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ORIGINAL INVESTIGATION

Neighborhood and healthy aging in a German city: distances to green space and senior service centers and their associations with physical constitution, disability, and health-related quality of life

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Abstract The composition of the residential environment may have an independent influence on health, especially in older adults. In this cross-sectional study, we examined the associations between proximity to two features of the residential environment (green space and senior service centers) and three aspects of healthy aging (self-rated physical constitution, disability, and health-related quality of life). We included 1711 inhabitants from the city of Augsburg, Germany, aged 65 years or older, who participated in the KORA-Age study conducted in 2008/2009. We calculated the Euclidian distances between each participant's residential address and the nearest green space or senior service center, using a geographic information system. Multilevel logistic regression models were fitted to analyze the associations, controlling for demographic and socioeconomic factors. Contrary to expectations, we did not find clear associations between the distances to the nearest green space or senior service center and any of the examined aspects of healthy aging. The importance of living close to green space may largely depend on the study location. The city of Augsburg is relatively small (about 267,000 inhabitants) and has a high proportion of greenness. Thus, proximity to green space may not be as important as in a densely populated metropolitan area. Moreover, an objectively defined measure of access such as Euclidian distance may not reflect the actual use. Future studies should try to assess the importance of resources of the residential environment not only objectively, but also from the resident's perspective.

Keywords Residential environment · Green space · Distance · Geographic information system · Healthy aging

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Background

With increasing life expectancy, the process of 'healthy' or 'successful' aging is receiving growing attention. Although a commonly accepted definition of healthy aging does not exist so far (Cosco et al. 2014; Depp and Jeste 2006), there is a general agreement that healthy aging is a multidimensional process and refers to the capacity to function across many domains (Glass 2003). Previous studies used definitions of healthy aging based on five constructs (physiological constructs, well-being, engagement, personal resources, and extrinsic factors) (Cosco et al. 2014). The common denominator is physical functioning, in particular absence of disability, frequently used in combination with well-being (Cosco et al. 2014; Depp and Jeste 2006). This scientific operationalization of healthy aging

also corresponds quite well with the perception of older adults (Phelan et al. 2004).

It is evident that individual characteristics such as age and socioeconomic status [SES] are important determinants of health. Above that, the residential environment may have an independent influence. The term 'residential environment' comprises the sum of both the built features and the immaterial conditions of a geographically defined living area within a city. This living area is here defined by the term 'neighborhood'. The residential environment may either support or restrict activities from which the individual derives well-being (Gerstorf et al. 2010). In a study from Germany, about 8 % of the between-person differences in late-life well-being could be attributed to regional differences, e.g., in the regional socioeconomic status (Gerstorf et al. 2010). The regional influences are likely to be particularly distinct for older adults, given their increased sensitivity to their environment (Diez Roux 2002; Fitzpatrick and LaGory 2000) as they usually spend a large amount of their time in the vicinity of their homes. Environmental gerontology and life-span psychology provide a theoretical framework for exploring the role of the residential environment for older adults. In a similar vein, both Lawton's environmental docility hypothesis (Lawton 1990) and Baltes' model of selective optimization with compensation (Baltes 1997) suggest that environmental features become increasingly important with decreasing personal competences, as cultural resources compensate for the decline of biological potentials.

Many features of the residential environment have been investigated in the context of health, but few are receiving as much attention as green space. Several studies have shown an association between a green environment and different indicators of health, including overweight and obesity (Ellaway et al. 2005), self-rated general health (Maas et al. 2006; Vries et al. 2003), health-related quality of life (Stigsdotter et al. 2010), physician-assessed morbidity (Maas et al. 2009), and mortality (Mitchell and Popham 2008; Takano et al. 2002; Villeneuve et al. 2012). However, others saw no association between access to green space and body mass index [BMI] (Mowafi et al. 2012) or mortality (Richardson et al. 2010), indicating that study location may play an important role. Empirical studies from Germany concerning the association between proximity to green space and health are very rare. Voigtländer et al. reported an inverse association between walking distance to public green space and physical health, based on a dataset including adults aged 18 years or older living across Germany (Voigtländer et al. 2010).

The association between a green environment and health is thought to be mediated by two factors: exposure to the natural environment as such as well as enhanced physical activity such as recreational walking (Maas et al. 2006). Given that walking, along with gardening, is the most frequent physical activity in old age (U.S. Department of Health and Human Services 1996), and that physical activity is a central factor in healthy aging (Hartman-Stein and Potkanowicz 2003), green space is likely to be even more important for older adults than for other age groups. This may also explain why the association between access to green space and health has been found to be especially strong in older age groups (Maas et al. 2009).

