Cross-sectional and longitudinal associations of environmental factors with frailty and disability in older people

Cross-sectional and Longitudinal Associations of Environmental Factors with Frailty and Disability in Older People

Abstract

Purpose: To determine cross-sectional and longitudinal associations of environmental factors with frailty and disability.

Methods: This study was conducted in a sample of Dutch citizens. At baseline the sample consisted of 429 subjects (aged ≥ 65 years); a subset of this sample participated again two and half years later (N = 355). The participants completed a web-based questionnaire, “the Senioren Barometer”, comprising seven scales for assessing environmental factors, and the Tilburg Frailty Indicator (TFI) and the Groningen Activity Restriction Scale (GARS), for assessing frailty and disability, respectively. Environmental factors of interest were: nuisance; housing; facilities; residents; neighborhood; stench/noise; and traffic.

Results: Sequential regression analyses demonstrated that all environmental factors together explained a significant part of the variance of physical and social frailty and disability in performing activities of daily living (ADL) and instrumental activities of daily living (IADL), measured at Time 1 (T1) and Time 2 (T2). These analyses also showed that four of the environmental factors were associated with at least one of the outcome measures: housing, nuisance, residents, and neighborhood. Housing was the only environmental factor associated with three different outcome measures (social frailty, ADL disability, IADL disability), assessed at T1 and T2.

Conclusion: The findings offer health-care and welfare professionals and also policymakers starting points for interventions. These interventions should focus, in particular, on housing, nuisance, residents, and neighborhood, because their impact on frailty and/or disability was the largest.

Keywords: Older people; Frailty; Disability; Environmental factors, Tilburg Frailty Indicator, Groningen Activity Restriction Scale

1. Introduction

Population aging is occurring all over the world (United Nations Department of Economic and Social Affairs 2015). It has been forecast that by 2050, 33.2% of the population in the Netherlands will be 60 years or older (United Nations Department of Economic and Social Affairs 2015). In the Netherlands older people are motivated to "aging in place." The goals of "aging in place" are twofold. First, from the perspective of older people, most of them would like to stay at home surrounded by their family and friends for as long as possible, and to remain active, autonomous, and independent (Cutchin 2003; Horner and Boldy 2008; Mitzner et al. 2014). In addition, it enables them to keep their well-being and identity; institutionalization is considered to be the last resort. Second, from the perspective of policymakers, institutionalization is much more expensive than the provision of care in the community (Marek et al. 2012); this means that admission to a nursing home is only possible for severely dependent older people, including people with advanced dementia.

Related to the aging population is the increase in the number of people with frailty and/or disability. The Netherlands Institute for Social Research has forecast that the number of frail older people aged 65 years or older will continue to grow from 700,000 in 2010 to more than a million in 2030 (Van Campen et al. 2011). Prevalence figures of frailty in community-dwelling older people range from 4.0–59.1% (Collard et al. 2012). This strongly depends on the approach to frailty, i.e. whether it is considered only in terms of physical problems experienced by older people, or whether a multidimensional approach that also includes psychological and social problems is used. Based on previous studies that emphasize the relevance of using a multidimensional approach to frailty in relation to quality of life among older people in the Netherlands (Gobbens and van Assen 2014, 2017), we adopt the following definition of frailty in the present study: "Frailty is a dynamic state affecting an individual who experiences losses in one or more domains of human functioning (physical, psychological, social), which is caused by the influence of a range of variables and which increases the risk of adverse outcomes" (Gobbens et al. 2010b). Previous studies have shown that the physical, psychological and social domains of frailty are closely related (Gobbens et al. 2010c; Mulasso et al. 2016). Frailty could be considered as a preliminary stage of disability (Abellan van Kan et al. 2008).

Besides frailty, disability is also common among older people (Tas et al. 2007b). A recent study showed that 25.2% of Dutch people aged 75 years or older were disabled (Gobbens 2018). Disability is frequently defined as experiencing difficulty in carrying out activities that are essential to independent living, distinguishing activities of daily living (ADL) and instrumental activities of daily living (IADL) (Fried et al. 2004; Tas et al. 2007a; Vermeulen et al. 2013). Examples of ADL are “wash and dry your whole body” and “get on and off the toilet,” and examples of IADL are “prepare dinner” and “do the shopping.” In general, older people first experience disability in IADL and then in ADL; disability in ADL is a more severe form (Wong et al. 2010).

Both frailty and disability are associated with the same adverse outcomes in older people. Well-known adverse outcomes are: increased health-care utilization (Boyd et al. 2005; Gobbens et al. 2012; Rockwood et al. 2005), lower quality of life (Gobbens and van Assen 2014; Gobbens 2018), and premature death (Fried et al. 2001; Wei et al. 2018). Health- and social-care professionals must carry out interventions to prevent or at least postpone these adverse outcomes. Moreover, it is important to gain more knowledge about the determinants of frailty and disability; this provides a basis for early intervention. According to Gobbens et al. (2010a), dissatisfaction with the living environment is one of the determinants of frailty. Because aging in place” is now a topical theme, it has become increasingly important to obtain more insight into the effects of environmental factors on both frailty and disability.

