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Essi-Mari Tuomola

Physical Environments, Activity Destinations and Out-of-home Mobility in Old Age

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF SPORT AND
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ABSTRACT

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Outdoor mobility is important for the well-being of older adults and is influenced by individual and environmental factors. The purpose of this study was to investigate the individual resources, environmental factors, and activity destinations that contribute to the out-of-home mobility of older adults.

This dissertation is based on datasets from two research projects: Life-Space Mobility in Old Age (2012; n = 848, and 2016; n = 206); and Active Ageing – Resilience and External Support as Modifiers of the Disablement Outcome (2017–2018; n = 901, and 2021–2022; n = 613). The participants were community-dwelling people aged 75 to 90 living in Central Finland. Self-reported 2-km walking difficulties, physical activity, sense of autonomy, and participation in leisure activities were assessed in home interviews. Visited destinations (physical exercise, attractive, regular) were collected using the Public Participation Geographic Information System (PPGIS) questionnaire. A neighborhood walkability index, the land use type around the destination, and the distance to the destination were calculated using geospatial datasets.

The older adults living in the highest walkability area had higher odds for frequent participation in cultural and individual activities and lower odds for participation in outdoor activities than those living in the lowest walkability area. Reporting intact walking or walking modifications was associated with frequent participation in leisure activities and a higher number of activity destinations and destinations located further away from home. The older adults reporting higher physical activity used a larger variety of physical exercise destinations and destinations located further away from home than those reporting lower physical activity. Visiting a lower number of activity destinations and destinations located closer to home was associated with a more restricted sense of autonomy outdoors.

This study highlights the importance of balancing environmental amenities and an individual's interests and functional abilities. Both objective environmental factors and subjective experiences should be considered to further understanding of the factors influencing activity behavior and choice of activity destinations among older adults.

Keywords: Outdoor mobility, walking difficulties, physical environment, geographic information, aging

TIIVISTELMÄ (ABSTRACT IN FINNISH)

Tuomola, Essi-Mari
Fyysinen ympäristö, aktiivisuuden paikat ja ulkona liikkuminen ikääntyessä
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Ulkona liikkuminen on tärkeää iäkkäiden ihmisten hyvinvoinnille ja siihen vaikuttavat useat yksilöön ja ympäristöön liittyvät tekijät. Tämän tutkimuksen tarkoituksena oli tutkia yksilöllisten resurssien, fyysisen ympäristön tekijöiden ja aktiivisuuden paikkojen yhteyttä iäkkäiden ihmisten ulkona liikkumiseen.

Tämä väitöskirja pohjautuu kahteen tutkimusprojektiin: Iäkkäiden ihmisten liikkumiskyky ja elinpiiri (LISPE) -tutkimuksen aineistoon (2012, n = 848), sen osatutkimukseen (2016, n = 206); ja Aktiivinen vanhuus (AGNES) -tutkimuksen aineistoon (2017–2018; n = 901 ja 2021–2022; n = 613). Tutkittavat olivat Keski-Suomen alueella kotona itsenäisesti asuvia 75–90-vuotiaita. Kotihaastattelulla selvitettiin tutkittavien kävelykykyä, fyysistä aktiivisuutta, autonomian tunnetta ja osallistumista vapaa-ajan toimintoihin. Karttapohjaisella kyselyllä tarkasteltiin aktiivisuuden paikkoja (liikuntapaikat, houkuttelevat ja säännölliset paikat). Lähiympäristön käveltävyys, maankäyttö paikkojen ympärillä ja etäisyys paikkoihin määritettiin paikkatietoaineistojen avulla.

Korkeimmalla käveltävyyden alueella asuvat iäkkäät henkilöt osallistuivat suuremmalla todennäköisyydellä useammin kulttuuritoimintoihin ja pienemmällä todennäköisyydellä ulkoiluun kuin matalimmalla käveltävyyden alueella asuvat henkilöt. Hyvä kävelykyky ja kävelyn muokkauskeinojen käyttö olivat yhteydessä säännölliseen vapaa-ajan toimintoihin osallistumiseen. Hyvän kävelykyvyn raportoivilla henkilöillä oli myös korkeampi paikkojen määrä, ja ne sijaitsivat kauempana kotoa kuin kävelyvaikeuksia kokevilla henkilöillä. Korkeamman fyysisen aktiivisuuden raportoivat henkilöt vierailivat liikuntapaikoissa erilaisissa ympäristöissä ja paikat sijaitsivat kauempana kotoa kuin matalamman fyysisen aktiivisuuden raportoivilla henkilöillä. Matala paikkojen määrä ja sijainti lähellä kotia oli yhteydessä rajoittuneempaan autonomian tunteeseen.

