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1 **Environmental Features Associated with Older Adults' Physical Activity in Different**
2 **Types of Urban Neighborhoods**

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17 Suggested running head: Physical Activity Facilitators in Urban Neighborhoods

1 **Environmental Features Associated with Older Adults' Physical Activity in Different**
2 **Types of Urban Neighborhoods**

Abstract

1
2 We studied associations of nature- and infrastructure-based features with physical activity
3 (PA) in different urban neighborhood types. 848 community-dwelling people aged 75-90
4 years reported PA and three perceived nature-based destinations and seven infrastructure-
5 based features as outdoor mobility facilitators. Neighborhood type was defined using a
6 geographic information system based on proximity to central service areas and residential
7 density (city center, subcenter, and dense and dispersed areas outside centers). PA was higher
8 in dense areas and city center. Binary logistic regression showed that perceiving nature-based
9 destinations increased the odds for higher PA in the city center and areas outside centers. In
10 dispersed areas, perceived infrastructure-based facilitators were especially associated with
11 higher PA. Environmental features were not associated with PA in subcenters. Higher
12 residential density, as proxy for higher amount of infrastructure, rather than center proximity
13 may underlie older peoples' PA. Spatial context should be acknowledged in studies on
14 environment–PA associations.

15 *Keywords:* aging, outdoor mobility, nature, infrastructure, GIS

Introduction

1
2 Urban neighborhoods are increasingly becoming the most common residential locations
3 (United Nations, 2018). At the same time, the proportion of people aged 60 or above in the
4 general population is already substantial and is forecasted to increase markedly in the coming
5 decades (United Nations, 2017). These concurrent trends of urbanization and aging, together
6 with climate change, present challenges for urban planners in designing inspiring urban
7 neighborhoods supporting an active and low-carbon lifestyle. For older people, neighborhood
8 environmental features are especially important, as their physical activity (PA) mostly takes
9 place close to their homes (Chaudhury, Campo, Michael, & Mahmood, 2016). Being
10 physically active is important for the functional capability, health, and life satisfaction of
11 older people, and thus should be encouraged.

12 Recent systematic reviews and meta-analysis have presented evidence on the close
13 associations of various environmental features with total PA in older adults (Barnett et al.,
14 2017), walking for transport (Cerin, Nathan, van Cauwenberg, Barnett, & Barnett, 2017), and
15 leisure-time walking (Van Cauwenberg et al., 2018). The availability and range of different
16 destinations, such as recreational facilities, parks and public open spaces (Barnett et al., 2017;
17 Van Cauwenberg et al., 2018; Cerin et al., 2017), and the availability of public transport
18 (Barnett et al., 2017; Van Cauwenberg et al., 2018) were associated with higher levels of PA.
19 PA was also higher in the presence of favorable features of the pedestrian infrastructure,
20 including the availability of resting places (Cerin et al., 2017), higher residential
21 density/urbanization and street connectivity (Cerin et al., 2017), a walk- or pedestrian-
22 friendly infrastructure (Barnett et al., 2017; Cerin et al., 2017), and higher walkability
23 (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al., 2018). Walkability is a
24 composite index of residential and intersection density and the evenness of land-use

1 distribution for residential, commercial, and office purposes (Frank, Schmid, Sallis,
2 Chapman, & Saelens, 2005).

3 The person-environment fit model posits that the balance between personal
4 capabilities and environmental demands is an important factor underlying a person's
5 possibilities to act in his or her surroundings (Lawton & Nahemow, 1973). For example, an
6 older person's walking capability, chronic conditions or socioeconomic status may affect the
7 way neighborhood environmental features are perceived and how they relate to PA (Portegijs
8 et al., 2013; Barnett et al., 2016; Koohsari et al. 2017; Sugiyama et al., 2017). However,
9 whether neighborhood characteristics moderate the associations of environmental features
10 with older adults' PA is less clear. Several recent reviews have found the evidence either
11 inconclusive or inconsistent (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al.,
12 2018).

13 In previous studies, neighborhoods have been characterized as urban/rural (Lee &
14 Park, 2015), urban/suburban/rural (Hanibuchi, Kawachi, Nakaya, Hirai, & Kondo, 2011;
15 Maisel, 2016), based on residential density (Troped et al., 2014) and perceived distance to
16 services (Van Cauwenberg et al., 2013), or, utilizing measures of walkability (Orstad et al.
17 2018, Bracy et al. 2014), perceived neighborhood walkability (Merom et al. 2015), number of
18 intersections (Li et al. 2005), and perceived pedestrian (Bracy et al. 2014) and traffic safety
19 (Li, Fisher, Brownson, & Bosworth, 2005). To the best of our knowledge, no previous study
20 among older adults has categorized neighborhood types as a single measure combining
21 objective environmental characteristics with spatial relations, that is, residential density and
22 proximity to a center. Here, a center was defined as a central area offering a wide variety of
23 services. Inclusion of an indicator of environmental context in research on associations
24 between environmental features and PA might yield new knowledge on the factors
25 underlying older adults' perceptions of environmental outdoor mobility facilitators and the

1 influence of these on their PA. Categorizing neighborhoods into city center, subcenters, and
2 dense and disperse areas outside centers could also enhance the value of research results for
3 urban planning. Moreover, viewing neighborhood types as separate spatial entities enables
4 their further characterization by the addition of environmental features.

