristics and transport-related walking depends on the size of the area for which environmental characteristics are considered, and on the frailty level of the elderly.

METHODS

Design

The Elderly And their Neighborhood (ELANE) study was conducted in the city of Spijkenisse (the Netherlands) in 2011-2013, with the aim to investigate associations between area characteristics and PA, independent living and quality of life in two samples: dismissed hospitalized older persons who participated in the Prevention and Reactivation Care Program [24], and a sample of randomly selected community-dwelling older persons. In this study we focussed on the random sample. In 2011, a sample of 2017 inhabitants of the city of Spijkenisse - a middle-sized town of about 73,000 inhabitants in the Rotterdam area, the Netherlands- of 65 years and older was randomly drawn from the municipal register of Spijkenisse. All persons included in online phone number registries (n=1190) were sent an invitation letter and subsequently phoned for an interview appointment. In total, 1040 persons answered the phone within five attempts. Participants had to be non-institutionalized, not bedridden, not wheelchair or scooter-bounded, and fluent in Dutch (68 persons were excluded). Of the 972 persons eligible for inclusion, 430 were willing to participate (response 44.2%). Interviews at home were carried out between September 2011 and July 2012; winter months in between were excluded to avoid seasonal variation in PA.

Subjects

Of the 430 participants, 408 persons were eligible for analyses since 22 persons were excluded from analyses due to incomplete data on frailty level (n=11), walking time (n=4), and area characteristics (n=7).

Transport-related walking

Transport-related walking included grocery shopping and visiting family and friends, but excluded non-recreational walking. Total transport-related walking in the past two weeks was calculated based on the answers to two questions from the LAPAQ (LASA Physical Activity Questionnaire), a valid and reliable instrument to measure PA among older persons [25]: 'On how many days did you walk for transport in the past two weeks?', and 'How long did you walk on average per day?'. We calculated total time spent on transport-related walking in minutes in the past two weeks by multiplying both answers. Total transport-related walking time was log-transformed, because 15% of the participants reported a walking time of zero minutes in the past two weeks. To meaningfully interpret the results, values were retransformed after the statistical analysis into minutes spent on transport-related walking in the past two weeks.

Frailty

Frailty level was defined based on four questions measured by a short version of the ISAR (Identification of Seniors at risk of functional loss) which has proven to have sufficient validity [26-28]. Scores ranges from 0 to 5 based on the following questions: 'Do you need assistance for instrumental activities of daily living (IADL) (e.g. assistance in housekeeping, preparing meals, shopping) on a regular basis?' (yes= '1', no= '0'), 'Do you need assistance for travelling?' (yes= '1', no= '0'), 'Do you use a walking device (e.g. a cane, walking frame, crutches)?' (yes= '2', no= '0'), and 'Did you pursue education after the age of 14?'(no= '1', yes= '0'). Persons with a score of 2 or higher were defined to be frail.

Residential area characteristics

Around each participant's residence, walking path network buffers were created. Starting from the nearest starting point of streets to the participant's residence on the street network, all walking routes up to 400, 800, 1200, and 1600 meters were traced in every direction. In this way, four buffers were created using ArcGIS.

Information about area characteristics was retrieved from street audits. Between June and October 2012, we audited 88.8% (n= 918) of all streets in Spijkenisse, and 214 additional street segments (as part of 143 streets), 8 parks, and 357 walking paths as identified by Google maps. When the physical lay-out of one part of a street was clearly different from other part(s) of the same street (e.g. big differences in aesthetics), it was split in two or more segments, which were audited separately. The audit instrument consisted of 41 items (appendix 1), and inter-rater reliability was good (Cohens kappa=0.71-0.88, $p < .001$). The audit was conducted by three raters (one rater per street).

Separate items were taken together in overall variables for aesthetics, functional features, safety, and the presence of facilities, as suggested by the framework of Pikora et al. (2003) [29]. Scores for aesthetics were based on the following 11 items: absence of dog waste, graffiti, and litter, presence of trees, gardens, other green, water, and parks, and maintenance of the streets, sidewalks, and benches (maximum score of '2' per item; total range 0-22). Functional features scores were based on 7 items: presence of a sidewalk of at least 2 meters wide at the left and right side, presence of flat curbs, benches, and waste bins, absence of sidewalk obstacles, and flatness of walking surface (i.e. paths where no cars are allowed) (maximum score of '2' per item; total range 0-14). Safety scores were calculated based on the presence of crossings, speed-limiters, sufficient lighting, supervision (i.e. persons on streets are clearly visible), houses (with ground-level and without ground-level), bicycle lanes, and traffic speed limits (maximum score of '2' per item; total range 0-16). The number of facilities per street was calculated based on the presence of the following 15 facilities: bus stop, supermarket, bakery, vegetable store, butcher, other shops, shopping center, hairdresser, café, ATM, sport facility, community-center, pharmacy, letterbox, and nursing home with scoring 1 per item in case one or more of that specific facility was present (maximum score of '1' per item; total range 0-15). A maximum score per item means that an item contributes positively to either the sum score of aesthetics, functional features, safety, or facilities. For example, a score of '2'on dog waste represents the absence of dog waste ('1'= little dog waste, '0'= much dog waste); a score '1' on supermarket represents the presence of a supermarket ('0'= no supermarket) (appendix 1).

Because the number of streets differed between buffers of different sizes and between participants, the scores for aesthetics of all audited streets within a certain buffer were summed and divided by the total number of audited streets in that buffer, resulting in an average street score for aesthetics for each buffer. The same was done for functional features and safety. For facilities, we summed the number of facilities of all the streets in each buffer.

Statistical analyses

Initial descriptive analyses included chi-square tests and t-tests to explore sex and age differences between the participants and non-participants and between frail and non-frail persons in terms of demographics, walking, and area characteristics. Pearson correlations were calculated between the scores on aesthetics, functional features, safety, and facilities for all buffers. Finally, for each buffer a linear regression analysis was performed to test associations between area characteristics and total walking time. Adjustments were made for age, sex, frailty, and the other area characteristics. In addition, interaction effects between frailty level and area characteristics on walking time were tested. After the log transformation of walking time, residuals of the linear regression did not completely show a normal distribution, which limited the ability to calculate confidence intervals. Therefore the analyses were bootstrapped. P-values were considered significant if below 0.05. Analyses were performed using SPSS 20.0.

RESULTS

No significant sex and age differences were found between participants and non-participants. Frail persons were significantly older and more often women. The average total walking time and average time per walk in the past two weeks were both lower for frail persons as compared to non-frail persons ($p<0.001$; table 1).

Table 1 shows the scores for area characteristics per street for each buffer size. The average scores for aesthetics, functional features, and safety decreased slightly with increasing buffer size; clearly, the accumulated number of facilities within a buffer

Table 1 Demographics and area characteristics of 408 residents from Spijkenisse within four buffer zones by frailty level

Buffer size		Total (N=408)	Non-frail (N=307)	Frail (N=101)
	Sex (% female)	**52.9**	**45.9**	**74.3****
		Mean ± sd	Mean ± sd	Mean ± sd
	Age (years; range 65-94)	75.1 ± 6.6	73.7 ± 5.7	79.4 ± 7.3**
	Total walking time in last two weeks (in minutes)	389.9 ± 579.0	446.2 ± 634.6	218.8 ± 305.0**
	Average total walking time per transport-related walk (in minutes)	35.3 ± 32.1	38.8 ± 33.7	24.7 ± 23.9**
400m	Number of observed streets	39 ± 14	38 ± 14	39 ± 14
	Aesthetics (range 0-22)	11.9 ± 0.9	11.9 ± 0.9	11.9 ± 0.9
	Functional features (range 0-14)	5.6 ± 1.6	5.5 ± 1.6	6.0 ± 1.5*
	Safety (range 0-16)	6.1 ± 1.0	6.1 ± 1.0	6.1 ± 1.0
	Facilities (range 0-∞)	9.4 ± 8.9	8.6 ± 11.9	11.9 ± 10.9*
800m	Number of observed streets	133 ± 42	132 ± 42	136 ± 43
	Aesthetics (range 0-22)	11.8 ± 0.7	11.8 ± 0.7	11.8 ± 0.7
	Functional features (range 0-14)	5.3 ± 1.1	5.2 ± 1.1	5.5 ± 1.0*
	Safety (range 0-16)	5.9 ± 0.8	5.9 ± 0.8	6.0 ± 0.7
	Facilities (range 0-∞)	26.7 ± 16.7	25.2 ± 16.0	30.9 ± 18.1*
1200m	Number of observed streets	274 ± 90	273 ± 91	276 ± 87
	Aesthetics (range 0-22)	11.7 ± 0.6	11.7 ± 0.6	11.8 ± 0.7
	Functional features (range 0-14)	5.2 ± 0.8	5.1 ± 0.8	5.3 ± 0.8*
	Safety (range 0-16)	5.9 ± 0.7	5.9 ± 0.7	5.9 ± 0.7
	Facilities (range 0-∞)	51.0 ± 24.8	49.5 ± 24.2	55.6 ± 26.1*
1600m	Number of observed streets	454 ± 147	453 ± 149	457 ± 143
	Aesthetics (range 0-22)	11.7 ± 0.5	11.7 ± 0.5	11.7 ± 0.5
	Functional features (range 0-14)	5.1 ± 0.7	5.0 ± 0.7	5.2 ± 0.6
	Safety (range 0-16)	5.8 ± 0.5	5.8 ± 0.5	5.89 ± 0.5
	Facilities (range 0-∞)	82.1 ± 32.4	80.5 ± 32.6	87.0 ± 31.4

**$p<0.001$; *$p<0.05$ (=significant higher score as compared to non-frail participants) increased with increasing buffer size. Frail persons had more functional features and facilities within a buffer up to 1200 meters compared to non-frail participants . Aesthetics, functional features, safety, and facilities were all positively correlated with each other, except for the correlation between the number of facilities and aesthetics. Aesthetics and safety showed the highest correlation with a Pearson correlation ranging from 0.71 in the 400 meter buffer to 0.89 in 1600 meter buffer ($p<0.01$).

As reported in table 2, an increase in the aesthetics score of one point within 800 and 1200 meter buffers, was found to be associated with respectively a 2.3-fold and 2.8-fold increase in minutes transport-related walking. The magnitude of the association between functional features and transport-related walking was similar across buffer sizes, but was only significant in the 400 meter buffer. An increase of one functional feature per street within 400 meters was associated with 26% less minutes walking in two weeks. No significant association was found for safety. An increase of one facility per buffer within 400 and 800 meters was associated with an increase in minutes of transport-related walking per two weeks of respectively 5% and 2%. The variance in walking time as explained by the models as presented in table 2, ranged from 6.3% in the 1600 meter buffer up to 8.8% in the 400 meter buffer. No interaction effect of frailty level and area characteristics was found for any of the buffer sizes.

DISCUSSION

More facilities within 400-800 meter buffers, and better aesthetics of 800-1200 meter buffers were associated with more transport-related walking among community-dwelling older persons. Better functional features were associated with less transport-related walking.

Higher scores on aesthetics were found to be associated with more time spent on transport-related walking, which is in contrast to previous studies [15,16]. This discrepancy may be due to the fact that within these studies aesthetics were measured differently, i.e. by less items or via self-report. The evidence for an association of functional features and safety with walking is mixed [6,17]. The inconsistent findings concerning the association between safety and transport-related walking among older persons has been attributed to the complexity of measuring safety [6]. Sub-analyses with only indicators of traffic- or crime-related safety both showed no associations with transport-related walking for any buffer size. The association

Table 2 Associations between area characteristics and transport-related walking in four buffer zones (N=408)

	400 meters			800 meters			1200 meters			1600 meters		
Characteristic[a]	B	(95% CI)	p	B	(95% CI)	p	B	(95% CI)	p	B	(95% CI)	p
Aesthetics	1.24	(0.84-1.84)	0.288	2.34	(1.11-4.75)	0.024	2.83	(1.12-7.28)	0.026	2.21	(0.56-9.08)	0.272
Functional features	0.74	(0.60-0.91)	0.006	0.71	(0.48-1.02)	0.072	0.58	(0.32-1.09)	0.069	0.69	(0.31-1.54)	0.361
Safety	1.18	(0.83-1.63)	0.385	0.69	(0.40-1.24)	0.205	0.80	(0.39-1.69)	0.524	0.80	(0.28-2.16)	0.664
Facilities	1.05	(1.02-1.08)	0.001	1.02	(1.01-1.04)	0.004	1.00	(0.99-1.01)	0.525	1.00	(0.99-1.01)	0.803

[a]Adjustments were made for age, sex, frailty, and the other area characteristics

Note: beta coefficients less than 1 represent negative associations, beta coefficients more than 1 represent positive associations between the presence of facilities and transport-related walking was found for buffers up to 800 meters, but was absent in the 1200 and 1600 meters buffer. This finding is in line with studies in which this association was found for buffers up to 1000 meters [17,18].

Whereas other studies often use a predefined buffer size [9], our results revealed that associations between area characteristics and walking behavior differed by buffer size. Nagel et al. found that associations between environmental factors and total walking time among older persons aged 65 years and older were similar across buffer size (400 and 800 meters) [17]. We extended this finding, as we also included buffer sizes larger than 800 meters for which also significant associations were found.

A possible explanation for the finding that facilities were particularly important for transport-related walking in small buffer sizes may be that, since older persons are generally less functionally fit than their younger peers, they may use a smaller area around their residence, and only use facilities in the close vicinity of their residence. Aesthetics was particularly important for larger buffer sizes. Elderly may only go for a further walk when the environment is pleasant (aesthetically appealing) to walk through. Whereas other studies found that a buffer of 1600 meters is important when looking into associations between the built environment and PA among elderly [19,20], no association was found between neighborhood characteristics and transport-related walking in our study. This may be due to a distance of 1600 meters being too far for older persons to walk regardless of the characteristics of the environment or because there was too little variation within this buffer. The larger the area in which the environment is measured, the more likely that environments of individuals will become similar which may reduce the chance of finding associations with PA levels.

Frail persons lived closer to facilities and had more functional features in their residential area as compared to non-frail persons. This could be the result of a selection process, whereby frail persons decide to move closer to facilities. However, in additional analyses, no differences between frail and non-frail persons were found in prevalence of and reasons for moving to their current residence in the past five years. The average total time per walk for frail persons was lower as compared to non-frail persons, which may suggest that frail elderly are more bounded to smaller areas around their houses as compared to non-frail elderly. Knowing the exact amount of PA that was practiced within specific buffers for both frail and non-frail elderly would allow for a more accurate estimation of associations between area characteristics and walking behavior in each specific buffer. It is therefore suggested to take this into account in future research, e.g. by combining GPS and accelerometer measurements [21].

Recently, differences were found in walking distances between disabled and non-disabled elderly [20]. Also, stronger associations were found between environmental characteristics and PA levels for disabled than non-disabled elderly [22]. As frail persons are at increased risk to develop disabilities [11,12], the role of the environmental characteristics for PA may become more important with increasing health complaints as compared to non-frail persons.

A strength of this study concerns the personal geographical space units, i.e. the walking path based buffers around participants' homes, instead of the often used, pre-defined geographical units, for instance based on zipcodes or neighborhood boundaries. A personal geographical space unit provides more specific information on environmental characteristics to which persons are exposed as compared to a geographical unit. Furthermore, detailed qualitative and quantitative information about the residential areas of the elderly was collected by street audits. A limitation of this study was that area characteristics were collected up to 13 months after the first interviews took place. Thus, there is a possibility that the environmental characteristics may have changed meanwhile. To the extent that environmental characteristics determine walking, such changes in the environment may have resulted in an underestimation of the associations reported. The ISAR questionnaire was used to measure frailty, which overlaps in terms of measuring functional limitations and predicting the risk of adverse outcomes. Other studies used the Tilburg Frailty Index (TFI) which includes a broader set of indicators of frailty. It remains unknown however, of the TFI would have altered these associations [23].

As this study was conducted in a (middle-sized) city in the Netherlands, and the design of cities may differ across countries, it is unclear how these results also would apply for cities in other countries.

Our study has several implications. Firstly, for the appropriate linkage of environmental characteristics to walking (and other health behaviors), specific buffer sizes need to be used. It requires insight into the expected level of variation in the area, and it is important to realize that such variation may differ in different countries. We recommend to explore the variation of an characteristic prior to the analyses. Ultimately, such an approach may results in more consistent findings.

Secondly, living longer independently can be facilitated by a residential area that facilitates and inspires elderly to walk for daily activities. Improvements of neighborhood characteristics may increase levels of transport-related walking among community-dwelling elderly. More research is needed to get more insight in the role of area characteristics for frail elderly.

CONCLUSIONS

Better aesthetic features and more facilities in the residential area of community-dwelling older persons were associated with more transport-related walking. Better functional features were associated with less transport-related walking. The importance of area characteristics for transport-related walking differed by size of the environmental area, but not by frailty level. Increasing the number of facilities within the area close by elderly's residences (up to 400 and 800 meters respectively), and improving the aesthetics of a larger area up to 1200 meters, could increase their levels of transport-related walking. Subsequent studies are needed to investigate whether this also results in living longer independently.

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Appendix Street audit

Area characteristic		Score		
		0	**1**	**2**
Aesthetics	Litter	Much	Little	Absent
(range 0-22)	Dog waste	Much	Little	Absent
	Graffiti	Much	Little	Absent
	Park	Absent		Present
	Maintenance benches	Insufficient / n.a.	Reasonable	Sufficient
	Maintenance sidewalk(s)	Insufficient / n.a.	Reasonable	Sufficient
	Maintenance street	Insufficient	Reasonable	Sufficient
	Trees	None	Few	Many
	Gardens	None	Few	Many
	Other green	Absent	Partly	Mainly
	Water	Absent	Partly	Mainly
Functional	Sidewalk side 1	Absent	< 2 meters	≥ 2 meters
(range 0-14)	Sidewalk side 2	Absent	< 2 meters	≥ 2 meters
	Obstacles sidewalks	Many / n.a.	Few	None
	Flatness walking surface	Insufficient	Reasonable	Sufficient
	Curb cuts	Insufficient / n.a.	Reasonable	Sufficient
	Benches	None	One	More than one
	Wastebins	None	One	More than one
Safety	Crossings	Absent	Without traffic light(s)	With traffic light(s)
(range 0-16)	Speed limiters	None	One	More than one
	Lighting	Insufficient	Reasonable	Sufficient
	Supervision	Insufficient	Reasonable	Sufficient
	Ground-level houses	None	Few	Many
	Upper-level houses	None	Few	Many
	Bicycle lanes	Absent	Not seperated from carlane	Seperated from carlane
	Traffic speed limit[a]	Walking path	15km road	50km road
Facilities	ATM	Absent	Present	
(range 0-15)	Letterbox	Absent	Present	
	Bus stop[b]	Absent	More than one	
	Supermarket	Absent	Present	
	Bakery	Absent	Present	
	Vegetable store	Absent	Present	
	Butcher	Absent	Present	
	Other shops	Absent	Present	
	Shopping center	Absent	Present	
	Hairdresser	Absent	Present	
	Café	Absent	Present	
	Nursing home	Absent	Present	
	Pharmacy	Absent	Present	
	Community center	Absent	Present	
	Sport facility	Absent	Present	

[a] Combined walking/cycle path scored 0.5; a 30 km road scored 1.5; [b] One bus stop scored 0.5

5

Residential area characteristics and disabilities among Dutch community-dwelling older persons

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ABSTRACT

Background Living longer independently may be facilitated by an attractive and safe residential area, which stimulates physical activity. We studied the association between area characteristics and disabilities and whether this association is mediated by transport-related physical activity (TPA).