Tämä tutkimus korostaa ympäristötekijöiden ja yksilön kykyjen ja kiinnostuksen kohteiden välistä tasapainoa. Objektiiviset ympäristötekijät ja yksilön kokemukset tulisi huomioida tutkimuksissa, jotta voidaan ymmärtää tekijöitä, jotka vaikuttavat iäkkäiden ihmisten aktiivisuuskäyttäytymiseen ja paikkoihin.

Asiasanat: Ulkona liikkuminen, kävelyvaikeudet, fyysinen ympäristö, paikkatieto, ikääntyminen

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Jyväskylä 4.12.2024
Essi-Mari Tuomola

FIGURES

TABLES

LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following original publications, which will be referred to by their Roman numbers. The thesis also includes unpublished data.

I Tuomola, E.-M., Keskinen, K. E., Viljanen, A., Rantanen, T., & Portegijs, E. (2023). Neighborhood Walkability, Walking Difficulties, and Participation in Leisure Activities Among Older People: A Cross-Sectional Study and 4-Year Follow-Up of a Subsample. Journal of Aging and Health, 36(5-6). https://doi.org/10.1177/08982643231191444.

II Tuomola, E.-M., Keskinen, K. E., Rantanen, T., & Portegijs, E. (2024). Associations between walking limitations and reported activity destinations among older adults. European Journal of Ageing, 21(16). https://doi.org/10.1007/s10433-024-00813-1.

III Tuomola, E.-M., Keskinen, K. E., Hinrichs, T., Rantanen, T., & Portegijs, E. (2023). Older Adults' Self-Reported Physical Activity and Distance to and Land Use Around Reported Physical Exercise Destinations. Journal of Aging and Physical Activity, 31(4), 568-575. https://doi.org/10.1123/japa.2022-0105.

IV Tuomola, E.-M., Keskinen, K. E., Rantanen, T., & Portegijs, E. Visited activity destinations and sense of autonomy in outdoor activities among older people. Submitted for publication.

As the first author of the original publications, giving due consideration to the comments from my co-authors, I was responsible for drafting the study questions and designs, preparing the participant data for the statistical analyses, performing the statistical analyses, as well as having the main responsibility for writing the manuscripts. In Study I, I used pre-existing data from the Life-Space Mobility in Old Age (LISPE) and Life-Space Mobility and Active Aging (MIIA) projects and in Studies II, III & IV data from the Active Aging – Resilience and External Support as Modifiers of the Disablement Outcome (AGNES) project. In addition, I actively participated in the AGNES follow-up data collection by interviewing participants during the structured home interviews. AGNES follow-up data were used in Study IV.

ABBREVIATIONS

AGNES	Active Aging - Resilience and External Support as Modifiers of the Disablement Outcome
CHAMPS	Community Healthy Activities Model Program for Seniors
CI	Confidence interval
CLC	Corine Land Cover
GEE	Generalized estimating equations
GEOage	Geographic characteristics, outdoor mobility and physical activity in old age
GIS	Geographic information system
GLM	General linear model
GPS	Global Positioning System
IPA	Impact on Participation and Autonomy
IPAQ-SF	International Physical Activity Questionnaire—short-form
IQR	Interquartile range
IRR	Incidence rate ratio
km	Kilometer
km^2	Square kilometer
LISPE	Life-Space Mobility in Old Age
m	Meter
MIIA	Mobility and Active Aging
min	Minutes
MMSE	Mini-Mental State Examination
n	Number
OR	Odds ratio
PAA	Places of Active Aging
PASE	Physical Activity Scale for the Elderly
PPGIS	Public participation geographic information system
SE	Standard error
SD	Standard deviation
SPPB	Short Physical Performance Battery
YPAS	Yale Physical Activity Survey

CONTENTS

1 INTRODUCTION

Promoting healthy aging and enabling people to age in place is becoming increasingly important as a larger proportion of the population enters old age (Gough et al., 2023). In 2012, people aged 75 and over accounted for around 8% of the Finland's total population and in 2023 this proportion had risen to over 11% (Official Statistics of Finland, 2024). One of the key elements in maintaining healthy and active aging is the ability to move outside the home, which allows individuals to carry out daily activities in different environments (Webber et al., 2010). Engaging in an active lifestyle helps individuals to maintain independence and cognitive and physical function (Bushman, 2020). It also enables them to be socially active (Nathan et al., 2012). Older individuals have multiple reasons for leaving their homes, including participating in various physical and leisure activities and visiting meaningful places throughout the day. Walking is the most popular form of physical activity reported by older adults (Amireault et al., 2019; Schrack et al., 2016). Regular physical activity has many potential health benefits in old age, such as delaying the development of walking difficulties (Chodzko-Zajko et al., 2009; Portegijs et al., 2017).