5 The research questions were as follows:

- 6 1. Do neighborhood types in an urban structure differ in the proportions of people
7 reporting destinations in nature and features of the infrastructure as perceived
8 facilitators of outdoor mobility?
- 9 2. How are different nature- and infrastructure-based facilitators associated with PA in
10 different neighborhood types?

11 **Methods**

12 **Study Design**

13 This study forms part of the project “Geographic characteristics, outdoor mobility and
14 physical activity in old age” (GEOage) (Portegijs et al., 2017). In this study, we combine self-
15 reported participant data with objectively defined data such as that on urban structure. Data
16 on urban structure and on objective environmental characteristics were retrieved from openly
17 available geospatial datasets and studied in relation to participant data. Participant data,
18 including physical activity and perceived environmental features of the neighborhood,
19 collected from community-dwelling older adults, were drawn from the data gathered for the
20 “Life-Space Mobility in Old Age” (LISPE) project described earlier (Rantanen et al., 2012).
21 To enable objectively defining neighborhood type and neighborhood characteristics for each
22 participant, participants’ home addresses were geocoded using the Digiroad dataset (Finnish
23 Transport Agency, 2013) in Geographic Information System (GIS) software ArcMap 10.3
24 (ESRI, Redlands, USA).

1 Briefly, study participants were 75 to 90 years old and living in two Finnish
2 neighboring municipalities, Jyväskylä and Muurame, both located within the same urban
3 structure. In the year 2012, Muurame had about 9 500 inhabitants and Jyväskylä, the 7th
4 largest city in Finland, about 133 500 inhabitants (Statistics Finland, 2019). The main city
5 center and subcenters form compact areas for business, services, and residence, while areas
6 outside the centers form an urban fabric with varying residential density. A random sample of
7 2 550 people was drawn from the national population register and informed about the study.
8 Participants not willing to participate, not living independently, unable to communicate, or
9 residing outside recruitment area were excluded. Eventually, 848 people participated in the
10 face-to-face interviews, conducted in their own homes using a structured questionnaire.

11 All participants signed a written informed consent before the interview. The study
12 was conducted in accordance with the Declaration of Helsinki. Ethical approvals were
13 granted for the LISPE project on 2 November 2011 and for the GEOage project on 2
14 September 2014 by the Ethical Committee of the University of Jyväskylä, Finland.

15 **Study Measures**

16 ***Physical activity.*** Physical activity was assessed with one self-reported question “Thinking of
17 the past half year, which of the following best describes your physical activity?” Response
18 options (modified from Grimby, 1986) were (a) mostly resting, hardly any activity, (b)
19 mostly sitting, with PA confined to activities of daily living (grooming, dressing), (c) light
20 PA, such as light housework or light gardening or going for a walk two or three times a week,
21 (d) moderate PA about 3 hours a week, (e) moderate PA at least 4 hours a week or heavier
22 PA up to 4 hours a week, (f) engaging in active sports several times a week or heavy
23 gardening or leisure-time activities, at least 3 hours a week, and (g) participating in
24 competitive sports. For the analysis, we dichotomized PA into light PA only (a-c) and at least

1 moderate PA (d-g). The validity of the question on self-reported PA and its categorization
2 have been found adequate for assessing PA levels in older people (Portegijs, Sipilä, Viljanen,
3 Rantakokko, & Rantanen, 2016).

4 ***Perceived environmental facilitators for outdoor mobility.*** For each item on the checklist of
5 perceived environmental facilitators of outdoor mobility (PENBOM) (Rantakokko, Iwarsson,
6 Portegijs, Viljanen, & Rantanen, 2015), participants reported whether they perceived it as a
7 facilitator of outdoor mobility in their neighborhood. Of the 16 facilitators listed, three items
8 concerned nature-based destinations (nature and lakeside, walking trail and skiing track, and
9 park or other green area) and seven concerned features of the infrastructure (peaceful
10 walkways, services close, good lighting, safe crossings, even sidewalks, resting places by
11 walking route, walkways without steep hills) as facilitators of outdoor mobility. We omitted
12 six items from the current analyses as they addressed subjective social and safety aspects of
13 outdoor mobility (e.g., other people as motivators of outdoor mobility, familiar environment)
14 and thus were beyond the scope of this study. Furthermore, for the analyses, separate counts
15 were made of nature-based destinations and infrastructure-based facilitators and the result
16 divided into tertiles; for the nature-based facilitators the tertiles were 0-1, 2, and 3, and for the
17 infrastructure-based facilitators 0-1, 2-3, ≥ 4 .