Methods Longitudinal data of 271 Dutch community-dwelling adults aged 65 years and older participating in the Elderly And their Neighborhood (ELANE) study in 2011-2013 were used. Associations between objectively measured aesthetics (range 0-22), functional features (range 0-14), safety (range 0-16), and facilities (range 0-15) within road network buffers surrounding participants' residences, and self-reported disabilities in instrumental activities of daily living (range 0-8; measured twice over a nine months period) were investigated by using longitudinal tobit regression analyses. Furthermore, it was investigated whether self-reported TPA mediated associations between area characteristics and disabilities.

Results A one unit increase in aesthetics within the 400 meters buffer was associated with 0.86 less disabilities (95%CI -1.47 to -0.25; $p<0.05$), but other area characteristics were not related to disabilities. An increase in area aesthetics was associated with more TPA, and more minutes of TPA were associated with less disabilities. TPA however, only partly mediated the associated between area aesthetics and disabilities.

Conclusion Improving aesthetic features in the close by area around older persons' residences may help to prevent disability.

INTRODUCTION

In ageing societies, limitations in instrumental activities of daily living (IADL) will become increasingly prevalent among community-dwelling older persons. Studies among European older persons showed that the prevalence of one or more IADL limitations increases from 17-54% among adults aged 65 years or older up to >90% among adults aged 90 years or older [1-3]. Such limitations are associated with a loss of independent living and high healthcare costs. Policy aimed at improving independent living of older persons coincides with the wish of older persons to live independently for as long as possible, in which the built environment may play an important role.

The physical design of older persons' residential areas is suggested to contribute to independent living in several ways [4]. A safe and attractive residential area, and the nearby presence of shops and facilities, may increase independent living, as older persons are more likely to be able to do their daily groceries and to visit a hairdresser or pharmacy, independent of help from others. Current literature indeed shows that aesthetics (e.g. green spaces), facilities (e.g. grocery stores), and safety (e.g. lighting) are associated with less disabilities [5]. Previous studies exploring associations between residential area characteristics and disabilities have shown mixed results [6,7]. These studies generally used cross-sectional designs which may weaken associations with residential area characteristics, since disabilities can fluctuate over time [8]. Including repeatedly measured disabilities in a relatively short period captures this fluctuation, and may therefore provide greater reliability of estimates resulting in more robust associations. Importantly, they should not by definition be interpreted as a "real" change.

Physical activity (PA) has shown to slow the progression of disability by decreasing functional limitations. As older persons spend more time being physically active outside than inside their homes [9], transport-related PA (TPA) may play an important role in the prevention of disabilities. A high 'walkable' residential area may promote walking for recreation and transport, which helps older persons to stay physically fit and live longer independently [6,7]. Highly aesthetic residential areas and residential areas with many functional features (e.g. benches) or facilities are found to be associated with more minutes of transport-related walking [10]. Because older persons use residential areas for activities in daily life [11], transport-related physical activity (TPA) is thought to play an important role in the pathway between area characteristics and disabilities.

This study adds knowledge by investigating the association between residential area characteristics and repeatedly measured disabilities to better capture random fluctuation, and by investigating whether associations, if any, are mediated by TPA levels.

METHODS

Design

Data from the Dutch ELANE study (2011-2013) were used. This longitudinal study aimed at studying associations between residential area characteristics and PA, independent living, and quality of life among adults aged 65 years and older living in Spijkenisse, a middle-sized town in the Rotterdam area. Community-dwelling older persons were randomly selected from the municipal register of Spijkenisse. Of the 430 persons interviewed face-to-face at baseline (T0), 277 (response 64.4%) were again interviewed by telephone nine months later (T1). Some participants lacked data on residential area characteristics (n=5) or disabilities at follow-up (n=1), and therefore data of 271 persons were eligible for analyses. A more extensive description of the ELANE study can be found in chapters 1 and 4.

Disabilities

Disabilities were measured at baseline and follow-up by the Lawton and Brody scale [12], a reliable and moderately strong predictor of functioning [12-14]. Participants were asked whether they needed help with the following eight IADL activities: using the telephone, travelling (e.g. public transport), grocery shopping, preparing a meal, household tasks, taking medicines, finances, and doing laundry. All items had answering categories no (0) and yes (1), therefore sum scores could range between 0-8.

Transport-related physical activity

Three repeatedly measured TPA-outcomes were included in the analyses: walking for transport, cycling for transport, and a combination of the two (further referred to as walking, cycling, and total TPA). These were based on questions from the Physical Activity Questionnaire in the LASA study (LAPAQ), a valid and reliable instrument to measure PA among older persons [15,16]. We calculated total minutes of walking within the last two weeks by multiplying the answers to the following questions: 'On how many days did you walk for transport in the past two weeks?', and 'How long did you walk for transport on average per day?' Total minutes cycling were calculated based on similar questions for cycling. Total TPA was derived by summing minutes of walking and minutes of cycling. Because 18.1% and 42.6% of the study sample reported walking or cycling time of zero minutes at baseline, and respectively 19.9% and 46.1% at follow-up, total walking time, total cycling time, and total TPA time were logtransformed. To meaningfully interpret the results, coefficients and CIs were retransformed after the statistical analyses.

Residential area characteristics

In the appendix of chapter 4 (page 83) it shows the street audit instrument which was used to collect data on residential area characteristics (carried out between June and October 2012) [10]. Sum scores were calculated for aesthetics, functional features, safety, and the presence of facilities by taking together separate items, as suggested by the framework of Pikora et al. [17].

Since the influence of residential area characteristics on health outcomes depends on the size of the area under study [18], we created road network buffers around each participant's home including all routes from a participant's home to streets up to 400, 800, and 1200 meters. Road network buffers provide a more accurate exposure to environmental characteristic than traditional neighborhood boundaries [19]. Scores for aesthetics, functional features, and safety of all audited streets within a buffer were summed and divided by the total number of streets audited in that buffer, resulting in average street scores for each buffer. For facilities, the number of facilities of all the streets in each buffer were summed [10]. For the analyses, longitudinal data were created assuming that the residential area characteristics remained stable over nine months.

Statistical analyses

Descriptive analyses included chi-square tests and t-tests to explore sex and age differences between those included (i.e. those participating at both T0 and T1) and those excluded from the main analyses (i.e. lost to follow-up) in terms of demographics, disabilities, and TPA.

Associations between residential area characteristics (aesthetics, functional features, safety, and facilities) and disabilities were tested, followed by analyses to investigate whether TPA mediated this association following conventional rules of mediation analysis as described by Baron and Kenny [20]. We subsequently tested the pathways A, B, C and A' as shown in figure 1.

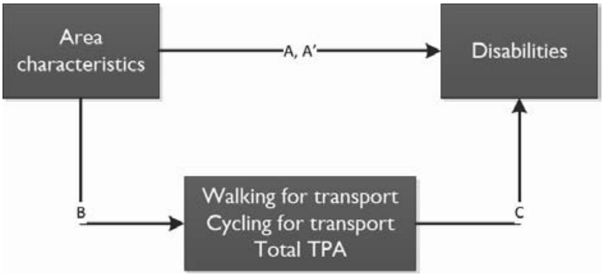

Figure 1 Conceptual model of the mediation analyses (based on Baron and Kenny, 1986)

The proportion of persons reporting to have no disabilities at both T0 and T1 was 56.8%. An additional 9.6% of the participants reported no disabilities at T0 only, and another 6.3% reported no disabilities at T1 only. This suggests that many older persons did not experience any limitations in IADL. While some persons reporting no disabilities are "close" to having disabilities, others may still be far away from becoming functionally limited. As such, disabilities can be seen as an underlying latent variable with an unrestricted range, of which the observed outcome is a truncated version [21]. Tobit regression models are suitable for repeatedly measured data and take into account such censored data. Furthermore, longitudinal tobit regression models take into account correlated observations over time within persons. Therefore, multivariate longitudinal sex- and age adjusted tobit regression analyses were conducted to test associations between residential area characteristics and disabilities (pathway A). Associations between area characteristics and TPA (pathway B) were explored by using Generalized Estimating Equations [22] since it is unlikely that the TPA data was censored. Multivariate longitudinal sex- age and for area characteristics adjusted tobit regression analyses were conducted to test associations between TPA and disabilities (pathway C).

Educational level was excluded from analyses because no association was found with disability level.

The longitudinal tobit model can be formulated mathematically as follows [21]:

$$y_{ij}^{*}|b_i = x'_{ij}\beta + b_i + e_{ij},\ e_{ij} \sim N(0, \sigma^2)$$
$$b_i \sim N(0, D)$$

in which y^* is a random latent variable that is not censored, β is the parameter, b_i is the case-specific random intercept with variance D, i refers to case i, j to the jth measurement within case i.

Finally, mediation of the association between area characteristics and disabilities by TPA was investigated (pathway A'). Analyses were performed by using STATA 14.1.

Before the regression analyses were performed, panel data were defined (including 271 cases over two time periods, resulting in 271 x two observations). P-values of 0.05 or lower were considered to be significant.

RESULTS

Sample characteristics

Persons lost during follow-up were more often female, and reported on average more minutes walking than the study sample. No differences were found in the composition of both groups by age, minutes of cycling, and disabilities. At T0, 33.6% of the study sample had one or more disabilities. Although no difference was found between the mean number of disabilities at T0 and T1, after nine months, 16.2% of the study sample had developed disabilities and 12.9% had recovered from disabilities. Also, total minutes of walking, cycling, and total TPA did not differ significantly between T0 and T1 (table 2). Table 3 shows the scores for residential area characteristics per street for each buffer size. The average scores for aesthetics, functional features, and safety decreased slightly with increasing buffer size; the accumulated number of facilities within a buffer increased with increasing buffer size.

Table 2 Descriptive characteristics of the study sample at baseline and months follow-up (N=271)

		Total
Sex T0	Females	49.1%
Age T0	Mean	74.6 years
Disabilities T0 (range 0-8)	One or more	33.6%
	Mean number of disabilities	0.71 ± 1.35
Disabilities T1 (range 0-8)	One or more	36.9%
	Mean number of disabilities	0.73 ± 1.25
TPA T0 (minutes per 2 weeks)	Walking	344.5 ± 423.8
	Cycling	165.3 ± 248.3
	Total	509.8 ± 517.8
TPA T1 (minutes per 2 weeks)	Walking	349.4 ± 445.7
	Cycling	180.8 ± 357.0
	Total	530.2 ± 601.1

Table 3 Residential area characteristics of the four buffer zones

Area characteristics	Area 400 meters	800 meters	1200 meters
Number of observed streets	39 ± 13	138 ± 40	294 ± 86
Aesthetics (range 0-22)	11.9 ± 0.9	11.8 ± 0.7	11.7 ± 0.6
Functional features (range 0-14)	5.8 ± 1.7	5.4 ± 1.1	5.3 ± 0.9
Safety (range 0-16)	6.1 ± 1.0	6.0 ± 0.7	5.9 ± 0.6
Facilities (range 0-∞)	10 ± 9	30 ± 16	57 ± 22

Area characteristics and disabilities

We subsequently tested the pathways A, B, C and A' (figure 1). Within all buffers, area aesthetics showed comparable associations with disabilities, but was only significant in the 400 meters buffer in which an increase in the aesthetics score of one point was associated with 0.86 less disabilities (95% CI -1.47 to -0.26; $p<0.05$; pathway A) (table 4). No associations for other area characteristics within the 400 meters buffer, or for area characteristics of the 800 and 1200 meters buffers with disabilities were found, although the association between aesthetics and disabilities in the 800 meters was close to significant.

Area characteristics and TPA

For all three buffer sizes, associations between area characteristics with minutes walking and cycling were found (pathway B). In the 400 and 1200 meters buffers, higher safety scores were associated with less cycling and walking respectively. With increasing buffer size, the strength of the association between aesthetics and minutes walking increased which was found significant in the two largest buffers. Only in the 1200 meters buffer, a significant association was found with total TPA: higher scores on aesthetics were associated with more total TPA (table 5).

Table 4 Age and sex adjusted associations between area characteristics and disabilities (pathway A and A'; N=271)

Area		pathway A						pathway A'					
		Disabilities			Disabilities adjusted for transport-related walking			Disabilities adjusted for transport-related cycling			Disabilities adjusted for total TPA		
	Area characteristic[a]	β	(95% CI)	p	β	(95% CI)	p	β	(95% CI)	p	β	(95% CI)	p
400 meters	Aesthetics	-0.86*	(-1.47 to -0.26)	0.01	-0.77*	(-1.34 to -0.19)	0.01	-0.71*	(-1.26 to -0.16)	0.01	-0.69*	(-1.21 to -0.16)	0.01
	Functional features	0.27	(-0.09 to 0.64)	0.14	0.22	(-0.13 to 0.57)	0.22	0.32	(-0.01 to 0.65)	0.06	0.22	(-0.10 to 0.53)	0.17
	Safety	0.22	(-0.35 to 0.78)	0.45	0.22	(-0.32 to 0.76)	0.43	0.06	(-0.46 to 0.57)	0.84	0.17	(-0.32 to 0.66)	0.49
	Facilities	-0.03	(-0.08 to 0.02)	0.21	-0.02	(-0.07 to 0.02)	0.28	-0.03	(-0.07 to 0.01)	0.15	-0.02	(-0.06 to 0.02)	0.26
800 meters	Aesthetics	-0.97	(-1.96 to 0.02)	0.05	-0.81	(-1.75 to 0.13)	0.09	-0.83	(-1.72 to 0.07)	0.07	-0.66	(-1.51 to 0.19)	0.13
	Functional features	0.35	(-0.30 to 0.99)	0.29	0.32	(-0.30 to 0.93)	0.31	0.40	(-0.18 to 0.99)	0.18	0.28	(-0.27 to 0.84)	0.31
	Safety	0.04	(-0.78 to 0.86)	0.93	-0.06	(-0.84 to 0.71)	0.88	-0.07	(-0.81 to 0.67)	0.86	-0.13	(-0.84 to 0.57)	0.71
	Facilities	-0.00	(-0.03 to 0.02)	0.74	-0.00	(-0.03 to 0.02)	0.93	-0.01	(-0.03 to 0.02)	0.51	0.00	(-0.02 to 0.02)	0.99
1200 meters	Aesthetics	-1.21	(-2.74 to 0.32)	0.12	-0.85	(-2.31 to 0.62)	0.26	-1.18	(-2.66 to 0.30)	0.12	-0.48	(-1.81 to 0.85)	0.48
	Functional features	0.62	(-0.64 to 1.88)	0.34	0.48	(-0.72 to 1.68)	0.43	0.63	(-0.60 to 1.85)	0.32	0.26	(-0.83 to 1.35)	0.64
	Safety	0.01	(-1.05 to 1.08)	0.98	-0.13	(-1.15 to 0.88)	0.80	-0.01	(-1.04 to 1.02)	0.99	-0.21	(-1.13 to 0.71)	0.65
	Facilities	-0.01	(-0.03 to 0.01)	0.50	-0.01	(-0.02 to 0.01)	0.57	-0.01	(-0.03 to 0.01)	0.44	-0.00	(-0.02 to 0.01)	0.70

[a]Adjustments were made for age, sex, and the other area characteristics
*$p<0.05$

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Table 5 Age and sex adjusted associations between area characteristics and TPA (pathway B; N=271)

		TPA								
		Walking			Cycling			Total TPA		
Area	**Area characteristic[a]**	**β**	**(95% CI)**	**p**	**β**	**(95% CI)**	**p**	**β**	**(95% CI)**	**p**
400 meters	Aesthetics	1.34	(0.86 to 2.11)	0.19	1.44	(0.85 to 2.46)	0.17	1.35	(0.91 to 2.00)	0.13
	Functional features	0.77	(0.60 to 1.00)	0.05	1.27	(0.93 to 1.72)	0.13	0.92	(0.73 to 1.15)	0.44
	Safety	1.09	(0.72 to 1.65)	0.68	0.56*	(0.34 to 0.91)	0.02	0.91	(0.63 to 1.30)	0.59
	Facilities	1.02	(0.98 to 1.05)	0.32	0.98	(0.95 to 1.03)	0.45	1.01	(0.98 to 1.04)	0.59
800 meters	Aesthetics	2.06*	(1.00 to 4.26)	0.05	1.10	(0.46 to 2.62)	0.82	1.77	(0.94 to 3.35)	0.08
	Functional features	0.85	(0.54 to 1.34)	0.47	1.42	(0.82 to 2.46)	0.21	0.93	(0.62 to 1.39)	0.72
	Safety	0.58	(0.32 to 1.05)	0.07	0.70	(0.34 to 1.42)	0.32	0.62	(0.37 to 1.05)	0.07
	Facilities	1.02	(1.00 to 1.04)	0.07	0.98	(0.96 to 1.00)	0.12	1.01	(0.99 to 1.03)	0.23
1200 meters	Aesthetics	4.53*	(1.49 to 13.79)	0.01	1.53	(0.53 to 4.44)	0.43	4.26*	(1.61 to 11.30)	0.00
	Functional features	0.60	(0.24 to 1.47)	0.26	0.81	(0.34 to 1.92)	0.63	0.51	(0.23 to 1.12)	0.09
	Safety	0.45*	(0.21 to 0.98)	0.04	0.77	(0.36 to 1.62)	0.49	0.54	(0.28 to 1.08)	0.08
	Facilities	1.01	(0.99 to 1.02)	0.42	1.00	(0.98 to 1.01)	0.56	1.01	(0.99 to 1.02)	0.30

[a]Adjustments were made for age, sex, and the other area characteristics

Note: beta coefficients less than 1 represent negative associations, beta coefficients more than 1 represent positive associations

*p<0.05

TPA and disabilities

Both higher levels of walking and cycling were associated with less disabilities (pathway C; table 6). An increase of 10 minutes walking per two weeks was associated with 0.01 less disabilities ($p<0.001$). An increase of 10 minutes cycling was associated with 0.02 less disabilities ($p<0.001$). An increase of 10 minutes total TPA was associated with 0.01 less disabilities ($p<0.001$).

Table 6 Associations between TPA and disabilities adjusted for area characteristics (pathway C; N=271)

		Disabilities		
		β	**(95% CI)**	**p**
Adjusted for area characteristics within 400 meters	Walking	-0.01*	(-0.02 to -0.01)	0.00
	Cycling	-0.02*	(-0.03 to -0.01)	0.00
	Total TPA	-0.01*	(-0.02 to -0.01)	0.00
Adjusted for area characteristics within 800 meters	Walking	-0.01*	(-0.02 to -0.01)	0.00
	Cycling	-0.02*	(-0.03 to -0.01)	0.00
	Total TPA	-0.01*	(-0.02 to -0.01)	0.00
Adjusted for area characteristics within 1200 meters	Walking	-0.01*	(-0.02 to -0.01)	0.00
	Cycling	-0.02*	(-0.03 to -0.01)	0.00
	Total TPA	-0.01*	(-0.02 to -0.01)	0.00

*$p<0.05$

Mediation

Inclusion of minutes walking and cycling separately to the model in which aesthetics of the 400 meters buffer was related to disabilities, resulted in minor attenuations of the coefficient (pathway A'; table 4). Adding total minutes TPA resulted in the largest attenuation: the regression coefficient changed from -0.86 to -0.69 (95% CI -1.21 to -0.16, $p<0.05$). Except for the coefficients for safety in the 800 and 1200 meters buffer, all coefficients representing associations between area characteristics and disabilities became closer to zero once TPA outcomes were added to the models.