According to socio-ecological models, older adults' out-of-home activity is influenced by both individual and environmental factors and the interactions between these (Lawton & Nahemow, 1973; Sallis et al., 2006). Due to age-related functional limitations, older adults' mobility patterns change and they may become more aware of features in their living environment that could hinder their engagement in outdoor mobility and participation in activities (Rantakokko et al., 2012). Hence, being able to maintain the ability to walk is crucial for participation outside the home (Rantanen, 2013). Older individuals may compensate for underlying walking limitations by adjusting their walking behavior (Mänty et al., 2007). The initial signs of decline in walking may manifest in such walking modifications as using an aid, walking slowly, or taking breaks when walking (Mänty et al., 2007; Richardson et al., 2023). By means of such modifications, older adults may be able to continue their engagement in outdoor activities (Richardson et al., 2023).

Individuals interact with various built and natural environmental features throughout their lives, and hence facilitating such interaction is an important public health goal (Barnett et al., 2017; Weiss et al., 2010). The physical environment encompasses the objective and perceived features of the environmental context in which people spend their time, such as their neighborhoods (Cerin et al., 2017). Various environmental features may either facilitate or hinder opportunities for maintaining one's health and participation (Sallis et al., 2006). For example, street connectivity, land-use mix, access to destinations, and perceived safety outdoors are the features that have most consistently been associated with older adults' physical activity (Barnett et al., 2017; Bonaccorsi et al., 2020; Rosso et al., 2011) and their participation in leisure activities (Vaughan et al., 2016). As people get older, their mobility and life-space area decrease, and they spend more time in their neighborhood environment (Satariano et al., 2012).

The out-of-home mobility of older adults can be facilitated if they have multiple destinations to visit in their living environment. Visiting destinations has been shown to increase the physical activity (Portegijs et al., 2015), maintain the functional capacity, and enhance the quality of life of older adults (Satariano et al., 2012). To the present author's best knowledge, understanding of the types of destinations visited by older adults and the environments in which these destinations are located remains limited. Hence, this study used Public Participation Geographic Information Systems (PPGIS), a participatory mapping method, to study older adults' activity destinations. Approaches of this kind have gained popularity in health research during the last two decades (Hasanzadeh, 2022; Hinrichs et al., 2020). A participatory approach can provide valuable insights into how older adults experience their environment and what factors influence their mobility and well-being (Fagerholm et al., 2021).

The purpose of this doctoral dissertation was to examine individual resources, environmental features, and destinations that support older adults' out-of-home mobility. Understanding the features of environments that can support the out-of-home mobility of older adults can help in finding ways to encourage them to engage in outdoor activities. The present research combined participant data on activity behavior and map-based destinations with the geographical characteristics of mobility environments. More specifically, the aim was to study how individual factors such as walking ability and level of physical activity are associated with reported activity destinations and participation in leisure activities. A further objective was to study how environmental features of neighborhood areas and activity destinations are associated with older adults' activity behavior and sense of autonomy. Understanding the meaning of individual and environmental factors affecting out-of-home mobility may assist in the planning of supportive and age-friendly environments.

2 REVIEW OF THE LITERATURE

2.1 Out-of-home mobility in old age

Mobility is broadly defined as the physical ability to move oneself independently or with the help of assistive devices within living environments from immediate neighborhood environments to areas further away in order to accomplish desired activities of daily living (Webber et al., 2010). The term refers all types of movement, such as walking, cycling, driving or use of public transport (Prohaska et al., 2011; Rantanen, 2013; Satariano et al., 2012). Mobility is considered as optimal when individuals' have the ability to safely and reliably travel where, when, and how they choose (Satariano et al., 2012). Outdoor mobility is crucial for accessing essential commodities and services and maintaining social relationships, as well as participating in various activities (Mollenkopf et al., 2006). The most common reasons for older adults to leave home are to run daily errands, shop, walk, and socialize (Chudyk et al., 2015; Davis et al., 2011; Tsai et al., 2016).