18 ***Neighborhood type.*** Using GIS, we first located the main city center and subcenter areas (six
19 in total) using the dataset Downtown areas and shopping areas (Finnish Environment
20 Institute, 2015) which comprises areas characterized by a higher availability and variety of
21 spatially connected service locations, considerably higher density of workplaces in services
22 and retail, and higher residential density than surrounding areas. Buffer zones with a radius of
23 500 meters were drawn up around each center area and participants living in these buffered
24 center areas were assigned to the corresponding neighborhood type (Figure 1). In research on
25 older peoples' PA, buffer zones of a 400- or 500-meter radius are commonly used to

1 delineate neighborhood areas (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al.,
2 2018). Moreover, the European Commission (2001) proposes 500 meters as the maximum
3 walking distance to public open spaces. For participants who lived outside these buffered
4 center areas, neighborhood type was defined based on the mean residential density within a
5 500-meter radius of the participant's home location. To enable mean residential density to be
6 calculated from the Population grid data 2012 (Official Statistics of Finland, 2015), the
7 original 1 kilometer x 1 kilometer grid data were transformed to a raster with a cell size of
8 100 meters x 100 meters. The median value of the mean residential densities in participants'
9 home buffer zones was applied as a cut-point to divide participants' neighborhood types into
10 dense (> 961 persons/km²) and dispersed (≤ 961 persons/km²) areas outside centers. Thus,
11 based on center proximity and residential density four neighborhood types were defined: city
12 center, subcenter, dense areas outside centers, and dispersed areas outside centers.

13 **Covariates**

14 *Neighborhood characteristics.* We used residential and intersection densities (Frank et al.,
15 2005) to approximate the amount of infrastructure supporting outdoor mobility in the
16 neighborhood. We calculated average residential density within a 500-meter radius of each
17 participant's home, based on Population grid data as described earlier. The Topographic
18 Database 2013 (National Land Survey of Finland, 2013) in GIS was used to calculate
19 intersection density for each participant. We merged intersections within a 10-meter distance
20 of one another and, based on road data, counted the total number of crossings comprising a
21 minimum of three roads, which were suitable for year-round walking located within 500
22 meters of each participant's home. Intersection density was the road intersection count
23 divided by the home buffer zone surface area. Higher residential and intersection densities
24 indicate reflect a higher amount of infrastructure.

1 As an index of overall greenness (Weier & Herring, 2000), we calculated a
2 normalized difference vegetation index (NDVI) using Landsat 5 satellite images taken in July
3 2010 available from the U.S. Geological Survey (2014) and processed for surface reflectance
4 as 30 x 30-meter raster datasets. We removed waterbodies (National Land Survey of Finland,
5 2013) from the raster dataset, as previously suggested (Ekkel & de Vries, 2017), and
6 calculated the mean NDVI within a 500-meter radius of each raster cell in GIS. We assigned
7 each participant the mean NDVI value of the raster cell in the participant's home location
8 (range -1 and 1, with higher values indicating higher greenness).

9 ***Participant characteristics.*** To account for personal and socioeconomic differences, we used
10 age, sex, difficulty in walking 500 meters, number of chronic conditions, and years of
11 education as covariates (Barnett et al, 2017; Cerin et al., 2017; Van Cauwenberg et al., 2018)
12 in the statistical analysis. In addition, to control for familiarity with the neighborhood
13 environment we adjusted the models for length of time lived in the current home. Age, sex,
14 and the latest change of address used for calculating the time lived in the current home were
15 retrieved from national population register data. We calculated a sum of self-reported
16 physician-diagnosed chronic conditions based on responses to a list of 22 chronic conditions
17 (yes/no) and an additional open-ended question (Rantanen et al., 2012). Self-reported years of
18 education was used as an indicator of socioeconomic status.

19 **Analyses**

20 We had few missing data. Perceiving safe crossings as a facilitator of outdoor mobility data
21 was missing for one participant, which also resulted in one missing case in the count of
22 infrastructure-based facilitators. For years of education, data were missing for eight
23 participants and no imputation was conducted. The last change of address was missing for 30

1 follows: 229 lived in the city center, 144 in subcenters, 237 in dense areas outside centers,
2 and 238 in dispersed areas outside centers.

3 City center participants were on average older than participants living in the other
4 areas ($p=0.002$), and, together with participants living in dense areas outside centers, had
5 received more years of education ($p=0.002$; Table 1). The proportion of women was higher in
6 the city center and subcenters than in areas outside centers ($p<0.001$). At least moderate PA
7 was more commonly reported in dense areas outside centers than in the other areas ($p=0.002$).
8 The city center had the highest residential and intersection densities but the lowest amount of
9 greenness; conversely, the lowest residential and intersection densities but highest amount of
10 greenness was observed in dispersed areas outside centers, leaving the other areas somewhere
11 in between (each $p<0.001$).

12 **Reports of Perceived Nature- And Infrastructure-Based Facilitators for Outdoor**

13 **Mobility by Neighborhood Type**

14 Nature and lakeside, walking trail and skiing track, and peaceful walkways were perceived as
15 outdoor mobility facilitators by more than half of all the respondents, and they were among
16 the five most reported facilitators of outdoor mobility in each neighborhood type (Figure 2).
17 Generally, infrastructure-based facilitators were more frequently reported in areas around
18 centers or areas with higher population density, while nature-based facilitators (except for
19 park and other green area) were more evenly reported. Park or other green area ($p<0.001$) and
20 services in close proximity ($p<0.001$) were reported as facilitators of outdoor mobility by
21 approximately 60% of those living in the city center and by less than 30% of those living in
22 dispersed areas outside centers (Figure 2). The number of nature-based destinations
23 ($p<0.001$) and infrastructure-based facilitators for outdoor mobility ($p<0.001$) reported by

1 participants was statistically significantly lower for participants living in dispersed areas
2 outside centers than for the others (Table 2).