DISCUSSION

Of the four area characteristics under study, only higher scores on area aesthetics within a 400 meters buffer were associated with less disabilities. While transport-related walking and cycling were associated with residential area characteristics and disabilities, only a small part of the association between aesthetics and disabilities was mediated by these factors.

Older persons living in areas with good aesthetics reported less disabilities, which is supported by other studies showing that those residing in areas with more green spaces and better neighborhood maintenance (e.g. maintenance of streets and pavements) had lower levels of disabilities [5,23]. We did not find associations with disabilities for the other area characteristics, which is in contrast to literature showing that more functional features (e.g. presence of sidewalks), traffic-related safety, and facilities (e.g. grocery stores) are associated with lower levels of disabilities [5,24]. Differences in results may be due to different measures of disabilities and area characteristics, but may also reflect that the influence of the built environment on disabilities varies by country. In a sensitivity analysis, area characteristics were linked to the specific IADL-items regarding 'limitations in travelling (e.g. by public transport)' and 'limitations in grocery shopping' which are perhaps more directly related to mobility as compared to some elements of our IADL scale. Associations with area characteristics were only found for travelling: higher scores on aesthetics within all buffers were associated with less limitations in travelling (beta coefficient up to -0.26 in the 1200 meters buffer, CI -0.42 to -0.11; $p<0.05$). This beta coefficient showed the highest drop (to -0.20) after total TPA was added to the model (appendix 1). Based on a systematic review it has been recommended to revise built environment instruments including more disability-specific items [25]. Although the measure for functional features the ELANE neighborhood scan did include width of side-walks and the presence of curb cuts, the scan for example did not include availability of signage or accessibility of green spaces or facilities [25]. Previous work based on ELANE baseline data showed a positive association between the presence of facilities and walking for transport [10]. We did not find this association in our current study, which may be caused by a lack of power due to the smaller study population.

A negative association was found between safety and transport-related walking in the 1200 meters buffer. There is inconsistent evidence for associations between safety and walking which could be attributed to the complexity of measuring safety [26]. In a sensitivity-analysis we split our safety measure into a set of traffic safety items (i.e. presence of crossings, speed limiters, bicycle lanes, and traffic speed limits) and a set of social safety items (i.e. presence of lighting, supervision, houses, and apartments). Within the 400 meters buffer, no significant associations were found between both safety measures and cycling (in contrast to the main finding presented in table 5). Within the 1200 meters buffer, higher scores for traffic safety were associated with less cycling. To improve research on safety and PA, Foster and Giles-Corti (2008) suggested to combine objective measurement of safety with subjective measures of safety in which besides judgements (e.g. crime is a problem in the neighborhood), and emotional responses (e.g. being fearful about the crime) should also be taken into account [26].

Although most associations were found non-significant, the results of the mediation analyses indicated the possible role of TPA in the associations between area characteristics and disabilities. TPA only partly explained the association between aesthetics and disabilities which may be due to the small effect size of the association between TPA and disabilities. The finding that an increase of 10 minutes cycling per two weeks was associated with 0.02 less disabilities, implicates that for example an increase of 25 minutes cycling per week may decrease disabilities (range 0-8) with 0.1. Other studies did also find effects of increasing minutes of physical activity per week. For example, Rist et al. found physical inactivity to be associated with 0.14 more IADL limitations over two years [27]. Another study by Boyle et al. showed that among non-disabled persons, the risk to develop IADL disability decreased with 7% for each additional hour of PA per week [28]. Despite the mixed findings of studies on the association between PA and disability, as some do not find significant associations, our findings relate to the thought that PA is modestly associated with disability [28]. TPA only partly explained the association between aesthetics and disabilities. It is of interest to investigate other possible mediating factors such as other health behaviors (e.g. recreational PA, nutrition), mental health, and social participation, which may be promoted by area characteristics [29,30] and could potentially prevent disabilities [31,32].

This study is among the first to study the role of area characteristics for disability among older persons and the role of transport-related physical activity. A main strength of the study was the use of repeatedly measured disabilities which was justified by the finding of substantial variation in disabilities between baseline and follow-up. For this purpose we applied longitudinal logit regression models which are able to capture these random fluctuations. The variation could be due to real differences in disabilities at both moments in time; previous studies also showed that the development of disabilities is a dynamic process [8]. The variation could also result from random measurement error of disabilities. Such measurement error increases the likelihood of bias towards the null in studies using disabilities measured at a single time. Although it is possible to recover from disabilities, older persons who have recovered are at high risk of recurrent disabilities [33].

Several limitations should also be mentioned. Firstly, 153 participants (35.6%) were lost to follow-up because they were not willing to participate (n=135), unreachable by telephone (n=11), had health problems (n=3) or provided other reasons (n=4). As compared to the overall sample at baseline, those lost to follow up were more often women, and reported more minutes walking at baseline, but did not differ in disability scores. It may limit the generalizability of the study results as those being most physically active may have been underrepresented in the study sample. The effect on the main outcome, pathway A, is expected to be limited as no differences were found in disability scores. Secondly, study participants were interviewed face-to-face at baseline and by telephone at follow-up. Although we cannot exclude the possibility that different methods may have resulted in over- or underestimations, the overall impact may be limited since the same procedure was used for all participants, i.e. both interviews asked for self-reported levels of PA and disabilities. Thirdly, the association between area characteristics and cycling for transport may be underestimated since 23.8% of the data used to measure area characteristics was related to walking only (i.e. characteristics of walking paths). Moreover, it is suggested to use larger longitudinal datasets and to use more accurate measurement of area characteristics related to cycling, in order to get more insight in associations between the built environment and disabilities and the role of TPA.

Fourthly, it should be recognized that causality cannot be proven, since findings presented are based on an observational study. Self-selection may have played a role in the interpretation of associations as active older persons self-selecting themselves into areas conducive for PA. Additional analyses showed that self-selection probably did not affect the results, as only 6.3% (n=17) had moved to their current residence in the past five years. The most prevalent reason for moving was a lower level of maintenance of the house (n=9). One person reported a reason related to the built environment, i.e. because of a more attractive neighborhood. Associations between TPA and disability may be confounded by other lifestyle factors such as smoking and BMI [34], and health-related factors such as mental health, as for example depressive persons are more likely to be less physically active and to develop disabilities as compared to non-depressed persons [35,36]. Finally, to capture the development of disabilities more accurately, it is suggested to study disabilities over a longer time-period.

CONCLUSIONS

Better aesthetic features of the area close by the residences of community-dwelling older persons were associated with less disabilities, but only a small part of this association seemed to be mediated by TPA. Higher scores for aesthetics and safety were associated with higher levels of TPA, and TPA was associated with disabilities. Preventive measures to reduce or prevent disabilities may include area characteristic improvements, however more research is needed to strengthen our results.

DECLARATIONS

Ethics approval and consent to participate

At T0, a random sample was informed about the study by letter and an information flyer, and was asked to participate in the study. Through phone calls it was investigated whether persons had received the letter and flyer, whether they fulfilled the inclusion criteria, and it was registered whether they were willing to participate through oral consent (according to the Dutch law). At follow-up, persons who participated at T0 were informed about the goals of the second measurement through phone calls, and again oral consent to participate in a short follow-up interview nine months after T0 was obtained. The study was approved by the institutional medical ethics committee of Erasmus MC Rotterdam (METC).

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APPENDIX 1

Results of pathway A, A' and C for IADL items grocery shopping and travelling

Table 1 Age and sex adjusted associations between area characteristics and grocery shopping (pathway A and A'; N=271)

Area		pathway A						pathway A'					
		Grocery shopping			Grocery shopping adjusted for transport-related walking			Grocery shopping adjusted for transport-related cycling			Grocery shopping adjusted for total TPA		
	Area characteristic[a]	β	(95% CI)	p	β	(95% CI)	p	β	(95% CI)	p	β	(95% CI)	p
400 meters	Aesthetics	-0.05	(-0.10 to 0.01)	0.08	-0.04	(-0.10 to 0.01)	0.12	-0.04	(-0.09 to 0.01)	0.12	-0.04	(-0.09 to 0.01)	0.15
	Functional features	-0.00	(-0.03 to 0.03)	0.88	-0.01	(-0.04 to 0.02)	0.64	0.00	(-0.03 to 0.03)	0.92	-0.01	(-0.03 to 0.02)	0.72
	Safety	0.03	(-0.02 to 0.08)	0.31	0.03	(-0.02 to 0.08)	0.27	0.02	(-0.03 to 0.06)	0.51	0.02	(-0.03 to 0.07)	0.36
	Facilities	-0.00	(-0.01 to 0.00)	0.55	-0.00	(-0.00 to 0.00)	0.66	-0.00	(-0.01 to 0.00)	0.46	-0.00	(-0.00 to 0.00)	0.63
800 meters	Aesthetics	-0.01	(-0.10 to 0.07)	0.75	0.00	(-0.09 to 0.09)	0.99	-0.01	(-0.10 to 0.07)	0.78	0.00	(-0.08 to 0.09)	0.88
	Functional features	-0.02	(-0.08 to 0.03)	0.46	-0.02	(-0.08 to 0.03)	0.39	-0.01	(-0.07 to 0.04)	0.59	-0.02	(-0.08 to 0.03)	0.39
	Safety	0.02	(-0.06 to 0.09)	0.66	0.00	(-0.07 to 0.08)	0.88	0.01	(-0.06 to 0.08)	0.78	-0.00	(-0.07 to 0.07)	0.98
	Facilities	0.00	(-0.00 to 0.00)	0.82	0.00	(-0.00 to 0.00)	0.60	-0.00	(-0.00 to 0.00)	0.97	0.00	(-0.00 to 0.00)	0.58
1200 meters	Aesthetics	-0.00	(-0.14 to 0.13)	0.97	0.03	(-0.11 to 0.16)	0.69	0.00	(-0.13 to 0.14)	0.99	0.05	(-0.08 to 0.18)	0.45
	Functional features	-0.03	(-0.14 to 0.08)	0.56	-0.04	(-0.15 to 0.07)	0.44	-0.03	(-0.14 to 0.08)	0.55	-0.06	(-0.16 to 0.05)	0.29
	Safety	0.01	(-0.08 to 0.11)	0.79	-0.00	(-0.10 to 0.09)	0.95	0.01	(-0.08 to 0.11)	0.82	-0.01	(-0.10 to 0.08)	0.84
	Facilities	0.00	(-0.00 to 0.00)	0.18	0.00	(-0.00 to 0.00)	0.13	0.00	(-0.00 to 0.00)	0.19	0.00	(-0.00 to 0.00)	0.09

[a]Adjustments were made for age, sex, and the other area characteristics
*$p<0.05$

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Table 2 Associations between TPA and grocery shopping adjusted for area characteristics (pathway C; N=271)

		Grocery shopping		
		β	(95% CI)	p
Adjusted for area characteristics within 400 meters	Walking	-0.02*	(-0.03 to -0.01)	0.00
	Cycling	-0.02*	(-0.03 to -0.01)	0.00
	Total TPA	-0.04*	(-0.05 to -0.02)	0.00
Adjusted for area characteristics within 800 meters	Walking	-0.02*	(-0.03 to -0.01)	0.00
	Cycling	-0.02*	(-0.03 to -0.01)	0.00
	Total TPA	-0.04*	(-0.05 to -0.02)	0.00
Adjusted for area characteristics within 1200 meters	Walking	-0.02*	(-0.03 to -0.01)	0.00
	Cycling	-0.01*	(-0.01 to 0.00)	0.00
	Total TPA	-0.04*	(-0.05 to -0.02)	0.00

*$p<0.05$

Table 3 Age and sex adjusted associations between area characteristics and travelling(pathway A and A'; N=271)

		pathway A						pathway A'					
		Travelling			travelling adjusted for transport-related walking			Travelling adjusted for transport-related cycling			Travelling adjusted for total TPA		
Area	**Area characteristic[a]**	**β**	**(95% CI)**	**p**	**β**	**(95% CI)**	**p**	**β**	**(95% CI)**	**p**	**B**	**(95% CI)**	**p**
400 meters	Aesthetics	-0.11*	(-0.17 to -0.05)	0.00	-0.11*	(-0.17 to -0.05)	0.00	-0.10*	(-0.16 to -0.04)	0.00	-0.10*	(-0.16 to -0.04)	0.00
	Functional features	0.03	(-0.00 to 0.07)	0.07	0.03	(-0.01 to 0.06)	0.10	0.04*	(0.01 to 0.07)	0.02	0.03	(-0.00 to 0.06)	0.08
	Safety	0.03	(-0.02 to 0.09)	0.20	0.04	(-0.02 to 0.09)	0.17	0.02	(-0.04 to 0.07)	0.50	0.03	(-0.02 to 0.09)	0.21
	Facilities	-0.01*	(-0.01 to -0.00)	0.03	-0.01*	(-0.01 to -0.00)	0.04	-0.01*	(-0.01 to -0.00)	0.01	-0.00*	(-0.01 to -0.00)	0.03
800 meters	Aesthetics	-0.17*	(-0.27 to -0.07)	0.00	-0.16*	(-0.26 to -0.06)	0.00	-0.17*	(-0.26 to -0.08)	0.00	-0.15*	(-0.24 to -0.06)	0.00
	Functional features	0.03	(-0.03 to 0.09)	0.37	0.03	(-0.04 to 0.09)	0.40	0.04	(-0.02 to 0.10)	0.18	0.03	(-0.03 to 0.08)	0.38
	Safety	0.10*	(0.02 to 0.18)	0.02	0.09*	(0.01 to 0.17)	0.02	0.09*	(0.01 to 0.17)	0.02	0.08*	(0.01 to 0.16)	0.04
	Facilities	-0.00	(-0.00 to 0.00)	0.31	-0.00	(-0.00 to 0.00)	0.41	-0.00	(-0.00 to 0.00)	0.12	-0.00	(-0.00 to 0.00)	0.45
1200 meters	Aesthetics	-0.26*	(-0.42 to -0.11)	0.00	-0.24*	(-0.40 to -0.09)	0.00	-0.26*	(-0.41 to -0.10)	0.00	-0.20*	(-0.34 to -0.06)	0.01
	Functional features	0.09	(-0.04 to 0.22)	0.16	0.08	(-0.04 to 0.21)	0.19	0.09	(-0.04 to 0.21)	0.17	0.06	(-0.05 to 0.18)	0.30
	Safety	0.13*	(0.02 to 0.23)	0.02	0.11*	(0.01 to 0.22)	0.04	0.12*	(0.02 to 0.23)	0.03	0.10*	(0.00 to 0.20)	0.04
	Facilities	-0.00	(-0.00 to 0.00)	0.07	-0.00	(-0.00 to 0.00)	0.08	-0.00	(-0.00 to 0.00)	0.06	-0.00	(-0.00 to 0.00)	0.10

[a]*Adjustments were made for age, sex, and the other area characteristics*
$p<0.05$

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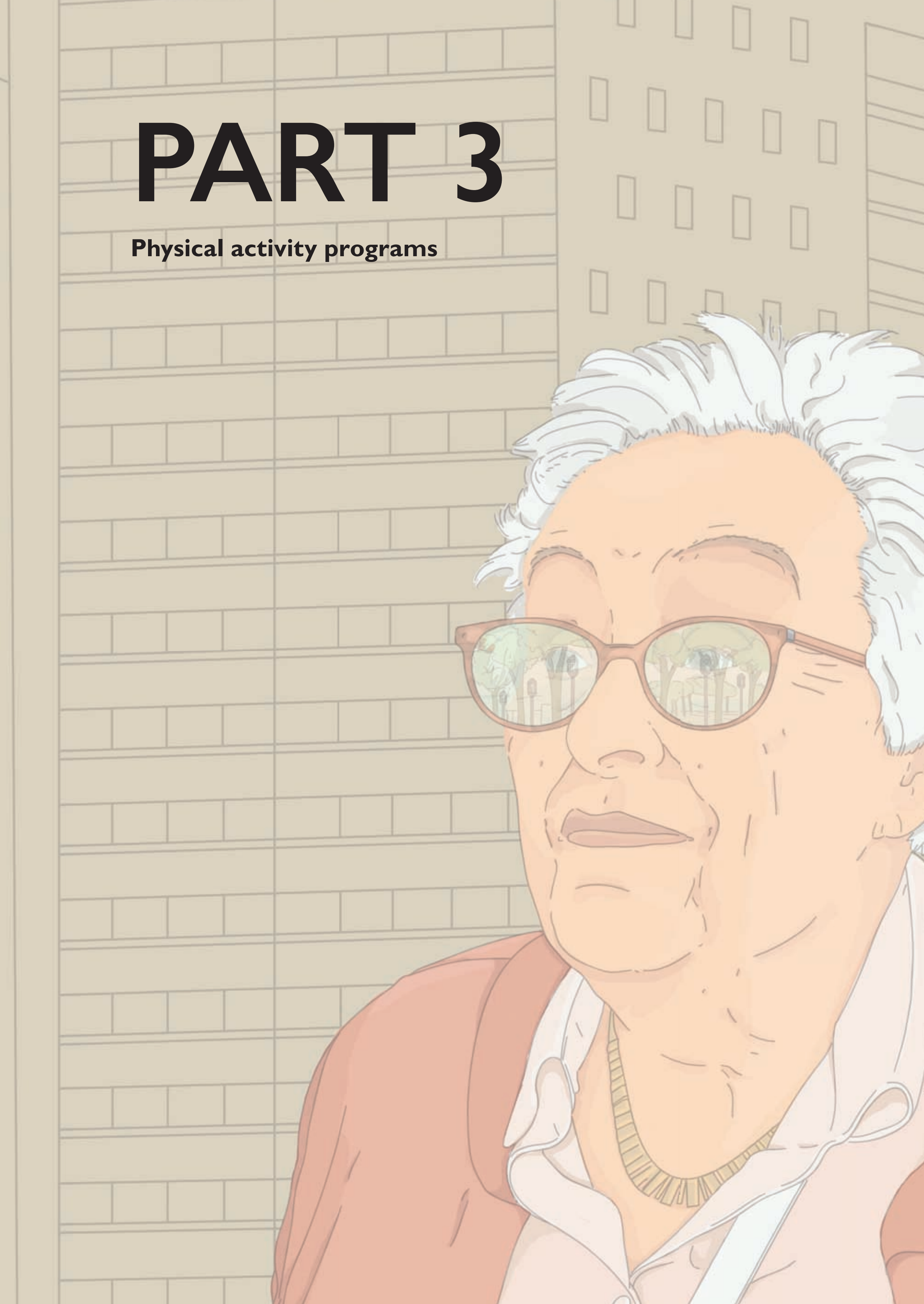
Table 4 Associations between TPA and travelling adjusted for area characteristics (pathway C; N=271)

		Travelling		
		β	**(95% CI)**	**P**
Adjusted for area characteristics within 400 meters	Walking	-0.02*	(-0.03 to -0.00)	0.01
	Cycling	-0.03*	(-0.04 to -0.02)	0.00
	Total TPA	-0.04*	(-0.06 to -0.03)	0.00
Adjusted for area characteristics within 800 meters	Walking	-0.01*	(-0.03 to -0.00)	0.01
	Cycling	-0.03*	(-0.04 to -0.02)	0.00
	Total TPA	-0.04*	(-0.06 to -0.03)	0.00
Adjusted for area characteristics within 1200 meters	Walking	-0.01*	(-0.03 to -0.00)	0.02
	Cycling	-0.02*	(-0.02 to -0.01)	0.00
	Total TPA	-0.04*	(-0.06 to -0.03)	0.00

*$p<0.05$

PART 3

Physical activity programs



6

Participation levels of physical activity programs for community-dwelling older persons: a systematic review

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ABSTRACT

Background Although many physical activity (PA) programs have been implemented and tested for effectiveness, high participation levels are needed in order to achieve public health impact. This study aimed to determine participation levels of PA programs aimed to improve PA among community-dwelling older persons.