Although older people seem to benefit especially from green areas in their neighborhood (Maas et al. 2006), only few studies have focused on older adults. Parra et al. found a positive association between a high density of parks and good self-rated health in older adults ($n = 1996$) (Parra et al. 2010). White et al. analyzed the association between self-reported features of the residential environment and disability in older adults ($n = 436$) (White et al. 2010). Their findings indicate that the absence of accessible parks and walking areas is associated with higher disability.

The health and well-being of older adults are also influenced by features of the residential environment which are more closely linked to the social organization of the community, such as senior service centers. Although their scope of activities and duties differ from community to community, senior service centers usually provide assistance concerning living conditions and health care. Thus, senior service centers enable older adults to maintain an independent life in their well-known environment, which is something that older adults rate very highly for their quality of life (Salkeld et al. 2000). We are not aware of an empirical study that has previously assessed the importance of senior service centers.

'Access' to features of the residential environment is defined differently among studies. Many studies rely on self-reported access (Stigsdotter et al. 2010; Takano et al. 2002; Voigtländer et al. 2010; White et al. 2010), although perceptions of distance do not correlate very well with objective measures (Macintyre et al. 2008). Other widely used methods are to calculate the proportion of green space within a neighborhood (Maas et al. 2009; Maas et al. 2006; Mitchell and Popham 2008; Mowafi et al. 2012; Parra et al. 2010; Richardson et al. 2010; Vries et al. 2003) or to use the postal code to define the respondents' home (Coombes et al. 2010; Villeneuve et al. 2012); all these methods might lead to an imprecise assessment of the factual individual distance. The associations between features of the residential environment and health tend to be small (Maas et al. 2009; Takano et al. 2002), and we assume that a more precise and objective measure such as Euclidian distance will lead to more distinct results.

In this study, we examine the association between the Euclidian distance to the nearest green space and senior service center and three aspects of healthy aging (self-rated physical constitution [SRPC], disability, health-related quality of life [HRQOL]) in 1,711 inhabitants from the city

of Augsburg, Germany, aged 65 years or older who participated in the KORA-Age study conducted in 2008/2009. In view of notions of environmental gerontology (Lawton 1990) and life-span psychology (Baltes 1997), we hypothesize that proximity to green space and to senior service centers is positively associated with healthy aging, with the latter association being somewhat weaker, as the relationship between senior service centers and health is rather indirect.

Methods

Ethics statement

The KORA-Age study has been approved by the Ethics Committee of the Bavarian Medical Association. All investigations have been conducted according to the principles expressed in the Declaration of Helsinki and written informed consent has been obtained from the participants.

Study population

We used data from the population-based KORA (Cooperative Health Research in the Region of Augsburg)-Age study, a follow-up of the four cross-sectional surveys (S1–S4) of the MONICA/KORA Study (Peters et al. 2011). These four surveys were conducted approximately every 5 years between 1984 and 2001 in the region of Augsburg (i.e., the city of Augsburg and two surrounding rural districts) located in southern Germany. The aim of KORA-Age was to investigate the determinants and consequences of multimorbidity in older adults and to analyze aspects of successful aging. The study included all S1–S4 participants aged 65 years or older. Between 2008 and 2009, 4565 community-dwelling participants (i.e., not living in nursing homes) completed a postal questionnaire. Of these, 4127 participants also completed a telephone interview. More details about the study design, sampling method, response rates, and data collection of the KORA surveys and KORA-Age have been reported elsewhere (Holle et al. 2005; Peters et al. 2011). The analyses are based on data from the telephone interview, and further, the analytical dataset was restricted to participants living in the city of Augsburg ($n = 1879$), both because the proximity to green space is mainly important for people living in cities as compared to people living in rural areas and because there are no senior service centers in the rural districts.

Physical constitution, disability, and health-related quality of life

Given that there is no commonly accepted definition of healthy aging so far (Cosco et al. 2014; Depp and Jeste 2006), we decided to use an operationalization based on the constructs physical functioning and health-related quality of life. This combination is frequently used to operationalize healthy aging (Cosco et al. 2014) and might therefore facilitate comparisons with other studies. Further, the prevalence of healthy aging as defined by researchers does not correspond very well with the self-rated prevalence (Cosco et al. 2014). This is why we decided to use two definitions of physical functioning: the respondents' self-assessment of their physical constitution on one hand and disability (defined by a validated, widely used research instrument) on the other.

Self-rated physical constitution was assessed in the questionnaire using the wording: 'How would you rate your current physical constitution?' Four categories were given (excellent, good, fair, and poor). To ensure sufficient group sizes, two groups were differentiated in the analyses: 'excellent/good' versus 'fair/poor'.