3 **Associations of Perceived Facilitators of Outdoor Mobility with Higher PA by** 4 **Neighborhood Type**

5 The associations of outdoor mobility facilitators and physical activity differed between the
6 neighborhood types (Table 3). Relatively similar associations were observed for participants
7 living in city centers and dense areas outside centers. For them nature and lakeside and
8 walking and skiing trails were associated with two- to fourfold higher odds for reporting at
9 least moderate vs. only light PA. Moreover, two-fold odds for higher PA were found for
10 walkways without steep hills, good lighting in city centers, and safe crossings in dense areas.
11 Participants living in dispersed areas reported parks as outdoor mobility facilitators less often
12 than participants living in the other neighborhood types; however, those who did so had two-
13 fold higher odds for at least moderate PA than those who did not. In this neighborhood type,
14 peaceful walkways, good lighting and even sidewalks, although reported as facilitators less
15 often than in the other neighborhood types, also correlated with higher PA. However,
16 reporting a high number of infrastructure-based facilitators correlated with higher PA only
17 among city center residents. Excepting participants living in subcenters, for whom no
18 associations of outdoor mobility facilitators with physical activity were found, the more
19 nature-based facilitators participants reported, the more likely they were to report at least
20 moderate PA.

21 **Discussion**

22 The main findings of the present study were that physical activity levels, perceived
23 environmental outdoor mobility facilitators, and the associations of the outdoor mobility
24 facilitators with PA differed between the neighborhood types. These results emphasize the

1 importance of considering the spatial context when studying the associations of
2 environmental features with physical activity in older people.

3 Our analysis showed that the presence or absence of a center within a neighborhood
4 did not explain which types of facilitators were associated with PA. Rather, neighborhood
5 types with the highest population density (city center and dense areas outside the centers),
6 that is, areas with the highest amount of infrastructure with or without a center, showed
7 similarities in that several nature-based destinations, but only few infrastructure-based
8 facilitators, were correlates of higher PA. Conversely, in dispersed areas outside centers, that
9 is, areas with the lowest amount of infrastructure, perceived infrastructure-based facilitators
10 were clearly associated with higher PA. Thus, it seems that, for older adults, the objectively
11 evaluated amount of infrastructure supporting outdoor mobility in the neighborhood is more
12 relevant than the proximity of a center.

13 In our study, infrastructure-based facilitators appeared to be of especial importance
14 for older adults' PA in dispersed areas outside centers, where perceived peaceful walkways,
15 good lighting, and even sidewalks were associated with PA. This differs from previous
16 studies in which no significant associations were observed between similar facilitators and
17 PA when the study samples were stratified into urban and rural (Lee & Park, 2015) and
18 urban, suburban, and rural (Maisel, 2016). Moreover, in our study, multiple types of
19 infrastructure-based facilitators showed higher associations with PA in the dispersed
20 compared to the other neighborhood types. This result supports Hanibuchi et al. (2011), who
21 found a higher number of significant associations between objective infrastructure indicators
22 and older adults' PA in rural than urban and suburban areas, although the associations were
23 positive for the frequency of sports activity and negative for total walking time, which is
24 closer to the measure used in the current study. In the city center area, however, perceiving a
25 high number of infrastructure-based facilitators compared to perceiving only one or none of

1 these was associated with an increased likelihood of higher PA. This result parallels that of
2 Van Cauwenberg et al. (2013), who found higher numbers of perceived infrastructure-based
3 facilitators to be associated with increased likelihood for daily transportation walking among
4 older adults in neighborhoods with self-reported medium distance to service destinations but
5 not with short or long distances.

6 Perceiving nature-based destinations as a facilitator for outdoor mobility was
7 associated with higher PA, especially when participants perceived several of these. For
8 example, walking trails and skiing tracks were especially important facilitators in densely
9 populated areas with or without a center, while parks were associated with increased
10 likelihood for higher PA in dispersed areas outside centers, as also found by Lee and Park
11 (2015). Only subcenters showed no association between any of the separate perceived nature-
12 based destinations or combinations of these with PA level.

13 Troped et al. (2014) found several destination-based facilitators to be associated with
14 higher PA in older women, but only in neighborhoods with the highest population density.
15 Bracy et al. (2014) reported that the proximity of a recreation facility increased the likelihood
16 of walking for leisure among older people who perceived the infrastructure as supporting
17 pedestrian safety in their neighborhood but not among those who did not. In this connection,
18 Yen and colleagues (2014) proposed that perception of safety is the central mechanism
19 bridging environmental factors and older adults' decisions about mobility in their
20 environment, and that safety may be reflected in perceived features as well as in objective
21 measures. In fact, a recent systematic review and meta-analysis conducted by Van
22 Cauwenberg et al. (2018) concluded that favorable walking environments, e.g., a suitable
23 pedestrian infrastructure, provided the strongest evidence for an environmental factor to act
24 as a moderator in the association between recreational facilities and older adults' leisure-time

1 PA. Moran et al. (2014), in their systematic review, also suggested that the pedestrian
2 infrastructure is a factor underlying older adults' PA.