Several studies have highlighted the importance of older adults remaining physically and psychologically active, including participating in social, cultural and physical activities and accessing meaningful places in their daily lives (Adams et al., 2011; Kizony et al., 2020; Levasseur et al., 2010; Sowa et al., 2016). Hence, maintaining outdoor mobility is important for older adults' well-being (Eronen et al., 2013). Additionally, an active lifestyle outdoors helps maintain independence and cognitive and physical function and decreases the risk of falls and injuries (Bushman, 2020). An older adult's mobility behavior is affected by the interaction of their individual characteristics with environmental factors (Yang et al., 2018). Due to the aging process, diseases and functional limitations increase the risk for mobility decline (Rantanen, 2013), which manifests in a variety of ways (e.g., development of changes in walking or driving behavior) (De Silva et al., 2019).

2.1.1 Walking limitations in outdoor mobility

The ability to move within one's community is one of the main factors determining older adults' participation outside the home (Dickerson et al., 2019). Mobility limitations, such as walking difficulties, may limit outdoor mobility and the possibility of participating actively in out-of-home activities (Chung et al., 2015; Rantakokko et al., 2012). The risk for developing walking difficulties increases as a result of age-related diseases and functional decline (Verbrugge & Jette, 1994). Walking difficulties are, therefore, common among older adults, and they are often the first signs of a decline in functional function (Guralnik et al., 1994; Hirvensalo et al., 2000). The perception of walking limitations increases with increasing age (Ferrucci et al., 2016; Satariano et al., 2012). In 2022, around 60% of 65- to 74-year-olds did not perceive limitations in walking or climbing steps. The corresponding proportion in over 75-year-olds was 43%. Around 11% of 65- to 74-year-olds and 26% of over 75-year-olds experienced a lot of difficulties or were unable to perform the activity at all (Official Statistics of Finland, 2022).

However, the process of declining physical function can vary from a sudden event to a slow and gradual decline (Guralnik et al., 2001). Mobility decline may result from a traumatic event, such as a fall or fracture, or a gradually worsening health situation (Guralnik et al., 2001). Perceived walking difficulty in turn, may increase further adverse health conditions, such as risk for recurrent falls (Tinetti & Kumar, 2010), dependency and institutionalization (Penninx et al., 2000; Rosso et al., 2011; Viljanen et al., 2021). It has also been linked to restricted life-space and lower levels of physical activity (Rantakokko et al., 2017). Environmental factors can limit or enhance the maintenance of functional capacity among older adults (Rantakokko et al., 2013). Environmental requirements that exceed an individual's capacity can lead to reduced participation and avoidance of activity, whereas environmental modifications that reduce the strain on the individual's physical functioning may help them continue their participation in meaningful activities (Lawton & Nahemow, 1973).

Changes in walking behavior first appear in relation to more demanding mobility tasks, such as walking longer distances (Rantanen, 2013). Older adults may be able to compensate for underlying limitations by modifying their task performance, such as changes in method, frequency, or time used (Mänty et al., 2007; Richardson et al., 2023). The early signs of decline in walking may manifest as walking modifications, such as using an aid, slower walking speed, or resting in the middle of walking (Mänty et al., 2007). Such modifications may enable older adults to continue walking (Fried et al., 2000; Mänty et al., 2007; Richardson et al., 2023). Walking modifications are often seen as evidence of preclinical disability and as indicating a transition from a good level of mobility to limited mobility (Fried et al., 2000). However, while walking modifications can help people pursue independent activities and arrive at meaningful destinations (Gitlin et al., 2017; Laborde et al., 2022; Rantakokko et al., 2016; Skantz et al., 2020), they may also predict further mobility decline and poor health outcomes (Mänty et al., 2007; Weiss et al., 2012). There is relative paucity of studies investigating how walking difficulty and walking modifications are associated with participation in activities outside the home.

Wide-spread methods of assessing mobility limitations and walking difficulties include standardized performance-related tests, such as the Short Physical Performance Battery (SPPB), self-reports (Rantanen, 2013) and wearable monitors (Chaudru et al., 2019). The SPPB test assesses lower extremity function, including measures of gait, balance and chair rises (Guralnik et al., 1994). Studies often rely on self-reports of difficulty walking specific distances, such as 500 meters, or 2 kilometers (Chung et al., 2015). Perceived difficulty in walking longer distances is an early indicator of functional decline (Mänty et al., 2007). Self-reports offer a subjective perspective on an individual's mobility in which individuals reflect on their personal ability to walk in their living environment and the challenges they experience in so doing (Rantanen, 2013). Such self-assessments have been shown to be a valid way to capture preclinical mobility limitations (Mänty et al., 2007) as well as being less time-consuming and more cost-effective than performance measures (Chung et al., 2015). More recently, wearable monitors, such as accelerometers and devices connected to the Global Positioning System, have become more common methods of assessing outdoor mobility and walking behavior (Chaudru et al., 2019).