Methods We searched five databases up until March 2013 (PubMed, PubMed publisher, Cochrane Library, EMBASE, and Web of Science) to identify English-written studies investigating the effect of PA programs on at least one component of PA (e.g. frequency, duration) among community-dwelling populations (i.e. not in a primary care setting and/or assisted living or nursing home) of persons aged 55 years and older. Proportions of participants starting and completing the PA programs (initial and sustained participation, respectively) were determined.

Results The search strategy yielded 11994 records of which 16 studies were included reporting on 17 PA programs. The number of participants enrolled in the PA programs ranged between 24 and 582 persons. For 12 PA programs it was not possible to calculate initial participation because the number of older persons invited to participate was unknown due to convenience sampling. Of the five remaining programs, mean initial participation level was 9.2% (± 5.7%). Mean sustained participation level of all 17 programs was 79.8% (± 13.2%).

Conclusion Understanding how to optimize initial participation of older persons in PA programs deserves more attention in order to improve the population impact of PA programs for community-dwelling older persons.

BACKGROUND

The worldwide population is ageing rapidly. Between 2000 and 2050, the world's population over 60 years will double from about 11% to 22% [1], and healthcare costs will rise substantially [2]. Participating in regular physical activity (PA) is important for older persons, since it has positive effects on muscle strength, flexibility, balance, falls risk, and occurrence of chronic diseases [3], and may prevent or delay loss of independent living [4]. Preventive measures aimed at increasing PA levels should focus on those aged 55 years and older since they have been found to be at increased risk of adverse outcomes such as frailty and disability [5,6].

High initial and sustained participation in PA programs is important for achieving public health impact [7]. However, although many PA programs have been implemented and tested for effectiveness [8], strikingly little is known about the participation levels of these programs [9,10]. For example, low-intensity programs with a small effect and high participation rates may have a higher overall impact as compared to high-intensity programs with large effects and low participation rates [11-13]. As such, the identification of PA programs with high levels of participation is important for the development of future PA programs. Therefore, a systematic review was conducted to determine participation levels of PA programs aimed to improve PA among community-dwelling older persons aged 55 years and older. Furthermore, it was investigated what program characteristics and characteristics of participants distinct PA programs with higher participation levels from PA programs with lower participation levels.

METHODS

Search strategy

Specified search strategies were developed for five bibliographic databases up until March 2013: PubMed, PubMed publisher, Cochrane Library, EMBASE, and Web of Science. The full electronic search strategy for Pubmed was:

((aged NOT (boy* OR girl* OR child*OR month* OR middle)) OR elder* OR senior* OR (old* AND (adult* OR people*))) AND (((communit* OR home) AND (living OR dwell* OR residen* OR based OR population*)) OR (residential* NOT (care OR home OR facilit*)) OR in home OR at home OR domestic*))) AND (exerci* OR sports OR physical OR activity OR activities OR walking OR swimming OR cycling OR strength OR endurance OR power OR pedometer OR accelerometer) AND (program* OR intervention* OR experiment* OR (group

AND lesson*) OR government*) AND (effectiv* OR evaluat* OR outcome* OR benefit*)

The search strategies for the other databases can be found in the appendix.

Study selection

Studies were included when they were: 1) written in English; 2) conducted among community-dwelling populations (i.e. not in a primary care setting and/or assisted living or nursing home); 3) among persons aged 55 years and older; 4) described programs targeting at least one component of PA (e.g walking group, exercise class); and 5) evaluating the effect of at least one component of PA (e.g. frequency, duration). Studies were excluded when these: exclusively targeted older persons with a specific medical condition (e.g. dementia, depression), focused on cost-effectiveness; and/or reported on study protocols only.

One reviewer (MvdD) performed the initial selection of titles and abstracts in the literature search. A second reviewer (AE) was consulted to screen a random sub-set, and in case of doubt to discuss until agreement was reached. All corresponding authors of included studies were contacted and reference lists of previously published systematic reviews were checked to make sure all relevant articles were captured. This extra search did not result in extra studies eligible for inclusion.

Data extraction

A data extraction form was used to collect information on participation levels (dependent variable) and characteristics of participants and program characteristics (independent variables). Characteristics of participants included sex distribution (% females) and mean age of the participants. The program characteristics included: sampling method (probability sampling vs. convenience); method of recruitment; location (home-based vs. group-based); content (e.g. walking group); duration (months); number of contacts; supervision (yes vs. no); and (maximal) group size. Probability sampling is a method of sampling that utilizes some form of random selection, whereas convenience sampling is a technique where subjects are selected because of their convenient accessibility and proximity to the researcher (e.g. inviting through advertisements). One reviewer (MvdD) performed the data extraction and a second reviewer (AE) verified all extracted data. In case of doubt, data were discussed until agreement was reached.

Participation levels

In order to calculate participation levels the following measures were used, numbers of persons that: 1) were invited to participate (i.e. available sample); 2) started the PA program; and 3) completed the PA program. By using these measures initial and sustained participation levels were calculated. Initial participation was defined as the number of participants that enrolled in the program divided by the number of persons invited to participate. Sustained participation was defined as the number of participants who completed the program divided by the number of participants that started the program [7].

Risk of bias

Studies reporting significant effects of PA programs on PA outcomes are more likely to be published as compared to studies in which no significant results were found. However, it is unlikely that this publication bias would affect our results since we focused on participation level as the main outcome, and no differences in participation level are to be expected between effective and non-effective PA programs.

Statistical analysis

Descriptive statistics (e.g. means, standard deviations, ranges) were used to summarize the results. Mean sustained participation level was calculated for all PA programs as well as for *effective* PA programs only. An *effective* PA program was defined as a program for which a significant effect on at least one PA outcome was reported. Pearson correlations were calculated in order to investigate the correlation between participation levels and: gender distribution of the participants; mean age of the participants; program duration; and group size.

RESULTS

Literature search

The search strategy yielded 11994 records. After removing duplicates, 6759 records remained which were screened based on title and abstract. Sixteen studies reporting on 17 PA programs, were included which were published between 2002 and 2013 since no studies prior to this time met the inclusion criteria (figure 1).

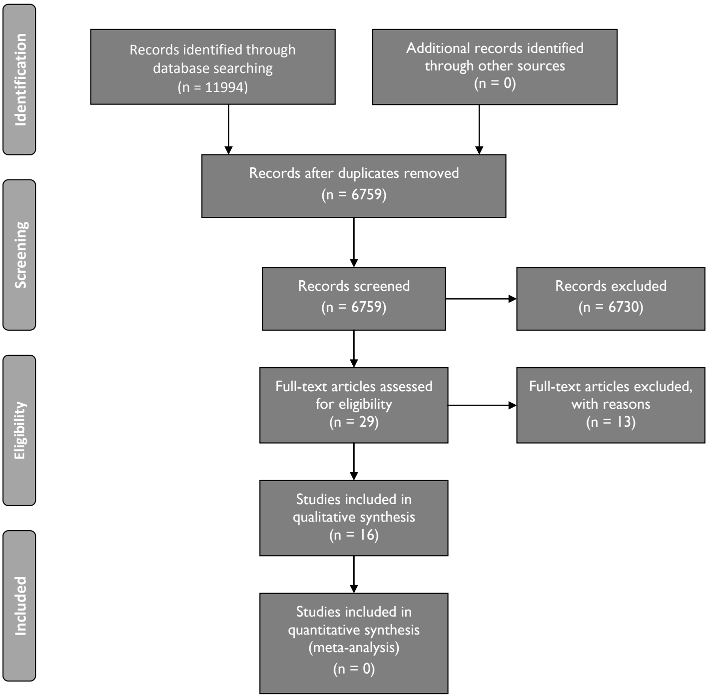

Figure 1 PRISMA Flow Diagram

Characteristics of participants and programs

The mean age of the participants ranged between 66 to 84 years (overall mean 73.8 ± 6.6 years). In three programs only females participated (20, 21, 28). Of the remaining 14 PA programs, on average 70.2% (± 13.3%) of the participants were females (range 47-89%).

Program characteristics that showed the most variation were the location at which the program took place and the content of the program. Six programs were home-based (14, 16, 19-21, 24), five programs were group-based (22-23, 26-28), and six were both home- and group-based (15, 17, 18, 25, 29). Three programs involved group-walking (16, 20, 28), seven programs involved multifaceted activities such as a combination of education and a training program (14, 15, 18, 21, 23, 24), and seven programs involved various PA such as a pedometer intervention or different exercise programs (17, 19, 22, 25-27, 29) (tabel 1). PA outcomes that were evaluated were: general PA level (n=9); walking (n=6); and household and sports activities (n=1).

Table 1 Characteristics of PA programs aimed at improving PA among community-dwelling persons aged 55 years and older (n=17)

Participation level			Characteristics of participants		Program characteristics							
Study	Initial participation (%)	Sustained participation (%)	% Females	Mean age in years (range)	Sampling method	Method of recruitment	Home- or group-based	Content	Duration	Contacts	Supervision	Group size
Burke, 2013 (14)	16.2 (478/2,949)	78.4 (375/478)	48	66 (range not reported)	Probability sampling	From 60 suburbs/ neighborhoods of a city; random selection (method not reported)	Home-based	Multifaceted: booklet with PA and nutritional recommendations, resistance band, pedometer	6 months	6-10 telephone calls and/or 2-5 emails	No	0
Hopman-Rock[a], 2002 (15)	12.9 (71/551)	70.4 (50/71)	63	Mean not reported (75-85)	Probability sampling	From a city selected and approached by mail for participation	Combination	Multifaceted; health education, group exercises, home exercises	3 months	Group meeting once plus exercises at home minimally 3 times/week	Yes	25
Cheng, 2009 (16)	8.2 (96/1,175)	79.2 (76/96)	47	70 (65-69)	Probability sampling	By using a list of names obtained from the department of households; letters were sent	Home-based	Walking training	3 months	3 meetings	Yes	0
Rosenberg, 2012 (17)	7.3 (87/1,196)	74.6 (64/87)	76	84 (69-98)	Probability sampling	From four senior-living facilities. Study information flyers were sent to all potential eligible residents	Combination	Standard intervention (pedometer, educational, group meeting) Enhanced intervention (+ telephone counseling, environmental awareness)	3 months	Biweekly group meeting	Yes	-
Rydwik, 2009 (18)	1.4 (96/6,999)	66.7 (64/96)	60	83 (range not reported)	Convenience sampling	By using questionnaires, advertisements in local newspaper, primary care and home service administration organized by the local authorities	Combination	Multifaceted: Training group (T) Group with training and nutrition (T+N) Nutrition-only group (N)	9 months	3 months twice a week training sessions (T and T+N), followed by 6 months home-based exercises (T)	Yes	5-8
Koizumi, 2009 (19)	-	100 (68/68)	100	67 (60-78)	Convenience sampling	From senior centers and advertisement in local papers	Home-based	Lifestyle PA: 9000 steps and 30 min moderate intensity PA per day	3 months	1 meeting individual	No	0

(continued) Characteristics of PA programs aimed at improving PA among community-dwelling persons aged 55 years and older (n=17)

Participation level			Characteristics of participants		Program characteristics							
Study	**Initial participation (%)**	**Sustained participation (%)**	**% Females**	**Mean age in years (range)**	**Sampling method**	**Method of recruitment**	**Home- or group-based**	**Content**	**Duration**	**Contacts**	**Supervision**	**Group size**
Shaw, 2008 (20)	-	100 (24/24)	100	Mean and range not reported	Convenience sampling	Four senior centers that host a program. One-on-one recruitment of other program participants and posting of signs in the center to announce the program	Home-based	A daily walking-for-exercise program at respective senior center (instruction to walk)	3 months	-	No	0
Bonnefoy, 2012 (21)	-	96.1 (98/102)	86	84 (78-97)	Probability sampling	Representatives and home helpers from associations involved in home assistance for the elderly, help to recruit people for participation	Home-based	Multifaceted; education meeting, nutrition supplement, 13 exercises per day at home	4 months	1 meeting	Yes	0
Fujita, 2003 (22)	-	95.4 (62/65)	54	67 (60-81)	Convenience sampling	From advertisements in local newspapers, bulletin, poster	Group-based	Progressive endurance training and resistance exercises	6 months	2-3 times/week	Yes	31
Sarkisian, 2007 (23)	-	90.2 (46/51)	89	77 (range not reported)	Probability sampling	From three senior centers (method not reported)	Group-based	Multifaceted; attribution retraining, PA class	1 month	Once a week	Yes	8-14
Croteau, 2007 (24)	-	82.6 (147/178)	78	73 (55-94)	Convenience sampling	From various educational, health, and social programs offered in area	Home-based	Multifaceted: pedometer, individual meeting, group meeting once a month	3 months	3 group- and 1 individual meeting	No	0
Opdenacker, 2008 (25)	-	78.3 (141/180)	49	67 (range not reported)	Convenience sampling	By using personal letters and advertisements on local radio and in local newspapers	Combination	Structural exercise intervention Home-based lifestyle intervention	11 months	3 times/week	Yes	10

(continued) Characteristics of PA programs aimed at improving PA among community-dwelling persons aged 55 years and older (n=17)

Participation level			**Characteristics of participants**		**Program characteristics**							
Study	**Initial participation (%)**	**Sustained participation (%)**	**% Females**	**Mean age in years (range)**	**Sampling method**	**Method of recruitment**	**Home- or group-based**	**Content**	**Duration**	**Contacts**	**Supervision**	**Group size**
Hernandes, 2012(26)	-	78.0 (238/305)	69	68 (64-71)	Probability sampling	Controls recruited among individuals participating in another project Experimental group recruited from 5 community-based exercise programs in the same city	Group-based	Community-based exercise program: aerobic exercises	4-40 months (on average 12 months)	2 times/week	Yes	13
De Vreede, 2007 (75)	-	75.5 (74/98)	100	74 (range not reported)	Convenience sampling	From advertisements in a local newspaper	Group-based	Functional tasks exercise program resistance strength exercise program	3 months	3 times/week	Yes	6-12
Michael, 2008 (28)	-	73.1 (424/582)	71	74 (range not reported)	Probability sampling	Neighborhoods in a city were selected demarcated by the city council	Group-based	Leader led walking group	6 months	3 times/week	Yes	10
Helbostad, 2004 (29)	-	68.8 (53/77)	81	81 (range not reported)	Convenience sampling	Invitations to participate were distributed by health care workers and by announcement in the local newspaper	Combination	Combined training: meeting at home, training classes	3 months	2 times/week	Yes	5-8
Hopman-Rock[b], 2002 (15)	-	50.3 (196/390)	82	72 (55-75)	Convenience sampling	Advertisement in local newspapers and other media, personal communication, and a brochure	Combination	Multifaceted; health education, group exercises, home exercises	3 months	Group meeting once plus exercises at home minimally 3 times/week	Yes	22 (maximum 25)

6

Initial and sustained participation

The number of participants enrolled in the PA programs ranged between 24 and 582, with a mean of 174 (± 165). It was not possible to calculate initial participation levels for 12 PA programs, because their applied sampling methods (e.g. convenience sampling) made it unclear how many older persons were invited to participate. The mean initial participation level of the five remaining PA programs was 9.2% (± 5.7%), with a range between 1% [18] and 16% [14]. It was not possible to calculate correlations of characteristics of participants and programs with initial participation levels because of the low number of studies reporting initial participation levels.

Between 24 and 424 (mean 129 ± 117) participants completed the PA programs. The mean proportion of persons completing the program was 79.8% (± 13.2%; n =17) ranging between 50.3% [15] and 100% [19,20]. Of the 12 *effective* PA programs (14-16, 18-20, 23-25, 28, 29) the mean proportion of persons completing the program was 71.3% (± 21.9%). Correlations showed that higher sustained participation levels were related to lower mean age of the participants (r= -.182), higher proportions of females (r= .279), lower duration of the program (r=-.137), and smaller group sizes (r= -.367), but none of these correlations reached significance.

DISCUSSION

This systematic review identified 17 PA programs that aimed to improve PA among community-dwelling older persons. The mean proportion of participants starting the program (initial participation level) was 9.2%, but could only be calculated for five PA programs. The 17 PA programs had a mean sustained participation level of 79.8%. No significant correlations were found for participant or program characteristics with sustained participation level.

The mean initial participation level of 9.2% is difficult to interpret without additional information about the method of recruitment and effort or resources invested. For example 9.2% seems high when recruitment is done by putting up an advertisement in a community building, but low when mailing people personally and subsequently phoning them. Although for public health impact it is important to have insight into the number of older persons that would participate when providing a PA program [30], for 12 PA programs important information was missing. This is striking since information on initial participation gives insight into potential selective participation and in the external validity of the results. Furthermore, in the recent CONSORT statement it was emphasized to include information on the eligible participants in order to increase validity [31]. Thus, it is important that at least an indication of initial participation levels is reported when the effects of PA programs are studied. Therefore, for future studies it is highly recommended to include information regarding the number of persons that were invited to participate in the PA program. Although, none of the included PA programs in this current systematic review included online components, it is of interest to study the growing implementation of online PA programs [32] which potentially increase the ease of initial participation.

The overall mean sustained participation level of almost 80% found in the current systematic review was higher than expected, as lower participation levels have been found among children [33,34], and for other types of health-behavior programs for older persons [10]. The mean sustained participation level of *effective* PA programs was lower than the overall mean. This could imply that the *effective* programs have a smaller overall population impact when implemented on a larger scale as compared to programs with smaller effects but higher sustained participation levels [11-13].

No significant correlations were found for participant or program characteristics with sustained participation level which may be due to the small number of studies that were eligible for inclusion. Although the size of the correlations indicated that a low mean age of the participants, high proportions of females participating, short duration of the program, and a small group size are likely to increase levels of sustained participation, these factors should be investigated further as potential determinants of sustained participation. Jancey et al. (2007) showed that can be related to low socioeconomic status, overweight, low PA level at the start, low walking self-efficacy, and loneliness may also be related to low sustained participation levels of PA programs among older persons [35].