3 It has previously been reported that the level of PA and mobility capability of a
4 person affects how environmental facilitators are perceived (Merom et al., 2015; Sakari et al.,
5 2017). Physically active older people are more likely to move through their neighborhood and
6 thus be more aware than their less active counterparts of the features in their environment that
7 facilitate outdoor mobility (Portegijs et al., 2013) These environmental features then appear
8 as perceived PA facilitators in the analysis. This may partly explain why we did not detect
9 any associations between environmental facilitators and PA for participants living in
10 subcenters, who were less physically active than those living in the other neighborhood types.
11 However, it is also possible that the areas included in the subcenter category differed from
12 each other more than the pooled areas in the other neighborhood types in potential
13 characteristics not assessed in the study.

14 The strengths of our study include the use of a population-based sample of
15 community-dwelling older adults in a spatially connected area comprising various
16 neighborhood types. With this urban structure, we were able confidently to assign each
17 participant to an objectively defined neighborhood type, thus achieving high reliability in the
18 objective categorization of the participants according to neighborhood types. A further
19 strength of our approach of taking urban structure as the basis for defining neighborhood
20 types is the high applicability of our results to urban planning. We also had versatile data on
21 participant-perceived facilitators for outdoor mobility, health, and socioeconomic
22 characteristics with very little missing information, enabling us to take individual factors
23 comprehensively into account in the analysis.

1 adults' PA, the hierarchies and moderating effects of environmental facilitators in different
2 neighborhood types warrant further research. Information on PA locations and perceived
3 environmental facilitators could help to create a more comprehensive picture of person-
4 environment interaction in the PA behavior of older people. Furthermore, the lack of
5 associations of perceived facilitators of outdoor mobility with PA in subcenter areas requires
6 further study. In conclusion, in order to successfully develop strategies to increase older
7 people's PA in different types of neighborhoods, it seems important to acknowledge the
8 varying degrees of infrastructure that exist across urban structures.

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17 **References**

- 18 Barnett, A., Cerin, E., Zhang, C.J., Sit, C.H., Johnston, J.M., & Cheung, M.M. (2016).
19 Associations between the neighbourhood environment characteristics and physical
20 activity in older adults with specific types of chronic conditions: the ALECS cross-
21 sectional study. *International Journal of Behavioral Nutrition and Physical Activity*,
22 *13*(53). doi:10.1186/s12966-016-0377-7
- 23 Barnett, D. W., Barnett, A., Nathan, A., Van Cauwenberg, J., Cerin, E., & Council on
24 Environment and Physical Activity (CEPA) – Older Adults, working group. (2017).

- 1 Built environmental correlates of older adults' total physical activity and walking: a
2 systematic review and meta-analysis. *The International Journal of Behavioral*
3 *Nutrition and Physical Activity*, 14(103). doi:10.1186/s12966-017-0558-z
- 4 Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects
5 Models Using lme4. *Journal of Statistical Software*, 67(1), 1-48.
6 doi:10.18637/jss.v067.i01
- 7 Bracy, N. L., Millstein, R. A., Carlson, J. A., Conway, T. L., Sallis, J. F., & Saelens, B. E.
8 (2014). Is the relationship between the built environment and physical activity
9 moderated by perceptions of crime and safety? *International Journal of Behavioral*
10 *Nutrition and Physical Activity*, 11(24). doi:10.1186/1479-5868-11-24
- 11 Cerin, E., Nathan, A., van Cauwenberg, J., Barnett, D. W., & Barnett, A. (2017). The
12 neighbourhood physical environment and active travel in older adults: a systematic
13 review and meta-analysis. *International Journal of Behavioral Nutrition and Physical*
14 *Activity*, 14(15). doi:10.1186/s12966-017-0471-5
- 15 Chaudhury, H., Campo, M., Michael, Y., & Mahmood, A. (2016). Neighbourhood
16 environment and physical activity in older adults. *Social Science & Medicine*, 149,
17 104-113. doi.org/10.1016/j.socscimed.2015.12.011
- 18 Ekkel, E. D., & de Vries, S. (2017). Nearby green space and human health: Evaluating
19 accessibility metrics. *Landscape and Urban Planning*, 157, 214-220.
20 doi.org/10.1016/j.landurbplan.2016.06.008
- 21 European Commission, Expert Group on the Urban Environment. (2001). *Towards a local*
22 *sustainability profile - European common indicators*. Methodology Sheets for testing
23 phase 2001-02. ISBN 92-894-1497-9.