To the best of our knowledge, not many studies have yet been conducted focusing on the associations between the environmental factors and frailty as well as disability. The Comprehensive Frailty Assessment Instrument (CFAI) is the only frailty instrument containing an environmental domain, including five items referring to housing (four items), and neighborhood (one item) (De Witte et al. 2013a). The CFAI was validated against the Tilburg Frailty Indicator (TFI), showing significant but weak correlations of the environmental domains with the physical, psychological, and social domains of the TFI (De Witte et al. 2013b). Cramm and Nieboer (2013) carried out a study among 945 Dutch community-dwelling older people aged 70 years or older, showing that feeling more secure in the neighborhood and having a stronger sense of social cohesion and neighborhood belonging are factors to protect against multidimensional frailty. Duppen et al. (2017) underline the importance of the social

environment in reducing or preventing frailty in older people. They argue that a broad approach to the social living environment of older people has to be taken into account when conducting studies focusing on prevention programs and community care aimed at targeting frailty. Furthermore, using data from the Hispanic Established Populations for Epidemiologic Studies for the Elderly (H-EPESE), including 963 Mexican Americans over 75 years of age, a protective neighborhood effect against physical frailty was demonstrated; ethnic homogeneity protected against the increasing state of physical frailty, independent of individual risk factors (e.g. age, number of medical conditions) (Aranda et al. 2011). The analysis of data from the 2000 U.S. Census for residents of New York City found strong associations between the prevalence of two types of disability (physical disability, going-outside-the-home disability) and several neighborhood characteristics (less residential stability) (Beard et al. 2009).

The aim of the present study was to determine associations of environmental factors with frailty and disability. The study is distinctive because it not only considers cross-sectional associations but also longitudinal associations between environmental factors and both frailty and disability. In addition, we examined these associations on the frailty domain (physical, psychological, social) and on the type of disability (ADL, IADL) level. In order to give a comprehensive picture of the satisfaction of older people with the environment in which they live, we included seven environmental factors. This provides policymakers, practitioners and researchers with specific information with regard to interventions aimed at preventing frailty and/or disability in older people.

2. Methods

2.1 Study population and data collection

The “Senioren Barometer” was used to collect the data. This is a web-based questionnaire to assess the opinions of Dutch people aged 50 years or older about different aspects of their life, e.g. frailty, disability, environmental factors. Older people can volunteer to take part and participation is always without obligation. More

information concerning the “Senioren Barometer” can be found in previous studies (Gobbens et al. 2013; Gobbens et al. 2014).

From December 2009 to January 2010 (Time 1) (T1), 1492 respondents completed at least part of the questionnaire, of whom 1031 filled out the part on frailty, disability and environmental factors; 723 (70.1%) of these respondents also completed this part of the questionnaire two and a half years later in May and June 2012 (Time 2) (T2). For this study the respondents aged 65 years or older were selected, because frailty and disability are related to greater age; 429 of these respondents completed all relevant parts at baseline and 355 (83%) of these did so at follow-up. This sample has been used before in a study aiming to assess the predictive power of eight physical frailty components for disability (Gobbens et al. 2014).

2.2 Ethical considerations

Medical-ethics approval was not necessary as particular treatments or interventions were not offered or withheld from the respondents. The integrity of the respondents was not encroached upon as a consequence of participating in the study, which is the main criterion in medical-ethical procedures in the Netherlands (Central Committee on Research inv. Human Subjects 2010). Informed consent, in terms of information-giving and maintaining confidentially, was respected.

2.3 Measurements

2.3.1 Frailty

Frailty was assessed by the Tilburg Frailty Indicator (TFI), a self-report questionnaire based on an integral approach to frailty (Gobbens et al. 2010c). The TFI contains two parts; part one includes ten items referring to determinants of frailty and part two includes 15 items referring to components of frailty. In this study only part two was used. Total frailty has a range of 0 to 15, with persons scoring 5 or higher considered to be frail (Gobbens et al. 2010c). Eight, four and three items, belong to physical, psychological and social frailty, with score ranges 0 to 8, 0 to 4, and 0 to 3,

respectively. Higher scores refer to greater frailty. The physical domain of frailty consists of the components: low physical activity, unexplained weight loss, difficulty in walking, difficulty in maintaining balance, vision problems, hearing problems, lack of strength in the hands and physical tiredness. The psychological domain includes: problems with memory, feeling down, feeling anxious or nervous and unable to cope with problems. The social domain consists of the components; living alone, lack of social relations and lack of social support. Many studies, including studies in the Netherlands, have shown that the TFI is a reliable and valid instrument for measuring frailty among community-dwelling older people (Gobbens et al. 2010c; Gobbens et al. 2012; Santiago et al. 2013; Uchmanowicz et al. 2016).

2.3.2 Disability

Disability was assessed by the Groningen Activity Restriction Scale (GARS), a self-report questionnaire containing 18 items (Kempen and Suurmeijer 1990; Suurmeijer et al. 1994). The total score ranges from 18 to 72, with individuals scoring 29 or higher considered to be disabled (Ormel et al. 2002). Eleven items relate to ADL and eight items relate to IADL. The score ranges from 11 to 44 and from 7 to 28 for the ADL and the IADL scales, respectively; higher scores indicate greater disability. For a description of the 18 items we refer to aforementioned studies. The psychometric properties of the GARS are good (Kempen et al. 1996; Suurmeijer et al. 1994).

2.3.3 Environmental factors

Seven environmental factors were considered: nuisance; housing; facilities; residents; neighborhood; stench/noise; and traffic. We used the scales developed by Gobbens and van Assen (2018), comprising 3–9 items (see Table 1). In our study, all higher scores refer to more satisfaction with an environmental factor. The reliabilities (Cronbach's alpha) ranged in the present study from 0.656 (stench/noise) to 0.905 (housing) (see Table 1).

Table 1. Scales for environmental factors, with items (numbers and wording), maximum and minimum scores, and reliability (Cronbach's alpha) per scale

Environmental factor (Cronbach's alpha)	Number of items	Minimum and maximum scores	Items
Nuisance (0.855)	9	9 - 38	Vandalism, crime, social insecurity in the evening, pollution, social insecurity during the day, nuisance of other groups, pets of others, adolescents' behavior, safety own neighborhood
Housing (0.905)	5	5 - 25	Comfort level of housing, housing as a whole, property size, number of rooms, housing facilities
Facilities (0.776)	7	7 - 35	Sport, recreation, shopping, neighborhood, entertainment, public transport, leisure
Residents (0.872)	8	8 - 39	Behavior of immediate neighbors, behavior of other local residents, residents' cultural composition, age structure of residents, neighbors, interaction between different groups, involvement with local residents, neighborhood demographics
Neighborhood (0.772)	4	4 - 20	Landscaping, paving, appearance of buildings, street etc., street lighting
Stench/noise (0.656)	3	3 - 12	(Legal) soft-drug locations, restaurant and bar, market, industry
Traffic (0.694)	4	4 - 17	Noise, danger, parked cars/bikes, parking facilities

2.3.4 Socio-demographic characteristics

The socio-demographic characteristics considered were: age, sex, marital status, educational level and net monthly income. Table 2 presents detailed information about the socio-demographic characteristics.