2.1.2 Participation in leisure and physical activities

Leisure activities

Leisure activity can be defined as activities in which people participate for enjoyment and well-being, and do not include work-related activities or activities of daily living (Kuykendall et al., 2018; Verghese et al., 2006). Instead, leisure behavior includes participation in a wide range of physical, cultural, and social activities, such as reading, outdoor aesthetics, singing and theater, and sports and physical activities (Pritchard et al., 2015; Sala et al., 2019; Sallis et al., 2006; Theis & Furner, 2011). Older adults who have retired from work have more leisure time than younger age groups and participation in leisure activities can provide a rhythm to their daily lives (Lu & Hu, 2005). Older adults' participation in activities outside the home may decrease due to several personal and environmental factors (Kizony et al., 2020). These factors include older age, lower socioeconomic status, changes in physical function (Yang et al., 2018), and lower availability of suitable urban infrastructure and street connectivity (Vaughan et al., 2016). Earlier studies have highlighted the importance of enabling older adults to utilize various transportation options to maintain their participation in out-of-home activities (Kizony et al., 2020). However, there is limited empirical evidence between the individual factors, environmental features and participation in specific leisure activities among older adults.

Leisure activities provide positive or restorative experiences and may therefore have a significant impact on older adults' well-being and health (Adams et al., 2011; Bone et al., 2022; Maier & Klumb, 2005; Michèle et al., 2019; Zhao et al., 2023). Participation in leisure activities has been found to be associated with better health behaviors (Chang et al., 2014; Soga et al., 2016), improved quality of life (Adams et al., 2011), and increased happiness (Menec, 2003). Leisure activities can provide pleasure, social support, artistic experiences, or a sense of being useful to others, all of which are essential to a fulfilling life, especially in old age (Rantanen et al., 2021). In addition, these activities are linked with a lower risk for premature death (Agahi et al., 2011; Kobayashi et al., 2022; Paganini-Hill et al., 2011), better functional capacity (Sala et al., 2019) and protection of cognitive function (Yang et al., 2022).

The wide range of leisure activities older adults participate in include gardening and walking as well as social activities (Michèle et al., 2019). Gardening, for example, has been found to be a popular leisure activity among older adults in many countries (Cheng et al., 2017; Pritchard et al., 2015). Social activities are particularly important for older adults (Rowe & Kahn, 1997). Social participation has two dimensions, namely engaging in activities that are meaningful and maintaining close relationships (Rowe & Kahn, 1997; Toepoel, 2013). Social participation in old age can reduce the risk of experiencing the possible loneliness and social isolation that accompany aging and the decrease in the individual’s social network (Adams et al., 2011; Kemperman et al., 2019; Toepoel, 2013). In 2017, over half of the Finnish older population aged 65 and above reported having participated in organizational activities within the last 12 months. Around 10% had participated in sports club activities. Cultural activities were particularly popular among, with nearly 70% of respondents reporting having attended such events as theater performances, concerts, and films. Over 60% reported engaging in berry-picking and approximately 20% had gone fishing (Official Statistics of Finland, 2017).

As individuals do not universally perceive the same activities as leisure activities and leisure time has been defined in various ways in different contexts, establishing a universal definition is a challenging task (Ball et al., 2007). The diversity, frequency, and quantity of participation in leisure activities has typically been evaluated using a questionnaire or diary (Kuykendall et al., 2018; Newman et al., 2014; Vaughan et al., 2016). Newman et al. (2014) distinguish between subjective and structural leisure. Subjective leisure focuses on an individual's perceived leisure activities, whereas structural leisure is measured using a structured list of activities presented by a researcher (Newman et al., 2014). Most studies have used their own list of leisure activities.