Disability was assessed during the telephone interview using the German version of the Health Assessment Questionnaire Disability Index [HAQ-DI]. The HAQ-DI is one of the most widely used instruments for measuring functional disability (Bruhlmann et al. 1994). It consists of 20 questions in eight domains (dressing and grooming, hygiene, arising, reach, eating, grip, walking, and common daily activities). Answers can be given on a scale from 0 (no difficulty) to 3 (unable to perform). The HAQ-DI score is generated as the mean of the highest scores in each domain; thus a HAQ-DI score of 0 corresponds to 'no disability', whereas a score of 3 corresponds to 'severe disability'. For a more detailed description of the HAQ-DI see Fries et al. (Fries et al. 1982). A HAQ-DI score ≥ 1 indicates at least some limitations in most domains and is thus often interpreted as a clinically relevant definition of 'disability' (Bruce and Fries 2003; Chakravarty et al. 2012; Cho et al. 2012; Sokka et al. 2003). This is why we dichotomized the score into HAQ-DI < 1 (no/mild limitations) and HAQ-DI ≥ 1 (moderate/severe limitations).

HRQOL was assessed in the questionnaire using the German version of the European Quality of Life questionnaire [EQ-5D]. This generic instrument consists of five questions, referring to the following five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each dimension has three response categories (no, moderate, or severe problems), generating a total of 243 different health states. To assess HRQOL, the health states are transformed into a single utility value, the EQ-5D index, using a scoring algorithm that is based on valuations derived from representative population samples. In this study, we used the European tariff suggested by Greiner et al. (Greiner et al. 2005). A more detailed description of the EQ-5D can be found elsewhere (The EuroQol Group 1990). As the distribution of the EQ-5D

index in our data was skewed to the left with a distinctive 'ceiling effect' (35 % of the participants reported the best possible HRQOL), we used a two-part model as suggested in the literature (Huang et al. 2008; Li and Fu 2009) by dichotomizing the EQ-5D index into 'perfect HRQOL' ('no problems' in any of the five dimensions) and 'imperfect HRQOL' ('moderate or severe problems' in at least one of the five dimensions).

Neighborhood

The study area was the city of Augsburg in southern Germany, with a population of about 267,000 inhabitants in 2009 (Stadt Augsburg. Amt für Statistik und Stadtforschung 2013). The Department for Social Planning of the city of Augsburg has previously designed 12 'senior care regions', in order to establish a small-scale social care system tailored to the particular needs of older adults. The average number of inhabitants per senior care region is 22,260 [minimum [min]: 7147; maximum [max]: 37,365; standard deviation [SD]: 7593.44], including an average of 4568 (min 1743; max 6439; SD: 1507.11) people aged 65 years or older (Stadt Augsburg. Amt für Statistik und Stadtforschung 2013). We used these regions as a proxy for 'neighborhood', because they were especially designed to represent the residential environment in which the older population is rooted. While the median age in the senior care regions is relatively equally distributed (average: 42.6 years; min: 37.6; max: 45.9 years; SD: 2.05 years), the proportion of foreign nationals (average: 15.7 %; min: 9.6 %; max: 28.7 %; SD: 5.91 %) as well as the proportion of inhabitants with a migration background (average: 43.0 %; min: 29.6 %; max: 61.7 %; SD: 9.52 %) differs among the regions. (All data from 2009); (Stadt Augsburg. Amt für Statistik und Stadtforschung 2013).

Green space and senior service centers

Two different features of the residential environment were included: green space and senior service centers. Green space was defined as all public green space, parks, and (landscaped) cemeteries larger than 0.5 hectare within the municipal area. The cut-off value of 0.5 hectare has been applied in German urban planning before (Informationssystem Stadt und Umwelt 2009), and it was chosen here as well because we assume that a minimum area of green space is necessary to enable recreation and physical activity. Geocodes of all green spaces were provided by the city of Augsburg.