- 1 Finnish Environment Institute. (2015). *Downtown areas and shopping areas 2010/2012*, 250
2 m. CSC - IT Center for Science Ltd., Finnish Environment Institute. Etsin research
3 data finder.
- 4 Finnish Transport Agency. (2013). *Digiroad road and street database, R-format 2013*. CSC –
5 IT Center for Science Ltd., Finnish Transport Agency.
- 6 Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005). Linking
7 objectively measured physical activity with objectively measured urban form:
8 Findings from SMARTRAQ. *American Journal of Preventive Medicine*, 28(2), 117-
9 125. doi:10.1016/j.amepre.2004.11.001
- 10 Grimby, G. (1986). Physical activity and muscle training in the elderly. *Acta Medica*
11 *Scandinavia*, 220(S711), 233-237.
- 12 Hanibuchi, T., Kawachi, I., Nakaya, T., Hirai, H., & Kondo, K. (2011). Neighborhood built
13 environment and physical activity of Japanese older adults: results from the Aichi
14 Gerontological Evaluation Study (AGES). *BMC Public Health*, 11(657).
15 doi:10.1186/1471-2458-11-657
- 16 Koohsari, M. J., Hanibuchi, T., Nakaya, T., Shibata, A., Ishii, K., Liao, Y., . . . Sugiyama, T.
17 (2017). Associations of neighborhood environmental attributes with walking in Japan:
18 Moderating effects of area-level socioeconomic status. *Journal of Urban Health*,
19 94(6), 847-854. doi:10.1007/s11524-017-0199-1
- 20 Lawton M. P., & Nahemow, L. 1973, Ecology and the aging process. In L.M.P. Eisdorfer C.
21 (ed.), *The psychology of adult development and aging* (pp. 619-674). American
22 Psychological Association, Washington DC.

- 1 Lee, H., & Park, E. (2015). Associations of neighborhood environment and walking in
2 Korean elderly women: A comparison between urban and rural dwellers. *Asian*
3 *Women*, 31(4), 1-21. doi:10.14431/aw.2015.12.31.4.1
- 4 Li, F., Fisher, K. J., Brownson, R. C., & Bosworth, M. (2005). Multilevel modelling of built
5 environment characteristics related to neighbourhood walking activity in older adults.
6 *Journal of Epidemiology & Community Health*, 59(7), 558-564.
7 dx.doi.org/10.1136/jech.2004.028399
- 8 Maisel, J. L. (2016). Impact of older adults' neighborhood perceptions on walking behavior.
9 *Journal of Aging and Physical Activity*, 24(2), 247-255. doi.org/10.1123/japa.2014-
10 0278
- 11 Merom, D., Gebel, K., Fahey, P., Astell-Burt, T., Voukelatos, A., Rissel, C., & Sherrington,
12 C. (2015). Neighborhood walkability, fear and risk of falling and response to walking
13 promotion: The Easy Steps to Health 12-month randomized controlled trial.
14 *Preventive Medicine Reports*, 2, 704-710. doi:10.1016/j.pmedr.2015.08.011
- 15 Moran, M., Van Cauwenberg, J., Hercky-Linnewiel, R., Cerin, E., Deforche, B., & Plaut, P.
16 (2014). Understanding the relationships between the physical environment and
17 physical activity in older adults: a systematic review of qualitative studies.
18 *International Journal of Behavioral Nutrition and Physical Activity*, 11(79).
19 doi.org/10.1186/1479-5868-11-79
- 20 National Land Survey of Finland. (2013). *Topographic database 2013*, 1:10 000. CSC - IT
21 Center for Science Ltd, 2015-10-08T00:00:00-00:00, urn:nbn:fi:csc-
22 kata00001000000000000181

- 1 National Land Survey of Finland, & Ek, K. (2015). *Administrative borders 2012*, 1:10 000.
2 CSC - IT Center for Science Ltd., National Land Survey of Finland. Etsin research
3 data finder.
- 4 Official Statistics of Finland. (2015). *Population grid data 2012*, 1 km x 1 km. CSC - IT
5 Center for Science Ltd., Official Statistics of Finland. Etsin research data finder.
- 6 Orstad, S.L., McDonough, M.H., James, P., Klenosky, D.B., Laden, F., Mattson M., &
7 Troped, P.J. (2018). Neighborhood walkability and physical activity among older
8 women: Tests of mediation by environmental perceptions and moderation by
9 depressive symptoms. *Preventive Medicine*, 116, 60-67.
10 doi.org/10.1016/j.ypmed.2018.08.008
- 11 Portegijs, E., Keskinen, K. E., Tsai, L., Rantanen, T., & Rantakokko, M. (2017). Physical
12 limitations, walkability, perceived environmental facilitators and physical activity of
13 older adults in Finland. *International Journal of Environmental Research and Public
14 Health*, 14(3) doi:10.3390/ijerph14030333
- 15 Portegijs, E., Rantakokko, M., Edgren, J., Salpakoski, A., Heinonen, A., Arkela, M., . . .
16 Sipilä, S. (2013). Effects of a rehabilitation program on perceived environmental
17 barriers in older patients recovering from hip fracture: A randomized controlled trial.
18 *BioMed Research International*, 2013, 769645. dx.doi.org/10.1155/2013/769645
- 19 Portegijs, E., Sipilä, S., Viljanen, A., Rantakokko, M., & Rantanen, T. (2016). Validity of a
20 single question to assess habitual physical activity of community-dwelling older
21 people. *Scandinavian Journal of Medicine & Science in Sports*, 27, 1423-1430.
22 https://doi.org/10.1111/sms.12782
- 23 R Core Team (2018). *R: A language and environment for statistical computing*. R Foundation
24 for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>