2.4 Data analysis

In this study, we used the data collected at T1 for the cross-sectional regression analyses (socio-demographic characteristics, environmental factors, frailty, disability); for the longitudinal regression analyses we used the socio-demographic characteristics and environmental factors assessed at T1 and both frailty and disability assessed at T2.

First, we determined the characteristics of the sample using descriptive statistics. Second, the scores on the environmental scales for non-frail and frail as well as for non-disabled and disabled older people were compared using Student's *t*-tests assuming unequal population variances. Effect sizes were assessed with Cohen's *d* (0.2, 0.5, and 0.8 corresponding to small, medium, and large effect sizes, respectively (Cohen 1988). Before we carried out regression analyses, the variables sex and marital status were coded. Sex was classified as "1" for women and "0" for men. Marital status was classified as "1" for married/cohabiting and "0" for the rest. Moreover, in accordance with previous studies, we incorporated linear effects of age, education and net month income in our analyses (Gobbens et al. 2014; Van Assen et al. 2016). Due to a low prevalence of non-Dutch people (3.7%) (see Table 2) we did not include ethnicity in our further analyses.

Bivariate analyses between each socio-demographic characteristic and environmental factors on the one hand, and the frailty domains (physical, psychological, social) and disability types (ADL, IADL) on the other, were tested using regression analyses. Then, we used sequential multiple regression analyses for assessing the effects of the individual environmental factors on the three frailty domains and the two types of disability. Before conducting these analyses, we tested the occurrence of multicollinearity between the predictive variables (background characteristics, ADL items, IADL items). A high level of multicollinearity is illustrated by a correlation between these variables ≥ .7 and a variance inflation factor (VIF) > 5

(Yu et al. 2015). All correlations between the variables were less than .7; the strongest correlation existed between the environmental factors nuisance and traffic (r = 0.512). The VIF ranged from 1.042 to 1.954, which excluded multicollinearity between the independent variables. Thus, all variables were included in the sequential linear regression analyses.

Both the cross-sectional and longitudinal regression analyses consisted of two blocks; the first block contained the socio-demographic characteristics of the participants (age, sex, marital status, educational level, net month income) and the second block contained the seven environmental factors (nuisance, housing, facilities, residents, neighborhood, stench/noise, traffic). The second block enabled the testing of the effect of the individual environmental factors on frailty domains and disability types, after controlling for all the other variables in the model. We carried out these analyses twice. The first time, we carried out cross-sectional regression analyses; socio-demographic characteristics and environmental factors were the independent variables and frailty and disability were the dependent variables in the model (all assessed at T1). The second time, we conducted longitudinal regression analyses; we included the same independent variables in the model (assessed at T1) with either frailty or disability assessed at T2 (two and a half years later) as dependent variables.

Power analysis using G*Power 3.1 (Faul et al. 2007) showed that the sequential multiple regression analyses on 355 participants had a power of at least 80% to detect an effect of Cohen's f^2 = .042, which is a small effect size (Cohen 1988). All statistical analyses were conducted using SPSS version 22.0 (IBM Corporation, Armonk, NY, USA). A p-value <0.05 was considered statistically significant.

3. Results

3.1 Participant characteristics

The previous study by Gobbens et al. (2014) showed that dropouts (n = 74) had lower education and were more disabled than those who did not drop out (n = 355). In addition, no significant differences were found with respect to age, sex, marital

status, net monthly income, the two continuous disability measures and the four frailty measures.

Table 2 presents the characteristics of the participants who completed the "Senioren Barometer" at T1 and T2. The mean age of the participants was 72.4 years (standard deviation 5.3; range 65−87). In total, 65.6% were men, 70.4% were married or cohabiting, most of them had secondary educational level (45.6%), and 16% had a net monthly income < €1500. The prevalence of frailty and disability was 25.6% and 9.6%, respectively.

Table 2. Characteristics of the participants at baseline, T1 (N=355)

Characteristic	N=355 *n (%)*
Age, mean ± SD, range	72.4 ± 5.3, 65−87
Sex, % of men	233 (65.6)
Marital status	
Married or cohabiting	250 (70.4)
Not married/single	38 (10.7)
Divorced	22 (6.2)
Widowed	41 (11.5)
Living apart together	4 (1.1)
Ethnicity	
Dutch	342 (96.3)
Other	13 (3.7)
Education	
None	15 (4.2)
Primary	26 (7.3)
Secondary	162 (45.6)
Polytechnic and higher vocational training	122 (34.4)
University	30 (8.5)
Net monthly Income*	
€999 or less	7 (2.1)
€1000 − €1499	46 (13.9)
€1500 − €1999	55 (16.7)
€2000 − €2499	80 (24.2)
€2500 − €2999	46 (13.9)
€3000 − €3499	41 (12.4)
€3500 − €3999	26 (7.9)
€4000 − €4499	14 (4.2)
€4500 or more	15 (4.5) -
Environmental factors, mean ± SD, range	
Nuisance	30.8 ± 5.0, 13−38
Housing	21.7 ± 3.2, 5−25
Facilities	24.1 ± 4.1, 10−35
Residents	30.3 ± 4.4, 11−39
Neighborhood	15.4 ± 2.6, 8−20
Stench/noise	11.4 ± 1.2, 6−12
Traffic	13.8 ± 2.7, 4−17
Frailty	
Physical frailty, mean ± SD	1.3 ± 1.6
Psychological frailty, mean ± SD	0.8 ± 0.96