The 12 senior service centers are a special feature of senior care in Augsburg. The catchment areas for the senior service centers are the 12 senior care regions, so there is one center per region. The senior service centers are the central contact and guiding point for older adults in their neighborhood. They offer information on social services and all aspects of care, give advice on problems of daily living and assist older adults in order to enable them to live independently for as long as possible and to age in their familiar neighborhood (Soziale Fachberatung für Senioren 2013). The senior service centers cooperate with and provide contact to senior clubs and multi-generation buildings, but they are not themselves a place for seniors to meet each other. Data from 2009 show that the older adults who visited the senior service centers were more likely to be female (66 %). About 10 % were younger than 65 years, 32 % were aged 65–75 years, 38 % were aged 75–85 years, and 18 % were older than 85 years (age not known: 2 %). A large proportion was widowed (38 %) or married (25 %). While 64 % of the visitors lived alone, only 12 % stated that they did not have an active social network (e.g., relatives, friends, and neighbors). About 44 % of the visitors had a low SES (high SES: 37 %; SES not known: 19 %) and 32 % had a migration background. Only 3 % did not report any kind of physical or psychological constraint and physical disability was quite common (55 %). Visitors mainly sought counseling for problems in the following areas: health care/home economics (42 %), finances/economic situation (33 %), health (21 %). (Soziale Fachberatung für Senioren in den Augsburger Stadtteilen 2010).

Distances

To measure the factual distances, we used the geocodes of the participant's residential address, applying a special data security concept to guarantee privacy and prohibit re-anonymization. The Euclidean distance between a respondent's home and the nearest green space and senior service center was measured using the Spatial Analyst tool of the ArcGIS 10 geographic information system [GIS] package (ESRI, CA, USA). For the main analysis, the distances were categorized into four buffers, i.e., <200, 200–<400, 400–<800, and ≥ 800 m. These buffer sizes have been proposed before (Michael et al. 2010), they follow Peace's suggestion that a quarter of a mile (about 400 m) is a critical distance for older people and that few can walk more than half a mile (about 800 m) (Peace 1982). In sensitivity analyses, we additionally examined the continuous distances in meters (m) in order to additionally assess the effect of the distances irrespective of the pre-fixed buffers sizes.

Covariates

The association between the residential environment and health could be influenced by a number of factors that affect both one's health and one's chance of living in a

certain neighborhood. We tried to minimize potential confounding by including the following covariates: four age groups (65–<70, 70–<75, 75–<80, and ≥80 years), sex, three groups of per capita income per month (≤750 €, 750–<1625 €, and ≥1625 €), and two groups of regional deprivation (low, high). Per capita income was calculated by dividing the net monthly household income by the number of people living in the household. Per capita income was distributed very unevenly. This is why we had to use the three categories mentioned above (instead of a simple algorithm such as quintiles or quartiles) in order to achieve comparable groups. Regional deprivation was defined according to the percentage of social welfare recipients in each of the 12 senior care regions, i.e., the number of people receiving social welfare divided by the number of all residents below 65 years of age (Bundesagentur für Arbeit 2009). The proportions from 2008 and 2009 were pooled to depict the situation at data collection. The 12 neighborhoods were then classified into 'low' versus 'high' deprivation according to their proportion of social welfare recipients, using a cut-off value of 10 %, as this was the average proportion in both 2008 and 2009.

Data analysis

168 participants had to be excluded because of missing information on their residential address, leaving 1711 participants for the analyses. In the multivariate models, because we used a complete case approach, we also had to exclude participants with missing values in outcome variables (SRPC: 4; disability: 5; HRQOL: 38) or covariates (income: 127).

Multiple logistic regression models were used to examine the associations between the Euclidian distance to green space or senior service center and the outcome variables, controlling for the covariates. Variables were entered into the model in three steps. Model 1 represents the bivariate association between the distance to green space or senior service center and the outcome variable. Model 2 controlled for potential confounding concerning individual variables (age, sex, and per capita income), and model 3 also controlled for regional deprivation. The associations between distances to green space and to senior service centers and the outcome variables are likely to be influenced by unmeasured neighborhood effects. Thus, we used random intercept multilevel models to allow an estimation of the percentage of total variance explained by between-neighborhood variance. Model 3 is specified in the following way:

$$Y_i = \beta_0 + \mu_{0j} + \beta_1 * \text{distance}_i + \beta_2 * \text{age}_i + \beta_3 * \text{sex}_i + \beta_4 * \text{income}_i + \beta_5 * \text{deprivation}_i + \varepsilon_{ij},$$

where Y_i represents the outcome (SRPC/Disability/HRQOL) for individual i, β_0 the overall intercept, μ_{0j} the random intercept within the neighborhood j, β_1 to β_5 the individual linear slopes, and ε_{ij} the error term.

In a subgroup analysis, we restricted the analyses to participants aged 75 years and older. As mobility decreases with age, distance might be even more important in this age group (as compared with the group '65 years and older'). All models were calculated using the GLIMMIX procedure in SAS 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

A characterization of the study population is shown in Table 1. The proportion of women was 52 %, and about 39 % of the participants were 75 years or older. About 88 % of the participants reported no or mild limitations (as assessed by the HAQ-DI), and about 71 % rated their physical constitution as 'excellent or good'. About 35 % reported 'no problems' concerning HRQOL.