CONCLUSIONS

Calculating initial participation levels of PA programs aimed to improve PA levels among community-dwelling older persons is hindered by high levels of convenience sampling. Sustained participation among those who started participating in PA programs is high. A low mean age of participants, high proportions of females participating, short duration of program, and a small group size are likely to increase levels of sustained participation. In order to improve the population impact of PA programs among community-dwelling older persons, more knowledge is needed into how initial and sustained participation levels can be optimized.

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APPENDIX

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7

The role of high-intensity physical exercise in the prevention of disability among community-dwelling older persons

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ABSTRACT

Background Moderate to vigorous physical activity (MVPA) is considered important to prevent disability among community-dwelling older persons. To develop MVPA programs aimed at reducing or preventing disability more insight is needed in the contributions of exercise duration and intensity and the interplay between the two.
Methods Longitudinal data of 276 Dutch community-dwelling persons aged 65 years and older participating in the Elderly And their Neighborhood (ELANE) study were used. MVPA exercise (yes/no), duration (hours per two weeks), intensity (Metabolic Equivalent of Task; METs), and energy expenditure (MET-hours per two weeks), and disability in instrumental activities of daily living (range 0-8) were measured twice within nine months to account for fluctuations over time. Associations between the four exercise measures and disability were tested with longitudinal tobit regression analyses.
Results MVPA exercise was associated with fewer disabilities. While exercise duration was not associated with disability, whereas an increase of one MET in exercise intensity was associated with 0.14 fewer disabilities (95%CI: -0.26 to -0.02). For exercise energy expenditure, an increase of one MET-hour exercise per two weeks was associated with 0.03 fewer disabilities (95%CI: -0.05 to -0.01).
Conclusions Higher-intensity exercise may help to prevent disability among community-dwelling older persons. Further investigation is needed to explore the preventive effects in more detail.

BACKGROUND

Preventing disability is of major importance in ageing societies. From 17% to 54% of community-dwelling people aged 65 years and older suffer from one or more disabilities in daily activities [1-3], which may result in a loss of independent living and increased healthcare costs. At older age, maintaining an active lifestyle through regular moderate to vigorous physical activity (MVPA) may delay age-related decline in physical functioning [4,5]. MVPA induces physiological cardiovascular adaptations (e.g. better vessel wall function and structure), improves physical performance through better balance and muscle strength, and as such may prevent loss of function [6-8]. Informing health-related policy and practice on key elements of interventions to stimulate MVPA among older persons is essential to accomplish the largest health gains. MVPA programs are increasingly offered to older persons [9,10]. However, the optimal "volume" (frequency, duration and intensity of exercise) to prevent disabilities is still unclear [11]. MVPA at increased duration, greater frequency, and/or higher intensity has been found most beneficial for many health outcomes [12]. However, little is known about the independent contributions of physical exercise duration and intensity, and their interplay in the prevention of disabilities [13,14], which was investigated in this study.

METHODS

Subjects

Longitudinal data from the Dutch Elderly And their Neighborhood (ELANE) study (2011-2012) were used. The ELANE study aimed at studying associations between area characteristics and physical activity, independent living, and quality of life among community-dwelling people aged 65 years and older living in Spijkenisse, a middle-sized town in the greater Rotterdam area. The exclusion criteria were: institutionalised, bedridden, wheelchair- or scooter-bound, or not fluent in Dutch. Of the 430 participants interviewed face-to-face at the first time-point (T0; autumn/winter 2011), 277 agreed to a second interview by telephone nine months later (T1; summer/autumn 2012). Only data of participants interviewed both at T0 and T1 were used. Because T1 data on disabilities were lacking for one person, data of 276 persons were eligible for analysis. Details of the ELANE study are provided in chapter 1 and 4.

Disabilities

Presence of disabilities was measured with the reliable Lawton and Brody functional ability scale [15,16]. Disabilities among older persons can be episodic and recurrent [16], which can be captured by repeated measurements. Participants were asked at both T0 and T1 whether they needed help with the following eight Instrumental Activities of Daily Living (IADL): using the telephone, travelling (e.g. public transport), grocery shopping, preparing a meal, household tasks, taking medicines, finances, and doing laundry. All items had the response categories 'no' (0) and 'yes' (1) and therefore the total score could range from 0 to 8.

MVPA exercise

Both at T0 and T1, questions from the Physical Activity Questionnaire of the LASA-study (LAPAQ), a valid and reliable instrument specifically developed for older persons [17,18], served to determine four exercise measures. MVPA *exercise participation* was based on the question 'Do you physically exercise?' with response categories 'yes' (1) or 'no' (0). If the answer was 'yes', the following questions was asked related to a maximum of two exercise activities on which they spent most time: 'In which type of physical exercise did you participate in the previous two weeks?', 'How often did you do this exercise in the previous two weeks?', and 'For how long did you usually do this exercise in the previous two weeks (minutes)?'. *Exercise duration* (hours) was calculated by multiplying the frequency with the total amount of time participating in exercise divided by 60. *Exercise intensity* was measured with the Metabolic Equivalent of Task (MET) (highest MET if two types of exercise were reported with different METs) based on the Compendium of Physical Activities in which exercise-specific intensities are listed as multiplies of the resting metabolic rate of 1.0 kcal/kg/hour [19]. *Exercise energy expenditure* (MET-hours) was calculated by multiplying exercise duration by intensity. Exercise duration and exercise energy expenditure were each summed for the maximum of two types of exercise. As MVPA exercises by definition are exercises with an intensity of 3 or more METs [20], participants reporting exercises with intensities lower than 3 METs were categorized as not participating in MVPA exercises.

Statistical analyses

Differences in sex, age, disabilities, and exercise participation between the study sample and persons lost to follow-up were tested with Chi-square tests and t-tests. The association between exercise intensity and duration was tested with a Pearson correlation.

Of the study sample, 72.8% reported to have no disabilities at T0 and/or T1. Although this suggests that many persons did not experience any limitations there still may be subtle differences in IADL-performance among these persons. We therefore applied tobit regression analyses, an elegant way of analysing such censored data [21]. The *longitudinal* tobit method was used to handle data from two time-points (see the appendix). Associations of the four exercise measures with disabilities were tested (sex- and age-adjusted) using STATA 13.1. A linear association between exercise duration and disabilities was found; therefore those who did not participate in exercise remained in the analyses. Educational level was not associated with disability. Additionally, adjustment for educational level did not change the results essentially, and educational level was therefore excluded from the analyses.

RESULTS

Descriptive findings

Age, number of disabilities, and exercise participation did not differ between those who participated at both time points (study sample) and those who only participated at T0. The latter sample had a higher proportion of women.

In the study sample, at both T0 and T1, about one third reported to have one or more disabilities (table 1).

Table 1 Characteristics of the study sample aged 65 years and older participating in the ELANE study (N=276)

			T0	T1
	Sex	(% women)	48.2	
	Mean age	(years)	74.6 ± 6.7	
	Disabilities (range 0-8)	(% one or more)	33.3	36.6
		(mean)	0.7 ± 1.4	0.8 ± 1.3
MVPA exercise[a]	Participation	(% yes)	46.4	42.4
	Mean duration	(hours in two weeks)	2.4 ± 4.6	2.1 ± 4.9**
	Mean intensity [b]	(METs)	2.7 ± 3.1	2.3 ± 2.9**
	Mean energy expenditure	(MET-hours in two weeks)	14.1 ± 32.8	11.7 ± 30.1**

**p<0.001

[a] all MVPA means are among the total study population

[b] mean score of T0 and T1 (in case participants participated in two different types of exercise, highest METs of both was used)

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More disabilities were found among women and with increasing age ($p<0.05$). While the number of disabilities had not changed between T0 and T1, exercise duration, intensity, and energy expenditure had all decreased. The proportion of persons participating in MVPA exercise was 46.4% at T0 (n=128) and 40.2% at T1 (n=111). Fitness, gymnastics (e.g. balance training), cycling on a stationary bike, and cycling tours were the most prevalent exercise types, and most respondents reported one type only (table 2). Exercise duration and exercise intensity were positively correlated ($r=0.60$; $p<0.001$).

Table 2 Nature of MVPA exercise at T0 and T1 among older persons participating in the ELANE study

		T0		T1	
	Intensity (METs)	**Exercise 1 (n=128)**	**Exercise 2 (n=37)**	**Exercise 1 (n=111)**	**Exercise 2 (n=21)**
Fitness	5.5	17.2%	13.5%	23.4%	33.3%
Gymnastics	4.0	13.3%	8.1%	8.1%	19.0%
Cycling on stationary bike	5.5	10.9%	8.1%	9.9%	0.0%
Cycling tours	8.0	8.6%	24.3%	3.6%	19.0%
Swimming	7.0	8.6%	13.5%	10.8%	4.8%
Dancing	4.5	6.3%	2.7%	6.3%	9.5%
Other	3.0-10.0	35.1%	29.8%	37.9%	14.4%

Physical exercise and disability

Those participating in MVPA exercise reported 0.96 fewer disabilities than those not participating in MVPA exercise (table 3, model 1). An increase in exercise duration and an increase in intensity were both associated with a decrease in disabilities (models 2 and 3). The association between exercise duration and disabilities became non-significant after adjustment for exercise intensity (model 4). Independent of exercise duration, a one MET higher intensity was associated with 0.14 fewer

Table 3 Age- and sex-adjusted associations between MVPA exercise measures and disabilities among community-dwelling older persons, ELANE study (N=276)

Model	**β**	**(95%CI)**	**p-value**
1. Exercise participation (yes/no)	-0.96	(-1.53 to -0.39)	0.001
2. Exercise duration (hours per two weeks)	-0.09	(-0.17 to -0.01)	0.034
3. Exercise intensity (METs)	-0.16	(-0.27 to -0.06)	0.002
4. Exercise duration (hours per two weeks), adjusted for intensity	-0.03	(-0.12 to 0.06)	0.508
5. Exercise intensity (METs), adjusted for duration	-0.14	(-0.26 to -0.02)	0.021
6. Exercise energy expenditure (MET-hours per two weeks)	-0.03	(-0.05 to -0.01)	0.002

disabilities (model 5). A one MET-hour increase was associated with 0.03 fewer disabilities (model 6).

DISCUSSION

Participation in MVPA exercise was associated with fewer disabilities. Exercise intensity had a stronger, negative association with disabilities than had exercise duration. When both exercise duration and intensity were taken into account, no association was found for duration, whereas higher intensity was associated with fewer disabilities. Exercise energy expenditure was also associated with fewer disabilities.

Strengths and limitations

This study is among the first to investigate the role of MVPA exercise duration, intensity, and the interplay between both in relation to disability, which information is highly relevant for exercise programs aimed at reducing or preventing disabilities among community-dwelling older persons. A key strength is the use of repeated measures, which provides more robust associations than the use of a single measure in cross-sectional designs. Although differences in other health-related factors cannot be ruled out, the factors age, number of disabilities, and exercise participation did not differ between the study population and those only participating at T0. We think, therefore, that there is only a small probability that a 'survival group' was interviewed.

A limitation of this study is that disabilities and exercise participation levels were self-reported, with the inherent risk of measurement error [22,23]. However, particularly for organized exercise activities conducted at predetermined hours and days per week (as reported by a substantial proportion of the study sample), reporting may be relatively easy and therefore less prone to bias. A methodological limitation is that participants were asked to report on a maximum of two exercise activities. To what extent this has led to an underreporting of MVPA is unclear, considering we do not know how many people actually participated in more than two exercise activities. Furthermore, we cannot rule out seasonal influences, although the reported decrease in exercise duration and increase in indoor sport activities in the summer makes it unlikely that our findings are affected by the difference in seasons at T0 and T1. Another limitation is that an exercise can be performed at different levels of intensity and consequently with different energy expenditure [24], which has not been taken into account. Measuring exercise intensity objectively, for example by using heart rate monitors or accelerometers [25,26], would introduce further precision about the intensity of exercise.

Discussion of findings

Older persons participating in MVPA exercise reported fewer disabilities than those not participating in MVPA exercise, which can be explained by two mechanisms: 1) persons experiencing disabilities are less likely to engage in MVPA exercise [27]; and/or 2) participating in MVPA exercise may prevent older persons from developing disabilities [28,29]. While the use of repeated measures allowed minimizing the impact of the episodic nature of disabilities, testing the direction of the association may require a longer study period (including multiple measurements) in which persons start to engage in exercise and develop disabilities.

The association between exercise duration and disabilities may be overestimated when intensity is not taken into account. This is in line with the finding that higher exercise intensity was associated with fewer disabilities, and that persons participating in higher-intensity exercise tended to exercise longer than did persons participating in lower-intensity exercise. Energy expenditure was weakly associated with disabilities. This can be largely attributed to exercise intensity, also considering that a systematic review found that high-intensity exercise programs have a positive effect on disabilities [13]. This indicates that besides evidence of an inverse association between physical activity and disability, intervening on disability by offering MVPA programs seems promising [13,30].

Implications

The results suggest that higher-intensity exercise (e.g. swimming or fitness) may be more effective in preventing functional loss among older persons than lower-intensity exercise (e.g. gymnastics or dancing). The finding that one MET-hour higher exercise energy expenditure was associated with 0.03 few disabilities may implicate that for example an increase of 3 MET-hours per two weeks, which can be realized by 35 minutes fitness exercise (at 5.5 METs; per two weeks), may decrease disabilities with 0.1. Arguably speculative, this would have a positive effect on independent living as one would have less difficulty with activities of daily life. As 17% to 54% of the over 65 year olds suffer from one or more disabilities and disability-associated health care expenditures accounts for 26.7% of all health care expenditures [31], the effect may be rather substantial. It would be of interest to investigate what activities of daily living would benefit most of higher-intensity exercise, and how this would affect health care costs.

Other studies support clear fitness, metabolic, and performance benefits of higher-intensity MVPA, although the MVPA programs not necessarily need to be of highest intensities to reduce health risks [12]. Exercise participation recommendations for persons already experiencing disabilities should be made with caution, since high-intensity exercise participation for this group may not be feasible [20].

CONCLUSION

Higher-intensity exercise may help to prevent disability among community-dwelling older persons. Further investigation is needed to explore the preventive effects in more detail.

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APPENDIX. APPLICATION OF THE LONGITUDINAL TOBIT REGRESSION ANALYSES

Background

The main reasons why we chose to use tobit regression analyses were:

a. Censored data

A large part of participants reported to have no disabilities, which suggests that many persons did not experience any limitations. However, there still may be subtle differences in IADL-performance among these persons. The use of tobit regression analyses allows to analyse censored data.

b. Fluctuations in disability level

Since disability level can fluctuate over time, using data from two time-points is preferred over generally used cross sectional designs. Therefore, the *longitudinal* tobit method was used to handle disability data from two time-points.

Tobit model

The tobit procedure models the association between the independent variable and an underlying latent variable, in this case, the number of reported functional limitations. The longitudinal tobit model can be formulated mathematically as follows:

$$y_{ij}^{*}|b_i = x'_{ij}\beta + b_i + e_{ij,}\ e_{ij} \sim N(0, \sigma^2)$$
$$b_i \sim N(0, D)$$

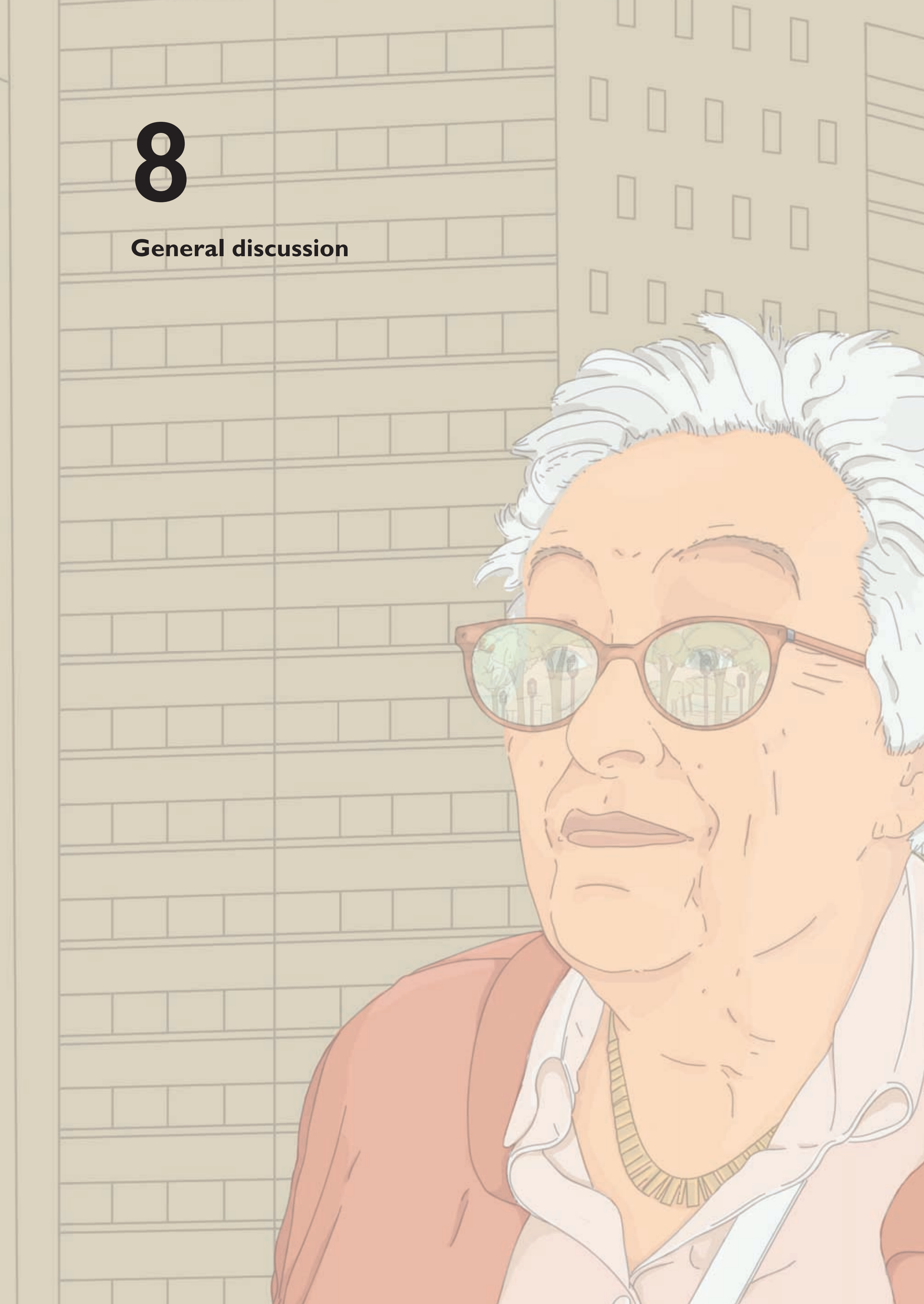
in which y^{*} is the uncensored latent (i.e. unobservable) dependent variable, β is the parameter, b_i is the case-specific random intercept with variance D, i refers to case i, j to the jth measurement within case i.

Tobit regression was estimated with the *xttobit* procedure in Stata. The dependent variable included longitudinal data on disabilities for which the lower limit was set at '0' which corresponds with the reporting of zero disabilities. Since the dependent variable was limited at one side, only a lower limit was needed.