Social frailty, mean ± SD	0.9 ± 0.93
Disability	
ADL disability, mean ± SD	12.4 ± 2.9
IADL disability, mean ± SD	9.2 ± 3.4

* 25 missing values (7.0%)
ADL = Activities of Daily Living; IADL = Instrumental Activities of Daily Living

3.2 Differences between groups on environmental factors

Table 3 presents the results of the *t*-tests aimed at testing the differences in the scores of the non-frail and frail participants as well as non-disabled and disabled participants on the seven environmental factors: nuisance, housing, facilities, residents, neighborhood, stench/noise, and traffic. Frail participants scored lower on six and five of the environmental factors in 2009 and 2012, respectively. No significant differences between the two groups appeared with respect to neighborhood. The effect sizes varied from 0.26 (stench/noise) to 0.60 (residents); the Cohen's *d* of residents and nuisance was 0.60 and 0.50 in 2009, respectively, indicating medium effect sizes (Cohen 1988). Comparing the scores between the non-disabled and disabled participants showed that disabled participants scored lower on nuisance and housing in 2009 and nuisance, housing, facilities, residents and traffic in 2012, with effect sizes varying from 0.34 (facilities in 2012) to 0.76 (nuisance in 2009); the Cohen's *d* of nuisance, residents and housing was 0.76 in 2009, 0.65 and 0.54 in 2012, respectively, indicating medium effect sizes (Cohen 1988).

Table 3. Comparison of environmental factors between frail and non-frail participants and disabled and non-disabled participants in 2009 and 2012

	2009 Non-frail n = 264 M (SD)	Frail n = 91 M (SD)	Results t-test[1]	*p*-value	Effect size Cohen's d[2]	2012 Non-frail n = 243 M (SD)	Frail n = 112 M (SD)	Results t-test[1]	*p*-value	Effect size Cohen's d[2]
Nuisance	31.48 (4.58)	28.98 (5.67)	t(132.74) = 3.81	<0.001	d = 0.50	31.39 (4.74)	29.65 (5.34)	t(194.46) = 2.95	0.004	d = 0.35
Housing	21.98 (3.00)	20.77 (3.44)	t(140.22) = 2.99	0.003	d = 0.38	22.03 (3.01)	20.89 (3.33)	t(197.53) = 3.07	0.002	d = 0.36
Facilities	24.53 (4.20)	22.99 (3.64)	t(178.88) = 3.34	0.001	d = 0.37	24.49 (4.02)	23.36 (4.24)	t(205.82) = 2.39	0.018	d = 0.28
Residents	30.95 (3.82)	28.34 (5.20)	t(125.18) = 4.40	<0.001	d = 0.60	30.79 (3.78)	29.17 (5.27)	t(165.53) = 2.93	0.004	d = 0.38
Neighborhood	15.56 (2.49)	14.94 (2.68)	t(146.87) = 1.93	0.055	d = 0.24	15.51 (2.50)	15.18 (2.66)	t(204.38) = 1.11	0.267	d = 0.13
Stench/noise	14.43 (1.16)	11.11 (1.35)	t(138.12) = 2.00	0.047	d = 0.26	11.43 (1.16)	11.16 (1.32)	t(193.00) = 1.87	0.063	d = 0.22
Traffic	14.09 (2.44)	12.93 (3.05)	t(131.91) = 3.26	0.001	d = 0.43	14.04 (2.50)	13.26 (2.92)	t(188.93) = 2.44	0.016	d = 0.29

Table 3. Continued

	2009 Non-disabled n = 321 M (SD)	Disabled n = 34 M (SD)	Results t-test[1]	*p*-value	Effect size Cohen's d[2]	2012 Non-disabled n = 309 M (SD)	Disabled n = 46 M (SD)	Results t-test[1]	*p*-value	Effect size Cohen's d[2]
Nuisance	31.20 (4.73)	27.50 (6.18)	t(37.21) = 3.38	0.002	d = 0.76	31.15 (4.84)	28.80 (5.62)	t(55.38) = 2.68	0.010	d = 0.47
Housing	21.79 (3.18)	2.50 (2.67)	t(43.62) = 2.64	0.011	d = 0.41	21.89 (3.13)	20.22 (3.00)	t(60.56) = 3.51	<0.001	d = 0.54
Facilities	24.20 (4.23)	23.50 (2.80)	t(50.62) = 1.31	0.195	d = 0.17	24.32 (4.25)	22.91 (2.88)	t(77.61) = 2.87	0.005	d = 0.34
Residents	30.38 (4.22)	29.32 (5.51)	t(37.21) = 1.09	0.284	d = 0.24	30.64 (4.07)	27.87 (5.41)	t(52.86) = 3.34	0.002	d = 0.65
Neighborhood	15.41 (2.57)	15.41 (2.41)	t(41.34) = -0.02	0.988	d = -0.00	15.47 (2.55)	14.98 (2.52)	t(59.55) = 1.23	0.224	d = 0.19
Stench/noise	11.37 (1.19)	11.09 (1.42)	t(38.08) = 1.13	0.266	d = 0.24	11.36 (1.19)	11.24 (1.37)	t(55.67) = 0.58	0.565	d = 0.10
Traffic	13.89 (2.59)	12.82 (3.08)	t(38.12) = 1.96	0.058	d = 0.40	13.95 (2.57)	12.71 (3.00)	t(55.26) = 2.65	0.011	d = 0.47

[1] Assuming unequal population variances; [2] Assuming equal population variances.