Physical activity

Physical activity is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” and includes movements in everyday life, such as those needed to perform daily activities (Caspersen et al., 1985; Chodzko-Zajko et al., 2009). Physical activity can be categorized in various ways. For instance, it can be broadly divided into exercise which is planned, structured, and aimed at improving physical fitness or skills, and lifestyle activities such as walking or gardening (Sherrington et al., 2020). Physical activity can also be classified based on four common domains: occupational, domestic, transportation, and leisure time (Strath et al., 2013). It can also be categorized based on its mode, purpose, and strenuousness, such as light, moderate, or vigorous intensity, as determined by its immediate physiological effects on energy expenditure (Strath et al., 2013).

The global and national physical activity guidelines for older adults (aged 65+) state that regular physical activity has a role in reducing the risks for multiple adverse health effects (2018 Physical Activity Guidelines Advisory Committee Scientific Report, 2018; Bull et al., 2020; Piercy et al., 2018; UKK Institute 2019). According to these guidelines, older adults should engage in at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity per week (UKK Institute, 2019). Older adults should engage in light-intensity physical activity, such as daily chores, shopping, and walking, whenever they can during the week. Older adults should also exercise balance, strength and flexibility at least twice a week (UKK Institute, 2019). Walking is the most common mode of physical activity among older adults, and they usually prefer low-intensity physical activities (Amireault et al., 2019; Schrack et al., 2016). Studies have shown that meeting the recommended guidelines for physical activity varies from 20% to 60% among older adults (Sun et al., 2013). The prevalence of meeting the physical activity guidelines varies across studies, owing to differences in sampling frames, participation rates, assessment methods, and analytical techniques (Borodulin & Anderssen, 2023). According to the Finnish National Health Examination Survey, only 26% of people aged 65 and older meet the physical activity recommendations (Wennman & Borodulin, 2021). The proportion of older adults meeting physical activity guidelines tends to decline with age (Sparling et al., 2015; Sun et al., 2013).

Physical activity is essential for healthy aging (Barnett et al., 2017; Christman et al., 2020) and especially maintaining outdoor mobility and independence in old age (Amireault et al., 2019; Bangsbo et al., 2019; Chodzko-Zajko et al., 2009). Staying physically active in old age has several health benefits (Bangsbo et al., 2019; Sun et al., 2013). Regular physical activity reduces the risk of chronic diseases (Chodzko-Zajko et al., 2009; World Health Organization, 2010), type 2 diabetes (Vogel et al., 2009), osteoporosis (McPhee et al., 2016) and falls (Guirguis-Blake et al., 2018; McPhee et al., 2016; Tricco et al., 2017). Additionally, it may postpone the onset of functional limitations (Chodzko-Zajko et al., 2009; Portegijs et al., 2017). It has also been linked with a few psychological benefits, such as decreased risk of depression, anxiety, and cognitive decline (Jackson et al., 2016) and better quality of life (Cunningham et al., 2020). Moreover, increasing physical activity can help reduce the strain on health and social care systems by promoting healthy aging (Chodzko-Zajko et al., 2009).

Physical activity can be assessed in terms of its mode or type, frequency, duration and intensity (Butte et al., 2012; Strath et al., 2013). These dimensions can be measured using indirect measures, such as self-report questionnaires and activity diaries, or direct measures, such as wearable devices (Kowalski et al., 2012; Schrack et al., 2016). The choice of measurement type will depend on the primary outcome variable, available resources, and participant burden (Kowalski et al., 2012; Strath et al., 2013). Self-report questionnaires are generally considered acceptable for collecting information on physical activity as well as less burdensome and less expensive as methods of assessing physical activity than direct measures (Kowalski et al., 2012; Sylvia et al., 2014). However, subjective measures have their disadvantages, such as being prone to over- or underestimation and misinterpretation (Kowalski et al., 2012). Commonly used questionnaires are the Community Health Activities Model Program for Senior (CHAMPS), International Physical Activity Questionnaire—short-form (IPAQ-SF), Physical Activity Scale for the Elderly (PASE) and Yale Physical Activity Survey (YPAS) (Kowalski et al., 2012; Sattler et al., 2020). Direct measures, such as accelerometers, pedometers, and heart rate monitors, use various ways of assessing movement and quantifying intensity (Kowalski et al., 2012). These devices measure acceleration, steps, heart rate, or any other indicator of physical activity or energy expenditure in real time (Strath et al., 2013). However, there is a lack of consistency across studies in device type, placement, and data interpretation (Schrack et al., 2016).