7

8

General discussion



This thesis aimed to investigate how physical activity (PA) and the built environment influence disability among community-dwelling older persons. This section includes a summary of the main findings, methodological considerations, interpretation of findings, activities undertaken to transfer knowledge from research to policy and practice, and recommendations for researchers and public health professionals.

8.1 MAIN FINDINGS

The three main research questions addressed in this thesis will be answered in the sections below, combining findings from all chapters.

Which groups of older persons are at increased risk of worsening in frailty?

Data of the SHARE study were analyzed to give insight in determinants of frailty and its development over time (chapters 2 and 3). It was shown that the probability to become frail and to worsen in frailty increased with age. Also, women had a higher probability to worsen in frailty. This means that women not only become (pre)frail more often as compared to men, they also more often worsen in frailty once they become frail. In Southern European countries frailty worsening started at an earlier age and women had a higher probability to worsen in frailty compared to those in Northern European countries. Frailty worsening was more prevalent among lower as compared to higher educated persons in all European countries. Smokers, alcohol abstainers, persons with chronic diseases, depressed persons, and those who do not participate in society were found to have a higher probability to worsen in frailty. Alcohol consumption, presence of chronic diseases, depression, and social participation were all associated with both educational level and frailty worsening, and as such partly contributed to educational inequalities in frailty worsening in all countries.

Which characteristics of the built environment are important for PA and disability among older persons?

In the ELANE study, four domains of the built environment were defined: aesthetics (e.g. green spaces, maintenance of pavements), functional features (e.g. availability of benches, flat pavements), facilities (e.g. bus stops, grocery store), and safety (e.g. traffic lights, crossings). As reported in chapter 4, it was found that more aesthetic features, more facilities, and less functional features, in areas ranging from 400 to 1200 meters around the residences of older persons, were related to more transport-related walking. Whereas facilities were found to be more important in close by areas, aesthetics were found to be more important in larger areas around the residences of older persons. No associations were found for traffic-related safety, and no differences were found between frail and non-frail persons in the role of the built environment for transport-related walking. Chapter 5 showed that the presence of more aesthetic features within 400 meters was associated with less disabilities. No associations with disabilities were found for the other three built environment domains. The association between aesthetics and disabilities was partly explained by transport-related walking and cycling.

Which characteristics of PA programs are useful to increase PA and decrease disability among older persons?

Based on the systematic review presented in chapter 6, it can be concluded that increasing initial participation levels of PA programs offers great potential to increase PA at a population level. The study showed that less than 10% of potential participants actually participated in such programs. Of these persons however, 80% sustained their participation. Sustained participation was higher in programs with more relatively young participants, more female participants, if the duration of the program was short and the group size small.

Chapter 7 reported, based on data from the ELANE study, that those who physically exercise reported less disabilities as compared to those who do not physically exercise. Independent of exercise duration, an increase in exercise intensity was associated with less disabilities.

8.2 METHODOLOGICAL CONSIDERATIONS

Frailty measurement

In this thesis two different instruments were used to measure frailty: Fried's instrument (chapter 2 and 3) and a short version of the Identification of Seniors At Risk – Hospitalized Patients (ISAR) questionairre (chapter 4). Frailty items based on Fried's criteria included weakness, weight loss, exhaustion, slowness and low activity. The ISAR questionnaire included items on assistance for IADL activities, assistance for travelling, on the use of walking device, and on educational level. Although it is generally agreed that frailty is a state of high vulnerability, there is no consensus yet on how it should be measured exactly. A recent systematic review showed that there are at least 27 frailty measures [1]. This shows that there is no need to develop new frailty instruments. Although all instruments intend to measure the same concept, the choice for a frailty instrument should be made deliberately, as its items may overlap or be closely related to its determinants or outcomes. For example, the ISAR questionnaire includes items on both determinants and outcomes of frailty, i.e. educational level and disabilities respectively. As such, when studying the role of educational level on frailty, or the role of frailty on disabilities, the ISAR questionnaire would not be the best choice to measure frailty. In chapter 4, educational level and the presence of disabilities were not included. Therefore, the application of the ISAR questionnaire to measure frailty was acceptable. In chapters 2 and 3 there was no overlap between frailty and its determinants or consequences in the use of Fried's criteria to measure frailty. However, for future research it should be taken into account that Fried's instrument does overlap with PA, a determinant of frailty, which makes this instrument less suitable for research on the role of PA for frailty.

Physical activity measurement

Data on PA used in chapters 2 to 5, and 7 were all based on self-report. In chapters 2 and 3, level of PA was based on self-reported frequency of engagement in activities that require a low or moderate state of energy (e.g. walking or gardening). In chapters 4 and 5, data on PA was based on self-reported frequency and duration of transport-related walking and cycling. It is increasingly argued that the use of objective and continuous measures (i.e. measuring over a longer time-period) such as accelerometers or heart rate monitors provides more accurate information on PA levels [2,3], and allow a linkage to other devices, such as GPS meters, in order to link PA to the built environment.

A systematic review of 173 studies, comparing self-report with objective measured PA among adults, showed that self-report becomes a problem only when focusing on vigorous PA levels (as compared to lower PA levels) [4]. This may reflect either the difficulty to capture higher PA levels via self-report, or a difficulty in recalling PA levels by participants. In chapters 2 to 5, the focus was on low to moderate PA levels, therefore no substantial under- or over-reporting of PA is expected. However, in future research on vigorous PA, the use of objective measures is the preferred option as it allows for measuring the variability in vigorous intensity level as these are to be expected to differ between persons participating in the same exercise.

Evaluation of the built environment

An important aspect when investigating area characteristics related to PA, is how to define a neighborhood area. Traditional research on the built environment has been criticized for the use of administrative neighborhood boundaries, as individuals have their own activity space that does not necessarily can be mapped within arbitrary geographic boundaries [5]. In the ELANE study (chapters 4 and 5), buffers were constructed to overcome the problem of exposure misclassification, based on walking path networks (by using GIS data) around a residence for which it is possible to cross neighborhood boundaries. In chapter 4 it was explicitly hypothesized that the size of the buffer mattered for the association between built environmental characteristics and PA. This approach has proven to be successful, resulting in new knowledge about the etiological role of built environmental characteristics for PA. A disadvantage of such an approach is that a direct translation to neighborhood policies becomes difficult. In order to improve health through policy, there is a need to better integrate the etiological and policy perspectives on neighborhoods and buffers.

Another important aspect when investigating area characteristics is the choice for a street audit instrument. In the ELANE study, a street audit was developed to assess the built environment in the Dutch context. This need for a context-specific instrument arose because street audits developed in other countries were not suitable to capture essential elements in the Netherlands. This points towards the inherent problem of evaluating the built environment in research. Since the built environment differs strongly between countries, many researchers have used context-specific street audits. Whether or not a country-specific audit should be used depends on the research question to be addressed. When searching for accurate information on determinants of PA relevant for national policymaking, a country-specific audit must be the preferred option. On the other hand, a comparison of contexts requires a street audit instrument applicable to different contexts.

Diversity in methods

In this thesis a combination of methods was used, including study designs, types of data, and data analysis. Changes in frailty status were studied at the European level in a longitudinal study in which country specific results were presented (chapters 2 and 3). The role of the built environment for PA was studied at a city level by using data from repeated measurement (chapters 4 and 5). The same accounted for the study on exercise measures and disabilities (chapter 7). Participation levels of PA programs were studied by doing a systematic review of international studies (chapter 6). An advantage of such a mixture of methods is that it provides insight for researchers and policymakers at different levels ranging from a European level to a Dutch city level. On the one hand, comparisons can be made between frailty changes among Dutch older persons and other European older persons, whereas on the other hand accurate knowledge is provided on characteristics of the built environment in a Dutch city. Also, insight in participation levels of PA programs is applicable both in the Netherlands as well as in other countries. Another advantage is that the use of longitudinal data and data abstracted from studies provides insight from different perspectives. Although focusing on the Dutch context only would allow for more extensive insight in the Dutch context, it would have limited the generalizability of study results and comparison with other countries.

Causality

It should be recognized that causality cannot be proven, since findings from this thesis are based on observational studies. Two possible problems could occur when interpreting associations: 1) associations may be based on (unmeasured) confounding, and 2) migration may play a role as older persons may move to attractive neighborhoods. Additional analyses showed that migration probably did not affect the results, however, it is unclear what factors may have confounded the associations found. To get better insight in possible underlying mechanisms in associations between the built environment and PA, McCormack et al. pointed towards the need of more quasi-experimental studies as these offer more robust evidence of causality compared to other designs [6]. To approach causality in quasi-experimental studies, these should include pre and post intervention data from cohorts (multiple measurements), multiple matched control groups and measures of individual-level exposure to the intervention [7].

8.3 INTERPRETATION OF FINDINGS

Determinants of frailty changes

In chapter 2 the role of socio-demographic factors for frailty was demonstrated. This corroborates with many studies in various countries showing that women, lower educated and persons above 65 years of age have an increased probability to become (physically) frail. Besides that these factors are associated with the onset of frailty, chapter 2 shows that they are also associated with frailty changes. Further, frailty development is not an irreversible pattern; apparently, frail persons can also improve again. Understanding the underlying causes of frailty changes opens perspectives for health interventions. One of the most promising interventions may be the promotion of PA. Besides its central role in the prevention of onset and aggravation of frailty, PA has shown to have a positive effect on many health outcomes. For example, participation in regular PA reduces the risk of diabetes, hypertension, and depression [8]. Two important ways to accomplish PA promotion are intervening in the built environment (chapters 4 and 5), or offering PA programs (chapters 6 and 7).

The role of the built environment

Chapters 4 and 5 suggest that improving aesthetics and the number of facilities in the surroundings of older persons is promising in the promotion of walking and prevention of disabilities among Dutch older persons. Increasing evidence of a link between neighborhood characteristics and PA [9,10], supports the vision that intervening in the built environment to increase PA levels is a valuable public health strategy [11].

Having said that, our study also finds negative and non-significant associations between area characteristics and both PA and disabilities. For example, our findings that more functional features were related to less walking (chapter 4), and more safety was related to less walking and cycling (chapter 5) seem counterintuitive. A plausible explanation is that the way safety was objectively measured (e.g. presence of crossings and traffic lights) represents the busyness of a street which may be less appealing to walk through for older persons. The lack of associations between the three domains aesthetics, functional features, facilities and cycling in any of the buffers (chapter 5) may be the result of the relatively well designed built environment for cyclists in the Netherlands and the traditionally high levels of cycling among the Dutch [12]. Although this suggests that there is no need to further improve this situation, continuous improvements in an already well-designed cycling environment, may be needed in order to retain high levels of cycling and to stimulate cycling among those who never do. Indeed, reviews have shown that intervening in the built environment is effective in different contexts, especially when interventions involved improvements to active transportation [13,14].

Offering PA programs

Up till now, little was known about participation levels of PA programs offered to older persons (chapter 6). Knowledge on reach of such programs can be seen as the first step in program evaluation for which the Reach, Effectiveness, Adaptation, Implementation, and Maintenance (RE-AIM) framework is often used [15]. Strikingly, most attention is given to effectiveness of PA programs, whereas in order to increase PA levels at a community level, it is of just as much importance that the reach of PA programs is high. Strategies to increase the number of persons enrolling in PA programs will increase the public health impact, given that most older persons starting PA programs will sustain their participation over prolonged periods. The effect of such programs on PA levels can be twofold: they can either improve PA behavior or maintain PA behavior. Therefore, attention to reach both persons with lower PA levels and persons with higher PA levels is important. When developing programs for persons least active, it should be kept in mind that they may be more susceptible to drop out of PA programs. In a health promotion perspective, it is important to know what type of PA programs should be offered to older persons. As such, chapter 7 points towards the importance of high intensity PA in the prevention of disability. As many PA programs are offered to older persons, there is a need to critically examine which programs have the best potential to be beneficial for health. The combination of findings does inherit a tension. A strategy to involve the least active, while offering a programs with high intensity levels may not be the optimal match. In reaching persons, consequences in terms of social contacts may be just as relevant as the health consequences. Increasing the intensity then seems to be possible only once participants show sustained participation.

8.4 FROM RESEARCH TO POLICY AND PRACTICE

A growing number of cities worldwide are striving to become "age-friendly" by meeting the needs of their older residents. In recent years, the Dutch government has increasingly focused its policy on the growing number of older persons in its society. Part of this focus is the action plan 'More at home in the neighborhood' which stated that it should be possible for older persons to be able to live independent in their neighborhood, receive support and health care at home, thereby making it possible to participate in society [16]. Dutch cities undertake different activities to become more age-friendly. For example, Den Haag tested the age-friendly level of its neighborhoods and results served as input for policy on elderly care. Amsterdam created a platform for professionals aiming for healthy and independent living for older persons. In Leiden, a walking route is being improved (so called 'Morslint') while taking into account the needs of older persons.

Both national and international policy documents include guidelines to improve neighborhoods, for example the WHO checklists to develop such age-friendly cities [17]. In the development of such guidelines, supporting scientific evidence is often lacking. This thesis provides insight that can serve as input for policymakers and practitioners. For example, ELANE findings support WHO recommendations on the need for facilities close by the residences of older persons and the importance of green spaces. In the ELANE study, different activities were undertaken to transfer the obtained knowledge to policymakers and practitioners (i.e. urban planners, designers, advisors) in the Rotterdam area which are described in the following sections.

Urban designs

The policy 'More at home in the neighborhood' does not provide indications on how this goal could spatially be achieved. Therefore, the Technical University Delft designed spatial interventions and defined design principles based on the ELANE study [18]. Visualizing study findings make them suitable for policymakers and practitioners, show solutions to improve neighborhoods, and as such allow for better communication between researchers, policymakers and practitioners. Figure 1 shows an example of how the built environment can be improved to become age-friendly. figure 1a shows a path connecting two neighborhoods in Spijkenisse in which green spaces are insufficiently maintained. It is only designed for cyclists, while it is also used by pedestrians. The design in figure 1b shows how this path can become age-friendly if well maintained, and with benches and a sidewalk. As such, the path becomes more attractive for pedestrians since feelings of safety increase,

Figure 1a Path connecting neighborhoods in Spijkenisse (photo taken in 2012)

Figure 1b Urban design

and the presence of benches allows older persons to take a break. These kind of suggestions to improve the built environment will also be beneficial for all ages, and therefore stimulate shared use.

Focus group interviews with participants

Focus group interviews with participants of the ELANE study were held in order to get better insight in the interplay between study findings and urban design. Results of these focus groups confirmed study findings. For example, it was confirmed that a well maintained and clean environment is attractive to walk through. Characteristics mostly discussed were: the importance of absence of dog waste on sidewalks and walking paths, and maintenance of green spaces (e.g. trees, bushes, plant pots). There were mixed feelings concerning the attractiveness of parks. Facilities addressed as being important for walking were shops (e.g. supermarket), facilities for personal care (e.g. pharmacy, hairdresser), social meeting points (e.g. restaurants, library, community center), public transport, and public toilets. In contrast to ELANE findings, participants mentioned that attractive surroundings to go for a walk include benches, wide and flat sidewalks, flat curbs, and no obstacles. Additional features that were mentioned were supporting handrails for stairs and slopes, enthralling designs of neighborhoods (corresponding with irregular grid patterns), and connectivity between neighborhoods. At the same time, older persons mentioned the maintenance of functional features as important as the presence of it. Insufficiently maintained functional features lead to feelings of unsafety, fear and insecurity and as such negatively influence walking. Besides sufficient lightning of streets and sidewalks, and presence of traffic lights, participants discussed the role of *social* safety for walking more than *traffic* safety.

Discussing barriers and facilitating factors for neighborhood improvements

To get insight in opportunities to improve neighborhoods to increase PA levels of citizens, barriers and facilitating factors for policymaking on improving neighborhood areas were investigated. In Spijkenisse a meeting was organized including policy advisors, urban planners, urban architects, and members of a social support advisory (in Dutch: WMO Adviesraad). Facilitating factors included: the availability of budget to maintain the built environment (e.g. benches and green spaces), the current use of design principles when building accessible facilities, a yearly organized day ("Maintenance Day") at which citizens are given the opportunity to improve their neighborhood (e.g. gardening), and the municipality being (financially) supportive towards citizens who show initiatives to improve neighborhood areas. Barriers included: a lack of budget for making adjustments (too much focus on maintenance), a lack of stimulating and monitoring maintenance and progress of citizen initiatives, too little attention towards and promotion of the "Maintenance Day", and a lack of cooperation between organizations outside the municipality (e.g. housing associations).

In Rotterdam a workshop for policy advisors and urban planners was organized by researcher from the ELANE study in corporation with Fieldacademy Rotterdam (in Dutch: Veldacademie), to get insight to what extent policy advisors and urban planners could relate to the study findings and urban designs, and what actions should be taken to improve walking and independent living among older persons. Results from the ELANE study met participants' expectations and accordingly attention is being paid in policy of the city of Rotterdam to improve area characteristics to increase PA levels of its citizens. Participants mentioned the following characteristics that could be improved to stimulate walking among older citizens: the presence of public toilets, connectivity of walking routes, presence of benches, and maintenance of green spaces. It was noted that for municipalities like Rotterdam, it is important to take into account shared use of the built environment, meaning that adjustments to residential areas should be relevant for different groups in society.

8.5 RECOMMENDATIONS

Frailty and linked concepts

For the measurement of frailty, many instruments are offered which complicates the choice for the most suitable instrument. In case the relationship between frailty and its consequences is being studied, components of adverse outcomes are sometimes integrated in frailty instruments, as for example frailty instruments may include components of disabilities [1]. Although, frailty and disability can co-occur as an individual can experience the vulnerability associated with frailty as well as difficulties with activities in daily live [19], frailty and disability are two different concepts. Therefore, it is recommended to choose a frailty instrument which allows to clearly distinguish between frailty and its consequences. The complexity of dealing with two different concepts also applies to measuring determinants of frailty. For example, when studying the effect of PA on frailty development, PA should not be included in the frailty measurement as increases in PA would automatically improve frailty levels. Similarly, when investigating inequalities in frailty, educational level should not be included in the frailty measure. As such, to be able to properly measure the effect of interventions on frailty, a clear distinction between cause and effect should be made. More generally, in the choice for the best frailty measurement it is important to be clear on the concepts of interest and to make use of measurements that distinguish these concepts.

Built environment interventions

In order to create age-friendly cities, policymakers and practitioners need input from researchers on what adjustments should be made to the built environment. Studies on determinants of health help to design appropriate interventions to improve health. The difficulty that arises in developing environmental interventions, is that randomized experiments are considered the 'gold standard' study design to determine causal pathways, while these are almost always too difficult to employ in public health research on social and physical environments [20]. In research on intervening in the built environment, particular barriers include ethical and political objections to the random assignment of participants to social housing in neighborhoods, or to the random assignment of neighborhoods to receive interventions [21]. Still, different studies have shown that evaluation of such interventions is possible. For example, quasi-experimental studies have been conducted showed mixed results in the promotion of PA. Droomers et al. [22] found no short-term effect of improving green spaces in deprived areas on PA and health, and Prins et al. [23] found both positive and negative effects on PA after introducing a new infrastructure. As nowadays even complete towns are newly built with a focus on healthy living [24], proper evaluation of such initiatives is of great value for researchers, policymakers and practitioners.