3.3 Bivariate and sequential multiple regression analyses (cross-sectional)

Table 4 shows the results of the bivariate regression analyses aiming to examine the effect of each background characteristic and environmental factor on three frailty domains (physical, psychological, social) and two disability types (ADL, IADL), all assessed simultaneously, at T1. The background characteristics were associated with one (age, education), two (marital status), and three (income) of the frailty domains and they were associated with none (sex, education), one (age), and two disability types. The individual environmental factors were associated with none (facilities), one (neighborhood), two (housing, stench/noise), and three (nuisance, residents, traffic) frailty domains. Stench/noise was associated with ADL disability and nuisance, housing and traffic were associated with ADL as well as IADL disability.

Table 4 also shows the results of the sequential multiple regression analyses. The rows ΔR^2 *(total)* indicate how much of the variance of the frailty domains and disability types was explained by all the predictors together (last row), or in each block (last row of each block), and whether the (increase in) explained variance was statistically significant. The last row shows that all the predictors together (background characteristics, environmental factors) explained 9.5% (psychological frailty) to 65.4% (social frailty). The second block containing the seven environmental factors explained a significant part of physical frailty (5.6%) (*p*-value = 0.004), social frailty (4.2%) (*p*-value < 0.001), and both ADL (8.0%) and IADL disability (7.2%) (*p*-values < 0.001), after controlling for the background characteristics, representing small effect sizes (physical frailty; f^2 = .07 to social frailty; f^2 = .12).

In addition, Table 4 shows the effect of each of the background characteristics and individual environmental factors on frailty domains and disability types, after controlling for all the other variables in the full model. Of the background characteristics, greater age was positively associated with physical frailty, ADL and IADL disability. Marital status (married) was negatively associated with social frailty and ADL disability. A higher net monthly income was negatively associated with physical and social frailty and a higher educational level was positively associated with physical frailty. Of the environmental factors, housing was negatively associated

with one frailty domain (social frailty), and both disability types. Residents was negatively associated with social frailty. Nuisance was negatively associated with ADL and IADL disability and neighborhood was positively associated with one disability type (IADL disability). Three environmental factors (facilities, stench/noise, traffic) had no effect on any of the frailty domains or disability types, after controlling for all other effects.

Table 4. Effect of background characteristics and environmental factors on frailty domains and disability types (cross-sectional regression analyses)

	Physical frailty						Psychological frailty					
	Bivariate			Multiple			Bivariate			Multiple		
	B	SE	p	B	SE	p	B	SE	p	B	SE	p
Sex (women)	0.441	0.173	0.011	0.052	0.197	0.790	0.274	0.107	0.011	0.150	0.129	0.246
Age	0.058	0.015	<0.001	0.060	0.015	<0.001	-0.013	0.010	0.187	-0.010	0.010	0.331
Marital status (married)	-0.717	0.178	<0.001	-0.320	0.214	0.136	-0.157	0.112	0.161	0.083	0.141	0.556
Education	-0.017	0.093	0.856	0.257	0.103	0.013	-0.170	0.057	0.003	-0.079	0.068	0.243
Net monthly income	-0.201	0.042	<0.001	-0.162	0.054	0.003	-0.105	0.027	<0.001	-0.061	0.035	0.085
ΔR^2				0.126		<0.001				0.059		0.001
Nuisance	-0.067	0.016	<0.001	-0.028	0.022	0.198	-0.043	0.010	<0.001	-0.022	0.014	0.135
Housing	-0.073	0.026	0.005	-0.032	0.027	0.244	-0.029	0.016	0.079	0.002	0.018	0.898
Facilities	-0.038	0.020	0.059	-0.019	0.021	0.359	-0.027	0.012	0.165	0.003	0.014	0.857
Residents	-0.055	0.019	0.004	-0.027	0.023	0.228	-0.042	0.012	<0.001	-0.022	0.015	0.150
Neighborhood	-0.065	0.032	0.046	0.052	0.038	0.174	-0.034	0.020	0.094	0.003	0.025	0.907
Stench/noise	-0.217	0.067	0.001	-0.108	0.077	0.159	-0.124	0.042	0.003	-0.052	0.050	0.300
Traffic	-0.114	0.031	<0.001	-0.035	0.036	0.341	-0.048	0.019	0.013	0.008	0.024	0.740
ΔR^2				0.056		0.004				0.036		0.086
R^2 *total*				0.182		<0.001				0.095		0.001

Table 4. Continued

	Social frailty						ADL disability					
	Bivariate			Multiple			Bivariate			Multiple		
	B	SE	p	B	SE	p	B	SE	p	B	SE	p
Sex (women)	0.755	0.096	<0.001	0.089	0.078	0.251	0.296	0.321	0.357	-0.277	0.371	0.456
Age	0.012	0.009	0.195	0.008	0.006	0.176	0.097	0.028	<0.001	0.098	0.029	<0.001
Marital status (married)	-1.534	0.071	<0.001	-1.401	0.084	<0.001	-1.200	0.328	<0.001	-1.301	0.403	0.001
Education	-0.082	0.055	0.141	0.050	0.041	0.218	-0.070	0.171	0.684	0.239	0.194	0.219
Net monthly income	-0.217	0.024	<0.001	-0.046	0.021	0.033	-0.212	0.081	0.009	-0.029	0.102	0.772
ΔR^2				0.612		<0.001				0.087		<0.001
Nuisance	-0.031	0.010	0.002	0.001	0.009	0.864	-0.139	0.030	<0.001	-0.127	0.041	0.002
Housing	-0.072	0.015	<0.001	-0.027	0.011	0.015	-0.145	0.048	0.003	-0.108	0.052	0.037
Facilities	-0.020	0.012	0.101	-0.009	0.008	0.257	-0.039	0.037	0.296	-0.031	0.040	0.438
Residents	-0.054	0.011	<0.001	-0.028	0.009	0.002	-0.068	0.035	0.052	0.003	0.043	0.948
Neighborhood	-0.034	0.019	0.077	0.012	0.015	0.419	-0.062	0.060	0.300	0.128	0.071	0.074
Stench/noise	-0.058	0.041	0.154	0.009	0.030	0.765	-0.455	0.123	<0.001	-0.277	0.144	0.056
Traffic	-0.077	0.018	<0.001	-0.026	0.014	0.067	-0.129	0.057	0.024	0.051	0.068	0.450
ΔR^2				0.042		<0.001				0.080		<0.001
R^2 *total*				0.654		<0.001				0.167		<0.001