A map of the study area depicting the green spaces and senior service centers is shown in Fig. 1. The city of Augsburg comprises both affluent and more deprived neighborhoods: the proportion of social welfare recipients in the 12 neighborhoods ranged from 4.6 to 22.1 % (average: 10.1 %; SD: 4.6 %). Augsburg is a mix of densely populated inner-city areas and less densely populated agricultural areas that are located especially in the southwest. Only 37 % of the city area is used for settlements and traffic, and about 24 % is covered by woodland. Also, as depicted in Fig. 1, green space is distributed very unequally. Although 65 % of the participants lived within 400 m of the nearest green space, Euclidian distances ranged from 0 to 1,888 m. As there is just one senior service center in each of the 12 neighborhoods, the Euclidian distance to the nearest center had a maximum range of about 5000 m, and only 13 % lived within 400 m of the nearest center.

The results of the multilevel logistic models with categorized Euclidian distances to green space and senior service centers are shown in Tables 2 and 3, respectively. As the associations between the distances and the outcome variables changed little from model 1 to model 3 and were very similar in direction and statistical significance, only the results from the fully adjusted model (model 3) are reported here. Increasing age, female sex, and low per capita income were all associated with increased odds for fair/poor self-rated physical constitution, moderate/severe limitations, and low HRQOL. In most cases, these associations were statistically significant. We did not find significant associations with regional deprivation, though, and

Table 1 Characteristics of the study population, KORA-age study Augsburg, 2008/2009 ($N = 1711$)

Variables	*N*	*%*
Self-rated physical constitution		
Excellent/good	1208	70.8
Fair/poor	499	29.2
Disability[a]		
No/mild limitations	1500	87.9
Moderate/severe limitations	206	12.1
Health-related quality of life[b]		
No problems	572	34.2
Moderate or severe problems	1101	65.8
Euclidian distance to green space (m)		
<200	619	36.2
200–<400	496	29.0
400–<800	501	29.3
≥800	95	5.5
Euclidian distance to a senior service center (m)		
<200	82	4.8
200–<400	148	8.6
400–<800	581	34.0
≥800	900	52.6
Sex (women)	882	51.5
Age (years)		
65–<70	537	31.4
70–<75	501	29.3
75–<80	355	20.7
≥80	318	18.6
Per capita income per month (€)		
≤750	260	16.4
>750–<1625	1018	64.3
≥1625	306	19.3
Regional deprivation		
Small	1154	67.5
High	557	32.5

[a] Assessed by the Health Assessment Questionnaire Disability Index (HAQ-DI)

[b] Assessed by the European Quality of Life questionnaire (EQ-5D)

no relevant between-neighborhood variance, with parameters being zero or close to zero. Accordingly, the random intercept estimates (μ_{0j}) for the 12 neighborhoods were all very small and not significant.

Concerning the Euclidian distance to the nearest green space or senior service center, we hardly found any significant association with the three outcome variables. Compared with the reference level (≤200 m), living further away from a green space or senior service center was associated with a lower rather than a higher odds for poor SRPC, disability, or low HRQOL (as indicated by odds ratios below 1.00). Also, we could not find a clear trend with increasing distance, and most odds ratios clearly miss the level of statistical significance. Only for low HRQOL, odds ratios for living further than 200 m away from a senior service center were in the hypothesized direction but, as for the other outcome variables, the odds ratios were not significant and there was no clear trend. Contrary to our hypothesis, the associations between distance to service centers and health were not weaker than the associations between distance to green space and health.

In sensitivity analyses, Euclidian distances to the nearest green space or senior service center were also included in the multilevel logistic models as continuous variables (data not shown in table). Here the odds ratios represent the odds for fair/poor SRPC, moderate/severe limitations, or low HRQOL for every additional 50 m distance from the nearest green space or senior service center. For the distance to the nearest green space, we found no significant association with fair/poor SRPC (OR 0.99, 95 % CI 0.97–1.02), moderate/severe limitations (OR 0.98, 95 % CI 0.94–1.01), or low HRQOL (OR 0.98, 95 % CI 0.96–1.00); (all results from model 3). Similarly, we found no significant association between the distance to the nearest senior service center and fair/poor SRPC (OR 0.99, 95 % CI 0.99–1.00), moderate/severe limitations (OR 0.99, 95 % CI 0.98–1.00), or low HRQOL (OR 1.00, 95 % CI 0.99–1.00); (all results from model 3).

The analyses were repeated for the subgroup of participants aged 75 years or older (data not shown). Odds ratios were similar to those in the main analysis, but the 95 % confidence intervals were much wider, indicating that the sample size was not sufficient for this additional analysis.