Environment-individual interactions

This thesis shows that specific groups of persons have a higher probability to worsen in frailty. Socio-ecological models suppose that associations between the built environment and PA may differ between such groups [25,26]. A next step would be to investigate whether the associations found between area characteristics and PA differ by age, sex, or educational level. Factors possibly underlying associations between the built environment and PA, that may be considered are psychosocial factors (e.g. social support), knowledge, and awareness [6]. This shows the complexity of studying effects of intervening in the built environment since we are dealing with an interactive 'system' of people and their environment [27,28]. To explore the impact of neighborhood interventions, the use of agent-based simulation models may be most feasible as these can take into account so called 'system-thinking' [29].

Reach of PA programs

Knowledge on mechanisms underlying low initial participation is essential to increase public health impact of PA programs. One of the main questions here is how to stimulate people not participating in PA, to become physically active. Therefore, it is useful to get insight in factors influencing participation in PA programs, for example the attractiveness of programs based on the training frequency, location, or time schedule; or the attractiveness of physical activity in general, e.g. because of the time investment or because of feelings of discomfort. Such knowledge would serve as input for methods to increase the reach. As a next step, it is suggested to critically assess PA programs currently offered to older persons, as these may not all be appropriate programs. It should be noted that reach may be low when offering higher intensity PA programs, as these may even be less attractive as compared to lower intensity PA programs. Especially those who have never participated in exercise, the willingness to participate in such programs will be very low.

Lower socioeconomic groups

In the promotion of PA among older persons, extra attention is needed towards lower socioeconomic groups, as these groups are known to have lower PA levels and have a higher probability to become frail and to worsen in frailty. Lower socioeconomic groups may be more exposed to less attractive neighborhoods and may be less exposed to PA programs, and this could underlie these differences in frailty. It should be taken into account that lower socioeconomic groups may have other needs and preferences compared to higher socioeconomic groups concerning neighborhood designs. The challenge here is to integrate the needs of both groups to stimulate shared use of the built environment. Furthermore, when offering PA programs, lower socioeconomic groups need extra attention as they are known to participate less in such health promoting programs. A first step is to reach these groups by offering attractive PA programs (e.g. low costs). Secondly, taking away barriers to participate would allow for PA to become integrated in their lifestyles.

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Summary

The increase of frail older persons will have a substantial impact on healthcare systems. In the Netherlands, the number of persons aged 65 years and older is expected to increase from 2.7 million in 2012 to 4.7 million in 2050. Among Dutch persons aged 65 years and older, 6 to 11% is physically frail. Frailty is highly predictive for disability, which consequently can lead to long-term care including homecare, assisted living, and long stays in hospitals. Frailty can be understood as a continuum with intermediate states potentially amenable to modification. Non-frail persons can become pre-frail, a precursor state of frailty. There is also a possibility to recover from a frail state to a pre-fail and potentially to a non-frail state. Given that the process of frailty may be delayed or even reversed, interventions specifically targeted towards pre-frail older persons are attractive. Better insight in sociodemographic determinants of frailty development allows defining target groups for interventions aimed at preventing or decreasing frailty among older persons. One of the most promising types of intervention may be the promotion of PA.

The high extent to which societies have to deal with frailty and its adverse outcomes calls upon the need to intervene at a societal level. It is from this perspective that there is an increased interest in the role of environmental determinants of PA and its role for disability. Using the local (built) environment as an entry point for interventions and policies to facilitate PA among older persons, requires good insights in which characteristics of the built environment are related to PA and disability among older persons. In addition to facilitating unorganised PA, people can also be physically active via organized PA programs. As many PA programs are offered to older persons, there is a need to critically examine which have the best potential to prevent frailty. It appears that still little is known about participation levels and components that are most effective to increase PA levels and on the long term decrease disabilities among older persons.

Accordingly, the following research questions were addressed in this thesis:

1. Which groups of older persons are at increased risk of worsening in frailty?
2. Which characteristics of the built environment are important for PA and disability among older persons?
3. Which characteristics of PA programs are useful to increase PA and decrease disability among older persons?

WHICH GROUPS OF OLDER PERSONS ARE AT INCREASED RISK OF WORSENING IN FRAILTY?

In chapter 2, sociodemographic determinants of changes in frailty status were investigated by using longitudinal data of the Survey on Health, Aging and Retirement (SHARE) of 14424 community-dwelling older persons aged 55 years and older residing in 11 European countries. Specifically, the study addressed the question whether sex, age, marital status, and level of education were related to a worsening in frailty state over a two-years period. The probability to worsen in frailty was higher for women, those aged 65 years and older, and lower educated persons, as compared to men, younger persons, and higher educated persons, respectively. Worsening in frailty started at an earlier age in Southern than in Northern European countries. Particularly in Southern European countries, women showed higher probability of worsening in frailty state as compared to men. In chapter 3, SHARE data were used to investigate whether lifestyle, health, and social participation mediate educational inequalities in frailty development. Smokers, alcohol abstainers, persons with chronic diseases, depressed persons, and those who did not participate in society showed a higher probability of worsening in frailty. Alcohol consumption, the presence of chronic diseases, depression, and social participation were associated with both educational level and frailty worsening, and partly contributed to educational inequalities in frailty worsening in all European countries. From these studies, we concluded that women, lower educated and older persons are at an increased risk to worsen in frailty, and that health behaviors, health and social participation are entry points for interventions the reverse or delay the process of frailty.

WHICH CHARACTERISTICS OF THE BUILT ENVIRONMENT ARE IMPORTANT FOR PA AND DISABILITY AMONG OLDER PERSONS?

Studies presented in chapter 4 and 5 were induced by a systematic review showing mixed results on the role of the built environment for PA in older persons. This inconsistency has partly been attributed to methodological shortcomings, including the use of inappropriate geographical units (e.g. one-size predefined areas). Studies included in this thesis used different sizes of "buffers" which allowed for more variation in area characteristics. These buffers were based on walking path networks around older persons' homes. In chapter 4, characteristics of the built environment potentially relevant for transport-related walking were studied by using data of Dutch community-dwelling older persons aged ≥65 years participating in the Elderly and their Neighborhood (ELANE) study (n=408). Associations were investigated for buffer sizes ranging between 400 and 1600 meters, and by frailty level. More aesthetic features, more facilities, and less functional features in areas around the residences of older persons were related to more transport-related walking. The association between facilities and walking was stronger in the smaller buffers, whereas the role of aesthetic features was found to be stronger in in larger buffers. No associations were found for traffic-related safety, and the associations were not statistically different between frail and non-frail persons. In chapter 5, associations between aesthetics, functional features, safety, and facilities and disabilities in instrumental activities of daily living (IADL) were investigated. IADL disabilities were measured twice over a nine months period to exclude random fluctuation. For this purpose longitudinal ELANE data (n=271) were used. It was also investigated whether transport-related PA mediated associations between area characteristics and disability. The presence of more aesthetic features in the immediate surroundings (within 400 meters) was associated with less disabilities. No associations with disability were found for the other three built environment domains in any of the buffers. Higher scores for area aesthetics were associated with more transport-related PA, and more transport-related PA was associated with less disabilities. The association between aesthetics and disability was partly explained by transport-related PA. From these studies it was concluded that transport-related PA among older persons may increase and disabilities may be prevented by neighborhood improvements, especially aesthetics.

WHICH CHARACTERISTICS OF PA PROGRAMS ARE USEFUL TO INCREASE PA AND DECREASE DISABILITY AMONG OLDER PERSONS?

Chapter 6 presents a systematic review in which participation levels of PA programs were summarized. A selection was made of 16 studies in which the effect of 17 PA programs on PA among community-dwelling older persons of 55 years and older was investigated. For most programs it was not possible to calculate the initial participation, because the number of older persons invited to participate was unknown. In studies in which it was possible, initial participation levels of older persons in PA programs were low. Strikingly, sustained participation was found to be high. Sustained participation was higher in programs with relatively young participants, and more female participants, if the duration of the program was short and the group size was small.

In chapter 7 the role of exercise participation, exercise duration, exercise intensity, and exercise energy expenditure (duration*intensity) for the prevention of disability was studied using data of the ELANE study (n=276). Associations were tested between these four exercise measures and disability, which were both measured twice over a nine months period. Those who exercised reported less disabilities as compared to those who did not exercise. Exercise duration was not associated with disabilities, whereas an increase in exercise intensity was associated with less disabilities (independent from exercise duration). Also, an increase in exercise energy expenditure was associated with less disabilities. From these studies it was concluded that understanding how to optimize initial participation of older persons in PA programs deserves more attention. As many PA programs are offered to older persons, there is a need to critically examine these programs to select those which have the best potential to be beneficial for health. Participating in higher-intensity exercise may be relevant in programs aimed at reducing or preventing disability among community-dwelling older persons. As these programs may be less attractive to participate in as compared to lower intensity PA programs, it should be taken into account that reach may be lower than of less intense PA programs.

DISCUSSION AND RECOMMENDATIONS

In addition to the main findings and their interpretations, chapter 8 includes methodological considerations, a description of activities undertaken to transfer knowledge, and recommendations for future research, policy and practice. Methodological considerations concerned measuring frailty, PA, and the built environment, the diversity of methods applied in this thesis, and a discussion on causality. To provide insight in opportunities to improve neighborhood areas to increase PA among older persons, activities were undertaken to transfer obtained knowledge to policymakers and practitioners. For this purpose, potential changes in the built environment were visualized, and used as input in focus group interviews with ELANE participants and meetings with local policymakers. It is recommended that future research on frailty should make a clear distinction between concepts under study (e.g. frailty in relation to PA) and to make use of instruments that are able to distinguish such concepts. Also, it is recommended to evaluate changes to the built environment by making use of quasi-experimental study designs, to further improve the understanding of both underlying mechanisms and reasons for differences in associations between sociodemographic groups. More research is needed that addresses reasons for low initial participation of PA programs for older persons. Besides, it is important to critically examine all PA programs that are offered.

Samenvatting

Het toenemende aantal kwetsbare ouderen is van grote invloed op de gezondheidszorg. Naar verwachting zal het aantal ouderen van 65 jaar en ouder in Nederland toenemen van 2,7 miljoen in 2012 naar 4,7 miljoen in 2050. Van deze ouderen is 6 tot 11% kwetsbaar. Kwetsbare ouderen hebben een grote kans beperkingen in het dagelijks leven te ontwikkelen, wat kan leiden tot langdurige zorg, ziekenhuisopname en wat zelfstandig wonen moelijker maakt. Kwetsbaarheid is een proces, waarbij niet kwetsbare ouderen "pre-frail" worden, en later "frail". Men kan echter herstellen van een kwetsbaar stadium naar een pre-frail stadium en mogelijk ook naar een niet-kwetsbaar stadium. Gegeven dat het ontwikkelingsproces van kwetsbaarheid dus omkeerbaar is of vertraagd kan worden, maakt het ontwikkelen van interventies specifiek gericht op pre-frail ouderen aantrekkelijk. Door beter inzicht in sociaal-demografische determinanten van veranderingen in kwetsbaarheid kunnen doelgroepen worden gedefinieerd voor dergelijke interventies. Het bevorderen van (meer) lichaamsbeweging is mogelijk een van de meest veelbelovende strategieën.

Tegen de achtergrond van de groeiende doelgroep, zijn op de bevolking gerichte interventies gewenst. Dit maakt dat er een toenemende interesse is in de rol van omgevingsdeterminanten voor bewegen en zelfredzaamheid. Interventies en beleid gericht op de aanpassing van de gebouwde omgeving vereisen inzicht in het verband tussen kenmerken van de gebouwde omgeving en bewegen en zelfredzaamheid onder ouderen.

Naast het faciliteren van (ongeorganiseerd) bewegen via beïnvloeding van de omgeving, kunnen ook georganiseerde beweegprogramma's worden aangeboden. Vanwege het grote aanbod van beweegprogramma's voor ouderen, is het van belang kritisch te kijken welke programma's de meeste potentie hebben om kwetsbaarheid te voorkomen. Ook hier is van belang dat die programma's niet alleen leiden tot meer bewegen, maar ook dat de deelname hoog is. Echter blijkt dat er nog steeds weinig bekend is over deelnamecijfers en componenten die het meest effectief zijn om bewegen te stimuleren en op lange termijn zelfredzaamheid te verbeteren.

Dit heeft geleid tot de volgende onderzoeksvragen

1. Welke groepen ouderen hebben een verhoogd risico op achteruitgang in kwetsbaarheid?
2. Welke kenmerken van de gebouwde omgeving zijn belangrijk voor bewegen en zelfredzaamheid onder ouderen?
3. Welke kenmerken van beweegprogramma's kunnen bewegen en zelfredzaamheid onder ouderen bevorderen?

WELKE GROEPEN OUDEREN HEBBEN EEN VERHOOGD RISICO OP ACHTERUITGANG IN KWETSBAARHEID?

In hoofdstuk 2 zijn sociaal-demografische determinanten van veranderingen in kwetsbaarheid onderzocht door gebruik te maken van data van 14424 thuiswonende ouderen van 55 jaar en ouder uit 11 Europese landen, die deel hebben genomen aan de longitudinale "Survey on Health, Aging and Retirement" (SHARE) studie. Er is specifiek gekeken of geslacht, leeftijd, burgerlijke staat en opleidingsniveau geassocieerd waren met achteruitgang in kwetsbaarheid. De kans om achteruit te gaan in kwetsbaarheid was groter voor vrouwen, personen van 65 jaar en ouder en lager opgeleiden. Achteruitgang in kwetsbaarheid begon op jongere leeftijd in Zuid-Europese vergeleken met Noord-Europese landen. Met name in Zuid-Europese landen, hadden vrouwen een grotere kans achteruit te gaan in kwetsbaarheid vergeleken met mannen. In hoofdstuk 3 zijn SHARE data gebruikt om te onderzoeken of opleidingsverschillen in de ontwikkeling van kwetsbaarheid werden gemedieerd door leefstijl, gezondheid en sociale participatie. Rokers, geheelonthouders, chronisch zieken, depressieve personen en personen die niet participeerden in de maatschappij hadden een grotere kans op achteruitgang in kwetsbaarheid. Alcoholconsumptie, de aanwezigheid van chronische ziekten, depressie en sociale participatie waren geassocieerd met zowel opleidingsniveau als achteruitgang in kwetsbaarheid en droegen deels bij aan opleidingsverschillen in de achteruitgang in kwetsbaarheid in alle Europese landen. Op basis van deze studies concludeerden wij dat vrouwen, lager opgeleiden en oudere personen een verhoogde kans hebben op achteruitgang in kwetsbaarheid en dat leefstijl, gezondheid en sociale participatie aangrijpingspunten zijn voor interventies gericht op het omkeren of vertragen van het ontwikkelingsproces van kwetsbaarheid.

WELKE KENMERKEN VAN DE GEBOUWDE OMGEVING ZIJN BELANGRIJK VOOR BEWEGEN EN ZELFREDZAAMHEID ONDER OUDEREN?

Aanleiding voor de studies die zijn beschreven in hoofdstuk 4 en 5 is een systematisch review waarin inconsistente resultaten werden gevonden ten aanzien van de rol van de gebouwde omgeving voor bewegen onder ouderen. Deze inconsistentie is deels toegeschreven aan methodologische beperkingen, waaronder het gebruik van ongeschikte geografische eenheden zoals vooraf gedefinieerde gebieden van een bepaalde grootte (bv. een cirkel met een vooraf bepaalde straal om eenwoning).

In studies in dit proefschrift is gebruik gemaakt van zogenaamde buffers van verschillende groottes, waardoor de variatie in omgevingskenmerken kon verschillen. Deze buffers zijn gebaseerd op wandelpad-netwerken rondom de woningen van ouderen. In hoofdstuk 4 is onderzocht welke gebouwde omgevingskenmerken relevant zijn voor transport-gerelateerd wandelen. Er werd gebruik gemaakt van data van Nederlandse thuiswonende ouderen van 65 jaar en ouder die deelnamen aan de Elderly and their Neighborhood (ELANE) studie (n=408). Verbanden werden onderzocht binnen buffers variërend van 400 tot 1600 meter, en er is gekeken of de verbanden anders waren voor kwetsbare en niet-kwetsbare ouderen. Hogere scores voor esthetiek, meer faciliteiten en minder functioneel ingerichte omgeving rondom de woningen van ouderen waren geassocieerd met meer wandelen voor transport. Het verband tussen faciliteiten en wandelen was sterker in kleine buffers, terwijl de rol van esthetiek sterker was in grotere buffers. Er werden geen associaties met wandelen voor transportdoeleinden gevonden voor verkeersveiligheid en er werden ook geen verschillen gevonden in de verbanden tussen kwetsbare en niet-kwetsbare ouderen. In hoofdstuk 5 zijn associaties tussen de esthetiek, functionele inrichting, verkeersveiligheid en faciliteiten in de woonomgeving en beperkingen in instrumentele activiteiten van het dagelijks leven (IADL) onderzocht. Beperkingen in IADL zijn tweemaal gemeten in een periode van 9 maanden om willekeurige fluctuatie uit te sluiten. Hierbij is gebruik gemaakt van longitudinale ELANE data (n=271). Ook is onderzocht of het verband tussen omgevingskenmerken en zelfredzaamheid door bewegen voor transport werd gemedieerd. De aanwezigheid van meer esthetische kenmerken in de nabije omgeving (binnen 400 meter) was geassocieerd met minder functionele beperkingen. Er werden geen associaties met functionele beperkingen gevonden voor de overige drie domeinen in geen van de buffers. Hogere scores voor esthetiek waren geassocieerd met meer bewegen voor transport en meer bewegen voor transport was geassocieerd met minder functionele beperkingen. De associatie tussen esthetiek en functionele beperkingen werd deels verklaard door bewegen voor transport. Op basis van deze studies werd geconcludeerd dat door aanpassingen van de gebouwde omgeving, met name de esthetiek, mogelijk bewegen voor transport kan worden gestimuleerd en zelfredzaamheid kan worden bevorderd.

WELKE KENMERKEN VAN BEWEEGPROGRAMMA'S KUNNEN BEWEGEN EN ZELFREDZAAMHEID ONDER OUDEREN BEVORDEREN?

Hoofstuk 6 betreft een systematische review waarin deelnamecijfers van beweegprogramma's in kaart zijn gebracht. Er is een selectie gemaakt van 16 studies die het effect van 17 beweegprogramma's op bewegen onder thuiswonende ouderen van 55 jaar en ouder hebben onderzocht. Voor de meeste programma's was het niet mogelijk om het percentage ouderen dat deelname bij aanvang van het programma vast te stellen omdat er geen informatie beschikbaar was over het aantal ouderen dat was uitgenodigd voor deelname. Voor programma's waarvoor deelnamecijfers wel berekend konden worden, was deelname bij de start van het programma laag. Opvallend was dat van de ouderen die een programma gestart waren, het overgrote deel het programma volledig heeft doorlopen. Programma's met de hoogste percentages ouderen die het volledige programma hebben doorlopen, kenmerkten zich door relatief veel jonge deelnemers, veel deelnemende vrouwen, een korte duur en een kleine groepsgrootte.