Table 4. Continued

	IADL disability					
	Bivariate			Multiple		
	B	SE	p	B	SE	p
Sex (women)	-0.128	0.382	0.739	-0.568	0.435	0.193
Age	0.165	0.033	<0.001	0.182	0.034	<0.001
Marital status (married)	-0.626	0.396	0.115	-0.108	0.473	0.819
Education	-0.130	0.203	0.523	0.258	0.228	0.259
Net monthly income	-0.252	0.095	0.009	-0.217	0.119	0.069
ΔR^2				0.106		<0.001
Nuisance	-0.142	0.036	<0.001	-0.121	0.049	0.013
Housing	-0.158	0.057	0.006	-0.151	0.061	0.013
Facilities	-0.025	0.044	0.569	-0.007	0.047	0.876
Residents	-0.073	0.041	0.078	-0.026	0.050	0.600
Neighborhood	0.032	0.071	0.655	0.275	0.084	0.001
Stench/noise	-0.220	0.149	0.140	0.076	0.169	0.655
Traffic	-0.174	0.068	0.011	-0.100	0.080	0.210
ΔR^2				0.072		<0.001
R^2 *total*				0.178		<0.001

ADL = Activities of Daily Living; IADL = Instrumental Activities of Daily Living

3.4 Bivariate and sequential multiple regression analyses (longitudinal)

We then examined the effects of background characteristics of the participants and environmental factors assessed at T1 on frailty domains and on disability types assessed at T2. The bivariate regression analyses demonstrated that all five background characteristics were at least associated with one frailty domain; a lower net monthly income was associated with physical, psychological and social frailty. Greater age was associated with ADL and IADL disability; both marital status (unmarried) and lower net monthly income were associated with ADL disability (see Table 5). Of the environmental factors, only nuisance was associated with all five outcome variables, and housing and residents were associated with four of these variables. Traffic was associated with both physical and social frailty and ADL disability; stench/noise was associated with the former and the latter.

Table 5 also presents the results of the sequential multiple regression analyses. The last row (ΔR^2 *total*) shows that 6.3% (psychological frailty) to 50.3% (social frailty) of the variance of the frailty domains and disability types was explained by all the predictors together. In this longitudinal design, the block with all five background characteristics explained 3.5%, 4.7% and 12.3% for psychological, social and physical frailty, respectively; these characteristics explained 7.3% of ADL disability and 11.6% of IADL disability. The block with all environmental factors explained 3.8% of physical frailty (*p*-value = 0.046) and social frailty (*p*-value = 0.001), 5.6% of IADL disability (*p*-value = 0.004) and 7.2% of ADL disability (*p*-value < 0.001, all representing small effect sizes (< .09); the explained variance of psychological frailty was not significant (*p*-value = 0.218).

After controlling for all the variables in the full model, the analyses demonstrated that the background characteristics age (greater) had a positive effect on physical frailty, ADL and IADL disability. In addition, marital status (married) was negatively associated with social frailty and ADL disability, and being a woman was positively associated with social frailty. Of the environmental factors only two had a significant effect on the frailty or disability variables; housing was negatively associated with social frailty, ADL and IADL disability, and residents was negatively associated with social frailty. The other five environmental factors demonstrated no significant effects on the frailty domains or the disability types, after controlling for all the other variables in the model.

Table 5. Effect of background characteristics and environmental factors on frailty domains and disability types (longitudinal regression analyses)

	Physical frailty						Psychological frailty					
	Bivariate			Multiple			Bivariate			Multiple		
	B	SE	p	B	SE	p	B	SE	p	B	SE	p
Sex (women)	0.577	0.185	0.002	0.143	0.211	0.496	0.167	0.109	0.129	0.117	0.133	0.380
Age	0.064	0.016	<0.001	0.072	0.016	<0.001	-0.011	0.010	0.250	-0.011	0.010	0.298
Marital status (married)	-0.691	0.192	<0.001	-0.288	0.229	0.210	-0.077	0.114	0.501	0.216	0.145	0.136
Education	-0.240	0.099	0.016	-0.073	0.110	0.510	-0.073	0.058	0.213	-0.013	0.070	0.855
Net monthly income	-0.206	0.045	<0.001	-0.103	0.058	0.075	-0.073	0.027	0.008	-0.061	0.036	0.097
ΔR^2				0.123		<0.001				0.035		0.040
Nuisance	-0.059	0.018	<0.001	-0.018	0.024	0.438	-0.032	0.010	0.002	-0.023	0.015	0.120
Housing	-0.078	0.028	0.006	-0.047	0.029	0.112	-0.032	0.016	0.054	-0.007	0.019	0.707
Facilities	-0.041	0.022	0.061	-0.017	0.023	0.456	-0.020	0.013	0.109	-0.004	0.014	0.771
Residents	-0.034	0.020	0.096	0.000	0.024	0.992	-0.038	0.012	0.001	-0.021	0.015	0.179
Neighborhood	-0.019	0.035	0.589	0.076	0.040	0.062	-0.038	0.020	0.060	-0.002	0.026	0.950
Stench/noise	-0.182	0.073	0.013	-0.062	0.082	0.446	-0.029	0.043	0.494	0.032	0.052	0.540
Traffic	-0.114	0.033	<0.001	-0.069	0.039	0.076	-0.029	0.020	0.141	0.011	0.024	0.659
ΔR^2				0.038		0.046				0.028		0.218
R^2 *total*				0.161		<0.001				0.063		0.049