2.1.3 Autonomy in participation outdoors

Autonomy refers to the sense of control people have over their lives and environment (Lange et al., 2018; Moilanen et al., 2021; Ng et al., 2012) and is related to participation and involvement in daily life situations (World Health Organization, 2002). Autonomy in mobility refers to individuals' preferences and perceptions regarding movement and participation (Berenschot & Grift, 2019). Autonomy in participation outdoors has been considered optimal when individuals feel they have the ability to control and make decisions about moving outside the home and participating in activities according to their own rules and preferences (Cardol et al., 2001; World Health Organization, 2002). Autonomy is part of an individual's psychological needs, along with competence and relatedness, and the fulfillment of these needs is related to better health and well-being (Ryan & Deci, 2000).

Older adults' perceived autonomy has been studied, especially in residential care. Previous reviews have shown that in residential care settings perceived sense of autonomy was linked with individual capacities, such as level of independence and physical and mental competence (Moilanen et al., 2021) whereas perceived reduction in autonomy has been associated with the negative sides of aging, including cognitive decline and comorbidities (Kraun et al., 2022). Older age, lower socio-economic status, low social support and loneliness, and mobility limitations have been linked to reduced autonomy in mobility among community-dwelling older adults (Leppä et al., 2021; Rantakokko et al., 2014; Sánchez-García et al., 2019; Wilkie et al., 2007). A low sense of autonomy may decrease older adults' attempts to be active (Webber et al., 2010). The most common restriction in participation is limited mobility outside the home (Wilkie et al., 2007). Participation restriction is thought to be an outcome of the interaction between health status, the individual and the environment (World Health Organization, 2002). For example, environmental features, such as perceived barriers have shown links with reduced autonomy (Rantakokko et al., 2017).

Sense of autonomy has often been studied using self-report questionnaires to assess individuals' satisfaction with their abilities and possibilities in various situations. The Impact on Participation and Autonomy (IPA) questionnaire was developed in the Netherlands to investigate autonomy and participation in adults with chronic conditions in the context of rehabilitation (Cardol et al., 2001). It has since also been validated in older adults (Hammar et al., 2014). The IPA is a generic outcome measure consisting of 31 items with five subscales: Autonomy indoors, Family role, Autonomy outdoors, Social life and relationships, Work and education (Cardol et al., 2001).

2.2 Physical environments

2.2.1 Defining physical environments

Natural and built physical environments can be characterized by both their objective and perceived features (Bonaccorsi et al., 2020; Sallis et al., 2006). Built environments include the physical form of a neighborhood area, comprising its buildings, spaces, objects and infrastructure that are human-made or modifiable (Bonaccorsi et al., 2020; Cerin et al., 2017; Tuckett, Banchoff, et al., 2018). It includes the design of a city and its physical elements (Sallis, 2009). In turn, natural environments include green spaces, such as parks, open public spaces and gardens (Jarvis et al., 2020; Sallis, 2009), and blue spaces, such as lakes and ponds (Jarvis et al., 2020). The physical environment in which they live significantly influences older adults' activity behavior (Weiss et al., 2010). Since individuals interact with various built and natural environmental features throughout their lives, creating environments that promote mobility is an important public health objective (Barnett et al., 2017; Weiss et al., 2010). Age-friendly environments foster healthy aging and quality of life by facilitating mobility outside the home (World Health Organization, 2017), whereas less age-friendly built and natural environments can restrict older adults' mobility and activity behavior (Sallis, 2009).

Previous studies have shown that multiple objective and perceived environmental features are linked to older adults' activity behavior. For example, walkability features (e.g., street connectivity, land-use mix), access to destinations (e.g., shops, restaurants) and features related to perceived safety have most consistently been associated with older adults' physical activity (Barnett et al., 2017; Bonaccorsi et al., 2020; Rosso et al., 2011). Compared to working age adults, older adults tend to spend more time in their neighborhoods (Bonaccorsi et al., 2020; Cerin et al., 2017; Levasseur et al., 2015), making neighborhood features especially important as they age. Different age groups may favor different types of physical environments (Laatikainen et al., 2017). Older adults may be more vulnerable to certain environmental features as their physical capacity declines (Lawton & Nahemow, 1973), a situation which can lead to the avoidance of outdoor activities (Tsai et al., 2013). It is, therefore, important to study subgroups of older adults, such as those with declining physical capacity, to better understand the relationship between their physical environment and their activity behavior.