Discussion

In view of notions of environmental gerontology (Lawton 1990) and life-span psychology (Baltes 1997), we hypothesized that proximity to features of the residential environment would be positively associated with healthy aging in this sample of 1711 adults aged 65 years or older from a city in southern Germany. However, we found no clear association between the Euclidian distance to the nearest green space or senior service center and self-rated physical constitution, disability, or health-related quality of life. A potential influence of the residential environment on healthy aging is likely to be small compared to the impact of individual factors such as age, sex, and socioeconomic status. It is thus possible that our study was insufficiently powered to detect these associations. This is further illustrated by the fact that we did not find significant associations of the outcome variables with regional deprivation. However, we did also not find significant associations

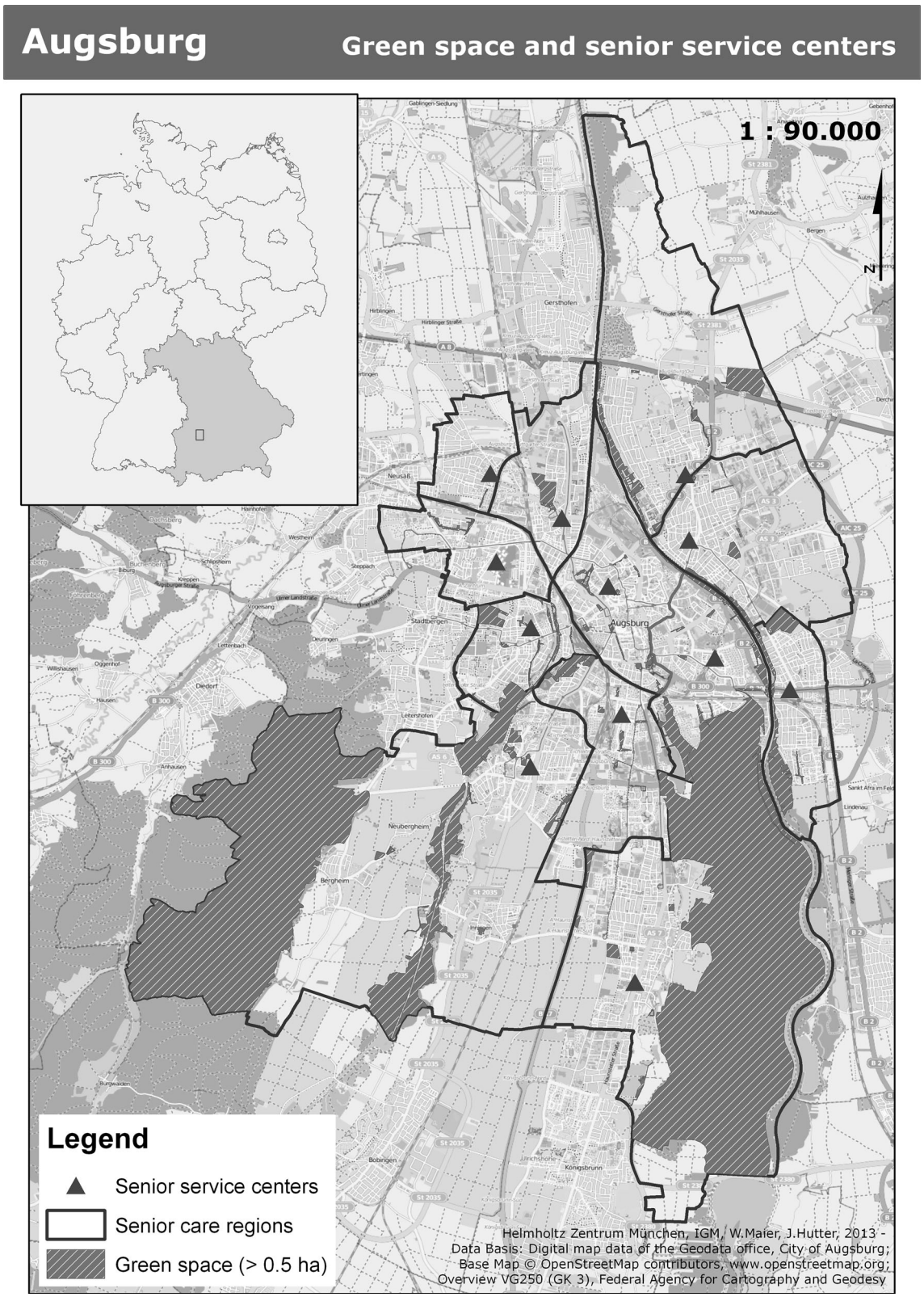

Fig. 1 City of Augsburg: green space and senior service centers. There are 12 senior service centers in the city of Augsburg. The senior care regions are the catchment areas for these centers