Table 5. Continued

	Social frailty						ADL disability					
	Bivariate			Multiple			Bivariate			Multiple		
	B	SE	p	B	SE	p	B	SE	p	B	SE	p
Sex (women)	0.683	0.090	<0.001	0.217	0.087	0.013	0.544	0.354	0.125	-0.005	0.407	0.990
Age	0.008	0.009	0.374	0.006	0.007	0.382	0.118	0.031	<0.001	0.117	0.031	<0.001
Marital status (married)	-1.239	0.077	<0.001	-1.016	0.095	<0.001	-1.186	0.364	0.001	-1.176	0.442	0.008
Education	-0.114	0.051	0.027	-0.013	0.046	0.780	-0.125	0.189	0.509	0.070	0.213	0.744
Net monthly income	-0.194	0.022	<0.001	-0.045	0.024	0.059	-0.181	0.088	0.040	0.058	0.111	0.610
ΔR^2				0.466		<0.001				0.073		<0.001
Nuisance	-0.019	0.009	0.035	-0.005	0.010	0.598	-0.121	0.033	<0.001	-0.080	0.045	0.080
Housing	-0.067	0.014	<0.001	-0.037	0.012	0.002	-0.200	0.052	<0.001	-0.132	0.057	0.021
Facilities	-0.005	0.011	0.671	0.005	0.009	0.589	-0.075	0.041	0.068	-0.036	0.044	0.408
Residents	-0.039	0.010	<0.001	-0.025	0.010	0.014	-0.115	0.038	0.003	-0.049	0.047	0.297
Neighborhood	-0.004	0.018	0.826	0.018	0.017	0.270	-0.082	0.066	0.216	0.127	0.078	0.104
Stench/noise	0.003	0.038	0.932	0.054	0.034	0.109	-0.444	0.137	0.001	-0.280	0.158	0.077
Traffic	-0.042	0.017	0.016	-0.005	0.016	0.737	-0.145	0.063	0.022	0.013	0.075	0.865
ΔR^2				0.038		0.001				0.072		<0.001
R^2 total				0.503		<0.001				0.145		<0.001

Table 5. Continued

	IADL disability					
	Bivariate			Multiple		
	B	SE	p	B	SE	p
Sex (women)	-0.184	0.415	0.657	-0.669	0.463	0.149
Age	0.204	0.035	<0.001	0.212	0.036	<0.001
Marital status (married)	-0.614	0.430	0.154	-0.249	0.503	0.621
Education	0.132	0.220	0.550	0.431	0.242	0.076
Net monthly income	-0.168	0.102	0.099	-0.158	0.127	0.214
ΔR^2				0.116		<0.001
Nuisance	-0.108	0.039	0.006	-0.087	0.052	0.093
Housing	-0.223	0.061	<0.001	-0.181	0.064	0.005
Facilities	-0.061	0.048	0.202	-0.005	0.049	0.914
Residents	-0.112	0.045	0.013	-0.063	0.053	0.242
Neighborhood	-0.044	0.077	0.573	0.171	0.089	0.055
Stench/noise	-0.054	0.162	0.740	0.179	0.180	0.320
Traffic	-0.145	0.074	0.050	-0.072	0.085	0.396
ΔR^2				0.056		0.004
R^2 *total*				0.172		<0.001

ADL = Activities of Daily Living; IADL = Instrumental Activities of Daily Living

4. Discussion

Both frailty and disability are considered as adverse outcomes in older people, because they are related to a lower quality of life, increased use of health care (e.g. hospitalization, institutionalization) and mortality (Boyd et al. 2005; Fried et al. 2001; Gobbens et al. 2012; Gobbens and van Assen 2014; Gobbens 2018; Rockwood et al. 2005; Wei et al. 2018) . Due to the fact that more and more older people are "aging in place," it is important to examine the influence of environmental factors on frailty and disability. The present study aimed to determine the cross-sectional and longitudinal associations of nuisance, housing, facilities, residents, neighborhood, stench/noise, and traffic on these two outcomes, in a sample of 355 Dutch inhabitants. A strength of this study is that we used two extensively validated instruments for measuring frailty and disability, the Tilburg Frailty Indicator (TFI) (Gobbens et al. 2010c) and the Groningen Activity Restriction Scale (GARS) (Kempen and Suurmeijer 1990), respectively.

The bivariate regression analyses showed that of the two background characteristics, only lower education and lower income were cross-sectionally or longitudinally associated with physical, psychological and social frailty. Education and income are the two commonly used measures of socioeconomic status (SES). Previous studies by Mulasso et al. (2014) and Hoogendijk et al. (2018) have also shown that people with a low SES are more frail than people with a high SES. Greater age and lower income were associated with ADL and IADL disability at T1 or T2. Of the environmental factors, only nuisance was associated with all frailty domains and disability types assessed at T1 and T2. In addition, residents as well as traffic were associated with all five outcome variables assessed at T1 or T2, and housing, stench/noise, and neighborhood were associated with four, three, and one of these variables, respectively. These analyses also showed that older people's satisfaction with facilities is not associated with frailty domains or disability types, although the *t*-tests revealed significant differences between frail and non-frail participants and disabled and non-disabled participants with regard to satisfaction with facilities.