- 1 Rantakokko, M., Iwarsson, S., Portegijs, E., Viljanen, A., & Rantanen, T. (2015).
2 Associations between environmental characteristics and life-space mobility in
3 community-dwelling older people. *Journal of Aging and Health*, 27(4), 606-621.
4 doi.org/10.1177/0898264314555328
- 5 Rantanen, T., Portegijs, E., Viljanen, A., Eronen, J., Saajanaho, M., Tsai, L., . . . Rantakokko,
6 M. (2012). Individual and environmental factors underlying life space of older people
7 - study protocol and design of a cohort study on life-space mobility in old age
8 (LISPE). *BMC Public Health*, 12(1), 1018. doi.org/10.1186/1471-2458-12-1018
- 9 Rikli, R. E. (2000). Reliability, validity, and methodological issues in assessing physical
10 activity in older adults. *Research Quarterly for Exercise and Sport*, 71, 89-96.
11 doi:10.1080/02701367.2000.11082791
- 12 Sakari, R., Rantakokko, M., Portegijs, E., Iwarsson, S., Sipilä, S., Viljanen, A., & Rantanen,
13 T. (2017). Do associations between perceived environmental and individual
14 characteristics and walking limitations depend on lower extremity performance level?
15 *Journal of Aging and Health*, 29(4), 640-656. doi.org/10.1177/0898264316641081
- 16 Statistics Finland. (2019). *Official statistics of Finland: Population structure*. Helsinki:
17 Statistics Finland.
- 18 Sugiyama, T., Cole, R., Thompson, R., Sahlqvist, S., de Sá, T. H., Carver, A., & Astell-Burt,
19 T. (2017). Area-level socio-economic disparities in active and sedentary transport:
20 Investigating the role of population density in Australia. *Journal of Transport &*
21 *Health*, 6, 282-288 dx.doi.org/10.1016/j.jth.2017.04.009
- 22 Troped, P. J., Starnes, H. A., Puett, R. C., Tamura, K., Cromley, E. K., James, P., . . . Laden,
23 F. (2014). Relationships between the built environment and walking and weight status

- 1 among older women in three U.S. States. *Journal of Aging and Physical Activity*,
2 22(1), 114-125. doi.org/10.1123/japa.2012-0137
- 3 United Nations, Department of Economic and Social Affairs, Population Division (2017).
4 *World Population Ageing 2017* (ST/ESA/SER.A/408). www.un.org
- 5 United Nations, Department of Economic and Social Affairs, Population Division (2018).
6 *World Urbanization Prospects 2018*. <https://population.un.org/wup/>
- 7 U.S. Geological Survey. (2014). *EarthExplorer, Landsat 4-5 TM CI level 2 imagery*.
8 Retrieved from <http://earthexplorer.usgs.gov>
- 9 Van Cauwenberg, J., Clarys, P., De Bourdeaudhuij, I., Van Holle, V., Verté, D., De Witte,
10 N., . . . Deforche, B. (2013). Older adults' transportation walking: a cross-sectional
11 study on the cumulative influence of physical environmental factors. *International*
12 *Journal of Health Geographics*, 12(37). doi.org/10.1186/1476-072X-12-37
- 13 Van Cauwenberg, J., Nathan, A., Barnett, A., Barnett, D. W., Cerin, E., & the Council on
14 Environment and Physical Activity (CEPA)-Older Adults, Working Group. (2018).
15 Relationships between neighbourhood physical environmental attributes and older
16 adults' leisure-time physical activity: A systematic review and meta-analysis. *Sports*
17 *Medicine*, 48(7), 1635-1660. doi.org/10.1007/s40279-018-0917-1
- 18 Weier, J., & Herring, D. (2000). *Measuring vegetation (NDVI & EVI)*. Retrieved from
19 https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetatio
20 n_1.php
- 21 Yen, I. H., Flood, J. F., Thompson, H., Anderson, L. A., & Wong, G. (2014). How design of
22 places promotes or inhibits mobility of older adults: Realist synthesis of 20 years of

- 1 research. *Journal of Aging and Health*, 26(8), 1340-1372.
- 2 doi.org/10.1177/0898264314527610

Table 1. Participant and neighborhood characteristics (mean \pm standard deviation or %) according to neighborhood type.

	All (n=848)	City center (n=229)	Subcenters (n=144)	Dense areas outside centers (n=237)	Dispersed areas outside centers (n=238)	p
Participant characteristics						
Age (yrs)	80.6 \pm 4.2	81.4 \pm 4.2	80.6 \pm 4.3	80.4 \pm 4.1	80.0 \pm 4.2	0.002^a
Chronic conditions (n)	4.4 \pm 2.4	4.3 \pm 2.4	4.8 \pm 2.6	4.3 \pm 2.4	4.3 \pm 2.4	0.229 ^a
Education (yrs)	9.6 \pm 4.1	10.0 \pm 4.2	9.5 \pm 3.8	10.0 \pm 4.5	8.8 \pm 3.8	0.002^a
Current home (yrs)	23.0 \pm 14.6	19.4 \pm 13.7	17.7 \pm 13.8	26.1 \pm 14.0	26.4 \pm 14.9	<0.001^a
Women (%)	62	70	70	59	52	<0.001^b
Walking difficulties (%)	26	28	28	20	28	0.177 ^b
At least moderate PA (vs. Only light, %)	64	64	58	73	58	0.002^b
Neighborhood characteristics						
Residential density (persons / km ²)	1958 \pm 1491	4070 \pm 717	1377 \pm 687	1747 \pm 589	488 \pm 295	<0.001^a
Intersection density (n/km ²)	60 \pm 24	85 \pm 16	61 \pm 15	58 \pm 15	38 \pm 20	<0.001^a
Greenness, NDVI (index -1...1)	0.39 \pm 0.12	0.24 \pm 0.08	0.40 \pm 0.05	0.44 \pm 0.05	0.48 \pm 0.07	<0.001^a

^a Kruskal-Wallis test; ^b Pearson's Chi-Square test

Table 2. Proportion of participants reporting nature- and infrastructure-based facilitators in each neighborhood type (n=848).