Table 2 Multilevel models: health outcomes and distance to green space

N	Self-rated physical constitution Fair/poor		Disability Moderate/severe limitations		Health-related quality of life Moderate/severe problems	
	1583		1580		1551	
	OR	[95 % CI]	OR	[95 % CI]	OR	[95 % CI]
Distance to green space (m)						
<200	Ref.	–		–		–
200–<400	0.94	[0.71; 1.24]	0.85	[0.57–1.26]	0.84	[0.64–1.11]
400–< 800	0.84	[0.64–1.12]	0.63*	[0.41–0.96]	0.76	[0.58–1.00]
≥800	1.11	[0.68–1.82]	1.02	[0.50–2.09]	0.89	[0.54–1.47]
Age (years)						
65–<70	Ref.	–		–		–
70–<75	1.63*	[1.20–2.21]	1.51	[0.87–2.62]	1.31*	[1.01–1.70]
75–<80	2.14*	[1.55–2.96]	2.89*	[1.70–4.93]	2.30*	[1.69–3.13]
≥80	3.21*	[2.31–4.45]	9.37*	[5.72–15.35]	3.42*	[2.41–4.83]
Sex						
Men	Ref.	–		–		–
Women	1.21	[0.97–1.52]	1.70*	[1.22–2.37]	1.32*	[1.07–1.64]
Per capita income per month (€)						
≥1625	Ref.	–		–		–
>750–<1625	1.48*	[1.09–2.02]	1.49	[0.95–2.33]	1.26	[0.96–1.65]
≤750	2.19*	[1.50–3.19]	1.57	[0.90–2.74]	1.69*	[1.17–2.44]
Regional deprivation						
Small	Ref.	–		–		–
High	1.22	[0.96–1.54]	1.00	[0.70–1.41]	1.09	[0.86–1.39]
Between-neighborhood variance (SE)	0		0		0.003 (0.02)	

* $p \leq 0.05$

between the distances and the outcome variables in the bivariate analyses (model 1). Associations with distance to senior service centers have not been studied to date, and it could be argued that no clear association with the health outcomes could be expected, as the potential pathways are rather indirect. Concerning the distance to green space, however, our results are somewhat surprising, as previous studies generally support the view that green space has a beneficial effect on health (Lee and Maheswaran 2011). There is empirical evidence in favor of a clear association between access to green space and self-rated health from several studies (Maas et al. 2006; Parra et al. 2010; Vries et al. 2003), and this relationship was shown to be especially strong for older people.

The fact that we found different results could be due to a number of reasons. First, these studies have assessed access to green space by its proportion in the neighborhood, and not by Euclidean distances. Second, our study population comes from a relatively small city, whereas other studies focused on a whole country such as the Netherlands (Maas et al. 2006; Vries et al. 2003) or on a huge and densely populated city such as Bogota (Parra et al. 2010). The differences within the city of Augsburg might not be pronounced strong enough, which is further illustrated by the missing between-neighborhood variance. Third, the city of Augsburg could be labeled a 'green city'. Green space seems to be readily available, with 36 % of the study participants living within 200 m of a green space of at least 0.5 hectare, and another 29 % living within 400 m.

It can be assumed that the association between proximity to green space and health differs according to the type of region studied, but this has rarely been discussed in any detail. Villeneuve et al. showed that living in areas with more green space is associated with reduced cardiovascular disease mortality, focusing on adults residing in 10 urban areas in the province of Ontario, Canada (Villeneuve et al. 2012). Takano et al. found that living in areas with walkable green spaces improved five-year survival rates among older residents of the Tokyo metropolitan area (Takano et al. 2002). In contrast, Richardson et al. found no evidence that access to green space influenced cardiovascular disease mortality among residents of small urban

Table 3 Multilevel models: Health outcomes and distance to a senior service center