The sequential regression analyses demonstrated that both the block with the background characteristics and the block with the environmental factors explained a

significant part of the variance of physical and social frailty and ADL and IADL disability, measured at T1 and T2. The total explained variance was highest for social frailty, 65.4% and 50.3% at T1 and T2, respectively. This can be explained by the fact that marital status is one of the socio-demographic characteristics and this variable has a lot of overlap with an item of social frailty of the TFI (living alone). Surprisingly, all the environmental factors taken together were not associated with psychological frailty. A previous study among 1,031 Dutch older people aged ≥ 65 years using the same environmental scales showed that the seven environmental factors taken together were significantly associated with the psychological domain of quality of life, assessed with a scale of the WHOQOL-BREF (Gobbens and van Assen 2018). Based on this, we conclude that frailty and quality of life are two different concepts with their own operationalizations. More studies on the influence of satisfaction with environmental factors and psychological frailty are recommended.

The sequential regression analyses also showed that four of the environmental factors were associated with at least one of the outcome measures: housing, nuisance, residents, and neighborhood. Housing was associated with social frailty, ADL disability, and IADL disability, assessed at T1 and T2; nuisance was associated with ADL and IADL disability, assessed at T1; residents was associated with social frailty, assessed at T1 and T2; and neighborhood was associated with IADL disability, assessed at T1. These analyses show, in particular, that dissatisfaction in older people with housing has an effect on social frailty, ADL and IADL disability. Our finding that housing is associated with disability is supported by Iwarsson (2005), who conducted a study with a follow-up over a six-year period in a sample of 72 people aged 75–84 years. In the aforementioned study, housing was the only environmental factor associated with all four quality-of-life domains (physical, psychological, social relations, environmental) (Gobbens and van Assen 2018). Adaptable, flexible housing that accommodates the changing needs of older people due to declining health and physical limitations can be regarded as a key component of “aging in place” (McLaughlin and Mills 2008). The Housing and Independent Living (HAIL) study, comprising 400 people aged 75–79 years living in the Sydney region (Australia), concluded that many homes might not accommodate increased frailty and disability in older people into the future; in particular, the bathrooms were not safe (Byles et al. 2014). The extent to which existing housing meets the needs of frailty and/or disabled older people in the Netherlands is an important question for

policymakers. It is the task of health-care professionals (e.g. community nurses) to properly assess whether the home is still adequate or whether adjustments should be made in the interest of the older occupant(s).

Our study showed that nuisance was associated with ADL and IADL disability. To the best of our knowledge, no study is available to compare our findings. What we do know is that nuisance is associated with quality-of-life domains physical health and environment (Gobbens and van Assen 2018). The scale we used contains nine items, three of which relate to feelings of unsafeness and social insecurity. According to Cramm and Nieboer (2013), feeling secure in the neighborhood seems to protect against frailty, even after controlling for sex, age, marital status and education. Policymakers should develop intervention programs with the aim of older people feeling safe in their neighborhood by creating, for example, safe sidewalks, walkable neighborhoods, and a close distance to services (De Donder et al. 2010).

Dissatisfaction with residents was associated with social frailty. In the residents scale the social environment is central. A recent systematic review concluded that social environment and frailty are indeed related (Duppen et al. 2017). Important topics in the residents scale are social cohesion and social capital. Social cohesion refers to interdependencies among neighbors and social capital refers to obtaining support through indirect ties, such as from neighbors (Cramm et al. 2013). Social frailty, defined by the TFI, contains the components living alone, loneliness and lack of social support (Gobbens et al. 2010c). Social cohesion and social capital may act as a buffer against the negative consequences of living alone (Cramm et al. 2013), e.g. loneliness and a lack of social support. In a population of 2,032 Chinese people of 70 years and older, Woo et al. (2005) found that social support from neighbors was related to lower frailty. For promoting well-being and preventing social frailty, interventions should be carried out to create a socially healthy environment.

Finally, dissatisfaction with the neighborhood was only associated with IADL disability, assessed at T1. This neighborhood scale includes items such as landscaping, paving and street lighting. No other study has examined this relationship, so a comparison with other results is not possible. From another study we do know that a scale containing items such as having clean streets and sidewalks explained the life satisfaction of 381 community-dwelling individuals aged 65–94 years in Germany (Oswald et al. 2011). In addition, neighborhood had an

effect on the environmental domain of quality of life in 1,031 Dutch people aged ≥ 65 years (Gobbens and van Assen 2018).

The findings in our study should be considered in the light of a number of limitations. First, the study sample is not representative for the older population aged ≥ 65 years; 65.6% of the sample were men, while in the Dutch population aged ≥ 65 years, 44.4% were men at T1 (2010) (Statistics Netherlands 2010). Probably, the sample is biased due to the fact that the data were collected with the "Senioren Barometer," a questionnaire that was conducted digitally. This participating bias may preclude the generalization of our findings. Second, the short follow-up period (two and a half years' interval) may be considered as a limitation. The cross-sectional and longitudinal differences between the associations of environmental factors with frailty and disability might have been larger with a longer time interval. Third, the scales that we used for assessing the seven environmental factors have been validated in the Netherlands, but they have not yet been validated in other countries. We recommend future research aimed at validating the environmental scales in other countries. Finally, the response rate was not perfect: 83% of the participants completed the "Senioren Barometer" at T1 and T2. However, no significant differences were found by the vast majority of variables.

5. Conclusion

In this study we found evidence that several environmental factors had an effect, both cross-sectional and longitudinal, on frailty and its domains (physical, psychological, social) and disability and its types (ADL, IADL). More studies are needed to address important research challenges in the area of environment and adverse outcomes of aging, such as frailty and disability. That is why it is important that researchers (e.g. in geriatric medicine and nursing, environmental epidemiologists) collaborate to deal with these challenges. The findings of our study offer health-care and welfare professionals and also policymakers (e.g. employed by municipalities) starting points for interventions. Based on our findings, these interventions should focus in particular on housing, nuisance, residents, and neighborhood, because these had the largest impact on frailty and/or disability. In the development and implementation of these interventions, it will always be necessary

to listen carefully to the older people involved. After all, they know better than anyone what is needed to actually give shape to “aging in place.”

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