	All (n=848)	City center (n=229)	Subcenters (n=144)	Dense areas outside centers (n=237)	Dispersed areas outside centers (n=238)	p [#]
Counts of nature-based destinations as facilitators (%)						<0.001
≤ 1 facilitators	42	43	36	35	52	
2 facilitators	30	22	34	33	31	
3 facilitators	28	35	30	32	17	
Counts of infrastructure-based facilitators (%)						<0.001
≤ 1 facilitators	46	31	38	43	68	
2 or 3 facilitators	30	37	35	28	20	
≥ 4 facilitators	25	32	28	28	12	

[#]Pearson's Chi-Square test

Table 3. Binary logistic regression of perceived facilitators of outdoor mobility and the odds (OR) for reporting at least moderate PA compared to only light PA. For the separate facilitators, reference group is those not perceiving the facilitator. For the sum of facilitators, reference group is those perceiving one or none of the facilitators. Analyses* were conducted separately for each neighborhood type.

	City center (n=229)		Subcenter (n=144)		Dense areas outside centers (n=237)		Disperse areas outside centers (n=238)	
	No OR	Yes OR (95% CI)	No OR	Yes OR (95% CI)	No OR	Yes OR (95% CI)	No OR	Yes OR (95% CI)
Nature-based destinations as facilitators								
Nature, lake-side	1.00	2.58 (1.26-5.28)	1.00	0.68 (0.22-2.06)	1.00	2.33 (1.08-5.03)	1.00	1.48 (0.70-3.16)
Walking trail, skiing track	1.00	4.38 (2.15-8.93)	1.00	1.07 (0.43-2.65)	1.00	3.07 (1.53-6.15)	1.00	1.65 (0.84-3.22)
Park or other green area	1.00	1.96 (0.97-3.96)	1.00	0.92 (0.38-2.21)	1.00	1.77 (0.87-3.60)	1.00	2.41 (1.03-5.59)
Infrastructure-based facilitators								
Peaceful walkways	1.00	1.35 (0.68-2.66)	1.00	1.25 (0.53-3.00)	1.00	1.06 (0.54-2.08)	1.00	2.60 (1.26-5.33)
Services close	1.00	1.46 (0.72-2.96)	1.00	1.73 (0.71-4.24)	1.00	0.98 (0.48-1.98)	1.00	0.52 (0.24-1.15)
Good lighting	1.00	2.19 (1.07-4.49)	1.00	0.70 (0.28-1.75)	1.00	0.99 (0.49-1.98)	1.00	2.46 (1.08-5.59)
Even sidewalks	1.00	1.98 (0.95-4.12)	1.00	0.82 (0.33-2.09)	1.00	1.10 (0.54-2.25)	1.00	2.75 (1.08-7.01)
Safe crossings	1.00	2.23 (0.98-5.06)	1.00	1.01 (0.38-2.70)	1.00	2.52 (1.14-5.58)	1.00	3.19 (0.91-11.09)
Resting places by routes	1.00	1.21 (0.59-2.50)	1.00	1.93 (0.67-5.52)	1.00	1.73 (0.70-4.30)	1.00	2.38 (0.66-8.61)
Walkways without steep hills	1.00	2.63 (1.03-6.74)	1.00	0.58 (0.19-1.80)	1.00	3.40 (0.96-12.09)	1.00	1.78 (0.40-7.86)
Sum of nature-based destinations as facilitators								
≤ 1 facilitators		1.00		1.00		1.00		1.00
2 facilitators		3.56 (1.41-8.98)		1.40 (0.48-4.06)		2.32 (1.05-5.11)		1.62 (0.77-3.43)
3 facilitators		4.60 (1.94-10.94)		0.98 (0.33-2.88)		3.32 (1.37-8.04)		2.96 (1.08-8.17)
Sum of infrastructure-based facilitators								
≤ 1 facilitators		1.00		1.00		1.00		1.00
2 or 3 facilitators		1.32 (0.59-2.97)		1.17 (0.42-3.25)		0.90 (0.41-1.97)		1.78 (0.76-4.15)
≥ 4 facilitators		2.73 (1.12-6.65)		1.14 (0.39-3.40)		1.99 (0.84-4.72)		2.13 (0.70-6.50)

*Univariable analyses adjusted for age, sex, difficulty in walking 500m, chronic conditions, education, and years in current home. OR= Odds Ratio. CI= Confidence Interval. Statistically significant associations are bolded.

© Downtown areas and shopping areas 2010/2012 (Finnish Environment Institute, 2015); Population grid data 2012 (Official Statistics of Finland, 2015); Administrative borders 2012 (National Land Survey of Finland & Ek)