In hoofdstuk 7 is de rol van sportdeelname, -duur, -intensiteit en -energieverbruik (duur*intensiteit) voor zelfredzaamheid bestudeerd op basis van ELANE data (n=276). Associaties werden getest tussen de vier sportmaten en zelfredzaamheid, die beide tweemaal gemeten waren in negen maanden. Ouderen die aan sport deden, rapporteerden minder beperkingen vergeleken met ouderen die niet aan sport deden. Geen associatie werd gevonden tussen sportduur en IADL beperkingen, terwijl een toename in sportintensiteit was geassocieerd met minder beperkingen (onafhankelijk van sportduur). Daarnaast was een toename in energieverbruik geassocieerd met minder IADL beperkingen.

Op basis van deze studies werd geconcludeerd dat meer inzicht nodig is hoe participatie van ouderen bij aanvang van beweegprogramma's geoptimaliseerd kan worden. Gezien het grote aanbod aan beweegprogramma's voor ouderen, is meer onderzoek nodig naar programma's die de meeste potentie hebben om gezondheid te bevorderen. Zwaarder intensief bewegen is een mogelijk relevant element van beweegprogramma's gericht op het verbeteren van zelfredzaamheid onder thuiswonende ouderen. Omdat dergelijke programma's denkbaar minder aantrekkelijk zijn om aan deel te nemen vergeleken met minder intensieve beweegprogramma's, moet in ogenschouw worden genomen dat het bereik lager zou kunnen zijn dan dat van minder intensieve programma's.

DISCUSSIE EN AANBEVELINGEN

Aanvullend op de hoofdresultaten en de interpretatie hiervan, bevat hoofdstuk 8 methodologische overwegingen, beschrijft het activiteiten die zijn ondernomen om kennis over te dragen en worden aanbevelingen gedaan voor toekomstig onderzoek, beleid en praktijk. De methodologische overwegingen betreffen het meten van kwetsbaarheid, bewegen en omgevingskenmerken, de diversiteit in methoden toegepast in dit proefschrift en een discussie over causaliteit. Om inzicht te krijgen in mogelijkheden bewegen onder ouderen te stimuleren door aanpassingen aan de gebouwde omgeving, zijn activiteiten ondernomen om kennis uit te wisselen met beleidsmakers en praktijkorganisaties. Hiertoe werden potentieel effectieve veranderingen in de gebouwde omgeving gevisualiseerd en gebruikt als input voor focusgroep-interviews met ELANE deelnemers en bijeenkomsten met lokale beleidsmakers. Het wordt aanbevolen in toekomstig onderzoek helder onderscheid te maken tussen concepten die bestudeerd worden (bv. kwetsbaarheid in relatie tot bewegen) en daarbij gebruik te maken van instrumenten die het mogelijk maken dergelijke concepten te onderscheiden. Daarnaast wordt aanbevolen veranderingen in de gebouwde omgeving te evalueren door gebruik te maken van quasi-experimentele studie-designs om zowel onderliggende mechanismen en redenen voor verschillen in associaties tussen sociaal-demografische groepen beter te kunnen begrijpen. Meer onderzoek is nodig naar redenen van lage deelnamecijfers van beweegprogramma's voor ouderen. Daarnaast is het van belang dat het aanbod van beweegprogramma's kritisch wordt onderzocht.

Dankwoord

Beste lezer,

Uw kennis op het gebied van kwetsbaarheid en de rol van de gebouwde omgeving en beweegprogramma's voor ouderen is door het lezen van dit proefschrift verder gegroeid of wellicht bent u juist begonnen met het lezen van dit hoofdstuk. In beide gevallen geldt dat voor hetgeen u gelezen heeft (of nog gaat lezen) mijn omgeving een belangrijke rol gespeeld heeft.

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Lieve vriendinnen, het feit dat jullie altijd voor me klaar staan en zorgen voor de juiste dosis ontspanning, betekent heel veel voor mij. Sorry dat ik wat minder initiatiefrijk geweest ben de afgelopen tijd. Nu mijn promotie een feit is, kunnen we elkaar gelukkig weer wat vaker zien. Mam, pap, schwes, bedankt voor jullie steun gedurende het hele traject. Mam, bedankt voor de extra stapels die je hebt weggestreken en de extra keren oppassen zodat ik tijd overhield om dit proefschrift te kunnen schrijven. Dankjewel paps voor je nuchtere en rationele kijk op alles. Bij jou kon ik altijd terecht als de boel weer even gerelativeerd moest worden. Ook Theo en Nel, lieve schoonouders, dank jullie wel voor alle steun en goede zorgen voor Roan. Lieve oma, u bent een grote inspiratiebron geweest voor mijn onderzoek. Zonder uw genen had ik dit niet voor elkaar gekregen!

Lieve Marcel, met trots staat dit proefschrift nu op naam van Schop-Etman. Dankjewel voor alles! Je bent mijn allergrootste steun en zal dit altijd blijven (lekker cliché maar heel erg waar). Waar nodig nam je wat hooi van mijn vork af waardoor ik me op de juiste zaken kon focussen. Tijdens mijn promotietraject hebben we elkaar ontmoet en veel moois meegemaakt: samenwonen, verhuizen, reizen, geboorte van Roan, trouwen, zal ons grote-mensen-huis gebouwd worden en dan nu mijn promotie. Laten we hier nog vele mooie herinneringen aan toevoegen! Lieve, lieve Roan, je wilde maar al te graag helpen met typen. Het is maar goed dat met jou in de buurt, ik mijn laptop bewust moest wegleggen en de boel de boel moest laten.

Tot slot: dankjewel Rotterdam! Door te lopen door je straten, je van bovenaf te bekijken of aan je te denken, heb ik de nodige inspiratie opgedaan voor mijn onderzoek. Nadat ik de eerste helft van mijn promotietraject in het Ae-gebouw van het Erasmus MC tegen een stuk beton van de garage aankeek, kon ik in de tweede helft van het uitzicht genieten vanaf de 21^{e} en later 23^{e} verdieping. Dit moet mijn onderzoek wel ten goede gekomen zijn. Ik heb trots dat ik in je mooiste gebouw De Rotterdam heb mogen wonen en je bent voorlopig nog niet van me af.

Wat een heerlijk gevoel om nog een laatste keer te kunnen zeggen: iedereen ontzettend bedankt voor alles! Het was een bijzonder boeiende en leerzame tijd.

Liefs,
Astrid

List of publications

THIS THESIS

Astrid Etman, Carlijn BM Kamphuis, Frank H Pierik, Alex Burdorf, Frank J van Lenthe. Residential area characteristics and disability among Dutch community-dwelling older adults. *Int J Health Geogr 2016 Nov 15;15(1):42*

Astrid Etman, Frank H Pierik, Carlijn BM Kamphuis, Alex Burdorf, Frank J van Lenthe. The role of high-intensity physical exercise in the prevention of disability among community-dwelling older people. *BMC Geriatrics 2016,Nov 9;16(1):183*

Astrid Etman, Carlijn BM Kamphuis, Tischa JM van der Cammen, Alex Burdorf, Frank J van Lenthe. Do lifestyle, health and social participation mediate educational inequalities in frailty worsening? *Eur J Public Health 2015 Apr;25(2):345-50*

Astrid Etman, Carlijn BM Kamphuis, Rick G Prins, Alex Burdorf, Frank H Pierik, Frank J van Lenthe. Characteristics of residential areas and transportational walking among frail and non-frail Dutch older persons: does the size of the area matter? *Int J Health Geogr 2014 Mar 4;13:7*

Mariëlle van der Deijl, Astrid Etman, Carlijn BM Kamphuis, Frank J van Lenthe. Participation levels of physical activity programs for community dwelling older persons: a systematic review. *BMC Public Health 2014 Dec 18;14:1301*

Astrid Etman, Alex Burdorf, Tischa JM van der Cammen, Johan P Mackenbach, Frank J van Lenthe. Socio-demographic determinants of worsening in frailty among community-dwelling older persons in 11 European countries. *J Epidemiol Community Health 2012;66(12):1116-1121*

OTHER PUBLICATIONS

Astrid Etman. Column: Gezond ouder in de stad. *AGORA magazine 2016-3, jaargang 32*

Marijke Jansen, Rick G Prins, Astrid Etman, Hidde P van der Ploeg, Sanne I de Vries, Frank J van Lenthe, Frank H Pierik. Physical activity in non-frail and frail older adults. *PLoS One 2015 Apr 24;10(4):e0123168*

Carlijn BM Kamphuis, Astrid Etman, Joost Oude Groeniger, Frank J van Lenthe. Relatie van de fysieke omgeving met leefstijl, redzaamheid en sociale verbindingen. In opdracht van Raad voor Volksgezondheid en Samenleving, maart 2015

Rick G Prins, Frank H Pierik, Astrid Etman, Reinier P Sterkenburg, Carlijn BM Kamphuis, Frank J van Lenthe. How many walking and cycling trips made by elderly are beyond commonly used buffer sizes: results from a GPS study. *Health Place 2014 May;27:127-33*

Astrid Etman, Gert-Jan Wijlhuizen, Marieke J van Heuvelen, Astrid Chorus, Marijke Hopman-Rock. Falls incidence underestimates the risk of fall-related injuries in older age groups: a comparison with the FARE (Falls risk by Exposure). *Age and Ageing 2012; Mar;41(2):190-195*

SUBMITTED

Frank J van Lenthe, Astrid Etman, Carlijn BM Kamphuis, Rick G Prins, Marijke Jansen, Charlotte Cammelbeeck, Reinier Sterkenburg, Frank H Pierik. Naar een beweegvriendelijke omgeving: een studie naar kenmerken van de woonomgeving en beweeggedrag van ouderen in Spijkenisse. *Accepted for publication in Tijdschrift voor Gezondheidswetenschappen (TSG; journal for health sciences)*

Carlijn BM Kamphuis, Rick G Prins, Astrid Etman, Reinier P Sterkenburg, Frank H Pierik, Frank J van Lenthe. Combining GPS- and accelerometer-data for a spatial match between area characteristics and physical activity among Dutch older adults.

Annemieke CM Nanne, Bianca F Fong, Astrid Etman, Lieneke van Wensveen, Laila de Groot, Hanneke IP de Vries. The effect of breech position on General Movements after birth in healthy born infants.

PhD portfolio

PHD TRAINING AND TEACHING

Name: Astrid Schop-Etman
Erasmus MC Department: Public Health
Research school: Netherlands Institute for Health Sciences (NIHES)
PhD period: August 2010 – August 2014
Promotoren: Prof.dr. A Burdorf, Prof.dr. FJ van Lenthe

	Year	Workload (ECTS)
PhD TRAINING		
General academic skills		
Presentation course	2012	0.3
Time and project management course for PhD students	2012	0.6
Workshop academic writing	2012	0.3
Didactic training	2013	0.3
Workshop Project Management	2015	0.3
Media contacts for researchers	2015	0.3
Research Integrity for PhD students	2016	0.3
In depth courses		
MSc. Health Sciences: Public Health, NIHES Rotterdam, the Netherlands	2010-2013	70.0
Short course Evaluating Complex Public Health Interventions, Development and Evaluation of Complex Interventions for Public Health Improvement (DECIPHer), Cardiff, Wales	2015	1.4
Conferences		
Conference on Integrated Care for Frail Older People, Leiden, the Netherlands: attendance	2011	0.2
Geriatrisch Netwerk Rotterdam (GENERO) symposium 'Ouderen en professionals: Samen bouwen aan zorg en welzijn van de toekomst', Rotterdam, the Netherlands: attendance and poster presentation 'De rol van de fysieke omgeving voor zelfredzaamheid van kwetsbare ouderen'	2011	0.2
World Congress on Active Ageing (WCAA) 2012, Glasgow, Scotland: attendance and oral presentation 'Sociodemographic determinants of worsening in frailty among community-dwelling elderly in 11 European countries'	2012	1.3
Conference 'Ruimte voor gezondheid' University Medical Center Groningen: oral presentation 'Langer vitaal in de stad'	2012	0.2

11^{e} Nationaal Gerontologiecongres 'Gelukkig worden we ouder!?', Ede, the Netherlands: attendance and oral presentation 'Hoe kunnen opleidingsverschillen in achteruitgang in kwetsbaarheid worden verklaard?'	2012	0.3
GENERO symposium 'Ouderen langer zelfstandig: innovaties voor een wijkgerichte aanpak in zorg en welzijn', Rotterdam, the Netherlands: attendance and poster presentation 'NPO-project: De rol van de fysieke omgeving voor zelfredzaamheid van ouderen: eerste resultaten'	2013	0.1
International Society for Behavioral Nutrition and Physical activity (ISBNPA) 2014, San Diego, USA: attendance and oral presentation 'Characteristics of residential areas and transportational walking among older adults: Does the size of the area matters?'	2014	1.4
ISBNPA 2015, Edinburgh, Scotland: attendance and poster presentation 'Residential area characteristics and functional limitations among Dutch community-dwelling older adults'	2015	1.1

Seminars

Seminars of the Department of Public Health, Erasmus MC Rotterdam, the Netherlands	2010-2016	3.6
SHARELIFE release (wave 3) - Survey of Health, Ageing and Retirement in Europe, Brussels, Belgium	2010	0.1
Seminar Moving away from frailty, Vereniging voor Bewegingswetenschappen Nederland, Amsterdam, the Netherlands	2011	0.1
Themadag: Wat staat er te gebeuren in de ouderenzorg?, Berkel en Rodenrijs, the Netherlands	2012	0.2
Minisymposium Beweegvriendelijke Omgeving, Rotterdam, the Netherlands	2013	0.1
Lezing Het Fitte Brein, Rotterdam, the Netherlands	2014	0.1

Other presentations

Section meeting Social Epidemiology, Department of Public Health Erasmus MC Rotterdam, the Netherlands: oral presentation 'What determines worsening in frailty among elderly?'	2011	0.1
Research meeting Department of Public Health, Erasmus MC Rotterdam, the Netherlands: oral presentation 'Sociodemographic determinants of frailty changes among elderly'	2012	0.1

Bijeenkomst Centre for Effective Public Health In the larger Rotterdam area (CEPHIR), Rotterdam, the Netherlands: oral presentation 'Kwetsbaarheid onder ouderen'	2013	0.1
Section meeting Social Epidemiology, Department of Public Health Erasmus MC Rotterdam, the Netherlands: oral presentation 'Neighbourhood characteristics and transportational walking among the elderly'	2014	0.1
Expertmeeting Kenniscentrum Sport, Ede, the Netherlands: oral presentation 'Ouderen en een beweegvriendelijke omgeving'	2014	0.1
Workshop 'Invloed gebouwde omgeving op bewegen en zelfredzaamheid van ouderen', Rotterdam, the Netherlands: oral presentation 'De rol van de gebouwde omgeving voor bewegen en zelfredzaamheid van ouderen'	2014	0.3

TEACHING ACTIVITIES

Teaching

Supervision of third year medical students' community projects	2011, 2013-2015	2.4
Skills training third year medical students 'Primaire Preventie in de arstenpraktijk'	2013-2014, 2016	1.2
Minor Public Health, lecture 'De Gezonde Grote Stad': 'Ouderen en de fysieke omgeving: Een proeverij van methoden'	2013	0.2
Honours course 'Vitality matters', Leyden Academy on Vitality and Ageing, Leiden, the Netherlands: oral presentation 'Residential area characteristics important for walking for transport among older adults'	2014	0.2
Guest lecture master program 'Vitality and Ageing' at Leyden Academy on Vitality and Ageing, Leiden: 'The built environment and physical activity among older people'	2015	0.2
Lecture 'Healthy aging' Utrecht University: oral presentation 'The role of the built environment for physical activity and functional limitations'	2016	0.2

Supervising master's theses

Supervision of master student Urbanism, department of Architecture, Delft University of Technology. Thesis title 'Greying Cities'	2012	1.0
Supervision of master student Sports and Physical Activity Interventions, Maastricht University. Thesis title 'What moves community-dwelling elderly to be physically active?'	2013	1.0

Supervision of bachelor student Human Geography and Spatial Planning, faculty of Geoscience, Utrecht University. Thesis title 'Kwaliteit van leven van ouderen in de stad'	2014	1.0

OTHER ACTIVITIES

Reviewer several international scientific journals (American Journal of Epidemiology, International Journal of Behavioral Nutrition and Physical Activity, Journal of Palliative Care, Preventive Medicine)	2013-2014	0.6

TOTAL		91.6

About the author

Astrid Schop-Etman was born on May 21st 1986 in Schiedam, the Netherlands. In 2004, she completed secondary school at SG Spieringshoek in Schiedam. Subsequently, she started studying at the University of Groningen where she obtained a bachelor's degree in Human Movement Sciences in 2007. She obtained a master's degree at the Free University of Amsterdam in 'Clinical Rehabilition and Physiotherapy' in 2008, and a master's degree in 'Movement, Aging, and Health' at the University of Groningen in 2010 (both related to Human Movement Sciences). At the Netherlands Organisation for Applied Scientific Research TNO (location: Leiden) she worked as an intern during her master's 'Movement, Aging, and Health', and afterwards as a junior researcher. In 2010, she started her PhD at the Department of Public Health at the Erasmus MC in Rotterdam. During her PhD, she completed a Master of Science degree, specialisation Public Health, in 2013 at the Netherlands Institute for Health Sciences. From August 2014, Astrid is working as a junior researcher at the Department of Public Health at the Erasmus MC. Her PhD research resulted in this thesis.

Astrid Schop-Etman werd geboren op 21 mei 1986 te Schiedam. In 2004 behaalde zij haar VWO-diploma aan de SG Spieringshoek in Schiedam. In september van hetzelfde jaar startte zij de studie Bewegingswetenschappen aan de Rijksuniversiteit Groningen en haalde haar Bachelordiploma in 2007. Haar Masterdiploma met afstudeerrichting 'klinische revalidatie en fysiotherapie' behaalde zij in 2008 aan de Vrije Universiteit in Amsterdam. Hierna is zij voor een korte periode teruggekeerd naar Groningen om een tweede Masteropleiding in 'bewegen, veroudering en gezondheid' af te ronden in 2010. Tijdens deze masteropleiding heeft zij onderzoek gedaan bij TNO (lokatie Leiden). Na haar stage, is zij hier werkzaam geweest als junioronderzoeker. Van augustus 2010 tot augustus 2014 was zij aangesteld als onderzoeker in opleiding op de afdeling Maatschappelijke Gezondheidszorg (MGZ) van het Erasmus MC in Rotterdam. Gelijktijdig volgde ze de onderzoeks-masteropleiding aan het NIHES (Netherlands Institute for Health Sciences) en behaalde in augustus 2013 haar MSc-diploma met specialisatie Public Health. Sinds augustus 2014 werkt Astrid als junioronderzoeker op MGZ. Haar promotieonderzoek resulteerde in dit proefschrift.

Astrid Schop-Etman:

Beweegstimulering is een veelbelovende strategie om kwetsbaarheid en bijkomende beperkingen in het dagelijks leven van ouderen te voorkomen. Naast het faciliteren van ongeorganiseerd bewegen in de gebouwde omgeving, kunnen ook georganiseerde beweegprogramma's worden aangeboden. Dit proefschrift biedt inzicht en aanbevelingen voor onderzoek, beleid en praktijk met betrekking tot het verloop van kwetsbaarheid en de rol van de gebouwde omgeving en beweegprogramma's voor bewegen en zelfredzaamheid onder ouderen.