N	Self-rated physical constitution Fair/poor		Disability Moderate/severe limitations		Health-related quality of life Moderate/severe problems	
	1583		1580		1551	
	OR	[95 % CI]	OR	[95 % CI]	OR	[95 % CI]
Distance to a senior service center (m)						
<200	Ref.	–		–		–
200–<400	0.94	[0.52–1.71]	0.90	[0.40–2.01]	1.45	[0.79–2.66]
400–<800	0.67	[0.40–1.11]	0.69	[0.35–1.34]	1.19	[0.71–1.99]
≥800	0.69	[0.42–1.13]	0.61	[0.32–1.17]	1.22	[0.74–2.02]
Age (years)						
65–<70	Ref.	–		–		–
70–<75	1.64*	[1.21–2.23]	1.51	[0.87–2.62]	1.31*	[1.01–1.70]
75–<80	2.16*	[1.56–2.99]	2.89*	[1.70–4.94]	2.34*	[1.72–3.19]
≥80	3.24*	[2.33–4.50]	9.49*	[5.80–15.55]	3.50*	[2.47–4.96]
Sex						
Men	Ref.	–		–		–
Women	1.20	[0.96–1.51]	1.68*	[1.21–2.34]	1.32*	[1.07–1.64]
Per capita income per month (€)						
≥1625	Ref.	–		–		–
>750–<1625	1.46*	[1.07–1.99]	1.48	[0.94–2.31]	1.25	[0.95–1.64]
≤750	2.18*	[1.49–3.18]	1.55	[0.89–2.70]	1.67*	[1.15–2.41]
Neighborhood deprivation						
Small	Ref.	–		–		–
High	1.20	[0.94–1.52]	0.95	[0.67–1.34]	1.08	[0.85–1.37]
Between-neighborhood variance (SE)	0		0		0.002 (0.02)	

* $p \leq 0.05$

areas in New Zealand (Richardson et al. 2010). These findings indicate that the influence of green space is strongest in large urban areas. Thus, we assume that in our study region distance to green space is not as important as it would be in a densely populated metropolitan region.

However, the picture seems to be more complicated. Maas et al. looked at the relationship between green space and physician-assessed morbidity in the Dutch population. They found the association to be strongest in slightly urbanized areas and not apparent in highly urbanized areas (Maas et al. 2009). They hypothesized that green space in highly urbanized areas often evokes feelings of insecurity and that therefore this green space might not be frequented very often. Although some studies reported a strong association between distance to green space and actual green space use (Coombes et al. 2010; Nielsen and Hansen 2007), an objectively defined measure does not necessarily reflect the resident's perception of the neighborhood. Mowafi et al. analyzed whether the availability of neighborhood green space was associated with BMI among adults in Cairo, Egypt, and found no significant association (Mowafi et al. 2012). They proposed the explanation that green space in Cairo may not be utilized for exercise, as this is not culturally acceptable for certain groups and, moreover, green space is not functionally built for exercise. In contrast, Voigtländer et al. studied the impact of neighborhood on subjective physical health in Germany and found that including the variable 'individual sport activities' in the regression analysis did not change the association between perceived distance to recreational resources and physical health (Voigtländer et al. 2010). Especially for older adults, however, it is quite possible that green space near their home is rarely used for recreational walking because of mobility barriers or safety concerns. This might also help to explain why we could not find clear associations with Euclidian distance to green space in our study.

Some limitations of our study need to be considered. It is cross-sectional, preventing any conclusions about the causal direction of the observed associations. We used Euclidean distances instead of network distances (thus underestimating the real walking distances), and we could

not take public transport into account. Also, we just included green space within the Augsburg municipal area (data on green space in the surrounding counties were not available). However, Augsburg is mostly surrounded by settlement and industrial areas and agricultural fields. We assume that these areas, even the agricultural areas, do not have the same importance as green space concerning recreation and physical activity. Another limitation was the relatively small sample size, especially concerning fair/poor SRPC and moderate/severe limitations in HRQOL as well as the relatively good health status of our study population. According to Lawton's environmental docility hypothesis (Lawton 1990), environmental features have a disproportional strong effect the more the personal competences decease. It is possible that our study population as well as our outcome categorizations did not sufficiently capture the group of individuals with the greatest need for cultural compensation (Baltes 1997).

Concerning the strengths of our study, it should be stressed that we used data from the KORA study, a large well-respected study. The distance to the nearest green space or senior service center was measured objectively and calculated on the basis of the respondents' point addresses. Also, we used a definition of neighborhood that was generated explicitly to correspond to the needs of older adults, i.e., the 'senior care regions' (instead of using administrative areas such as census tracts).

Conclusion

In this study, we did not observe an association between proximity to green space or senior service centers and health, focusing on older adults living in a relatively small city in Germany that is characterized by a good availability of public green space. The association between distance to green space and health seems to differ according to the study population and the type of region under study. More research is needed, especially for older adults, as they are more confined to their neighborhood than younger adults, and because results from studies using younger age groups might not be valid for older adults. Future studies should analyze differences between smaller cities and large metropolitan areas, assess actual use of green space, and apply a more refined definition of 'access' including walkability and public transport.

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Conflict of interest The authors declare that they have no competing interests.

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