2.2.2 Studying objective features of the environment

Several methods have been developed to measure features of the physical environment (Orstad et al., 2017). These features can be measured objectively, such as by making systematic observations or applying Geographic Information Systems (GIS), and subjectively, such as through self-administered questionnaires (Brownson et al., 2009; Orstad et al., 2017). Objective methods quantify attributes of the built environment or use GIS to analyze archival data sets (Brownson et al., 2009). The built environment has been operationalized in various ways using GIS, such as in identifying variations in neighborhood buffer sizes and defining variables (Brownson et al., 2009). These variations in GIS methods limit comparisons between studies and the finding of consistent results (Adams et al., 2014). The most frequently assessed GIS-based measures of the built environment in the context of physical activity include population density, land use, access to and availability of destinations, street connectivity, safety and traffic, and composite variables, such as a walkability index (Van Cauwenberg et al., 2018).

In contrast, subjective methods examine individuals' perceptions of various elements of their environment (Brownson et al., 2009; Orstad et al., 2017). Perceptions of the environment develop through interactive processes, and include social, cognitive, and affective dimensions (Orstad et al., 2017). This means that the methods used to measure the environment, i.e., objective versus perceived measures, may produce different results (Barnett et al., 2017; Bonaccorsi et al., 2020) and measure different constructs of the environment (Barnett et al., 2017; Orstad et al., 2017) that are important in determining the mobility of older adults (Rosso et al., 2011). For example, a previous study showed that older adults living in objectively different neighborhood environments had different associations between physical activity and the perceived nature-based and infrastructure-based features (Keskinen et al., 2020). Thus, combining objective and subjective measures may yield a more comprehensive and accurate picture of the environmental features that affect older adults' activity behavior (Bonaccorsi et al., 2020; Orstad et al., 2017).

Neighborhood environments are often assessed for their walkability, which refers to the built environment's walking-friendliness and suitability for walking to different destinations (Timmermans et al., 2021; Tuckett, Freeman, et al., 2018). Walkability is an important dimension of healthy communities (Edwards & Dulai, 2018). Enhancing walkable communities can support older adults' out-of-home activity and aging-in-place (Winters et al., 2015). The availability of shops, traffic, footpath quality, scenery, and places to stop and rest have been identified as key determinants of walkability for older adults (Kerr et al., 2012; Tuckett, Banchoff, et al., 2018). Urban planning and public health research have emphasized the link between neighborhood environmental features and physical activity (Frank et al., 2021). Previous studies have shown that neighborhood walkability is associated with older adults' overall physical activity (Barnett et al., 2017; Tuckett, Banchoff, et al., 2018), walking for transport (Cerin et al., 2017), and leisure time walking and physical activity (Van Cauwenberg et al., 2018). Walking-friendly environments can have positive impacts on health by encouraging physical activity and active transportation (Edwards & Dulai, 2018). Individuals living in higher walkability neighborhoods reported 22-40 more minutes/week of active transport than those in lower walkability neighborhoods (King et al., 2011). Neighborhood walkability has been shown to influence several activities outside the home engaged in by older adults and their level of independence (Bayar & Yılmaz, 2023; Tuckett, Banchoff, et al., 2018; Vaughan et al., 2016). However, only a few studies have focused on neighborhood walkability and participation in leisure activities (Vaughan et al., 2016). Walkable neighborhoods have also been linked to stronger social cohesion and connectedness (Edwards & Dulai, 2018).

Inconsistencies in how walkability features are defined and measured and differences in study designs, type of data, and geographic scale have made interpreting and comparing findings difficult (Frank et al., 2021; Weiss et al., 2010). As these studies have predominantly been conducted in North America and Australia, the results may not, due to cross-country differences in the design of the built environment, be comparable to those found for Western European and the Nordic countries. Neighborhood walkability has largely been studied using an index that combines several spatial components, such as population density, land use mix and street connectivity (Barnett et al., 2017; Frank et al., 2004; Timmermans et al., 2021). Population density is usually described as the average number of people living in an area of one square kilometer (Frank et al., 2004). A higher population density supports local commercial activity and better accessibility to destinations (Frank et al., 2004; Kligerman et al., 2007). Land use mix represents the variety of land use types in specific areas and more mixed land use has been found to predict pedestrian travel (Frank et al., 2004). Street connectivity is usually described by the number of street intersections per square kilometer. Higher street connectivity means that more direct pathways exist between destinations, and hence more travel route options and the possibility to travel through more direct routes (Leslie et al., 2007). The walkability index appears to be applicable across a broad range of research topics, including study of the associations between urban structure and multiple health outcomes, the monitoring of change over time, and identifying areas for transportation enhancements (Frank et al., 2010).

2.3 Activity destinations

2.3.1 Destinations promoting outdoor mobility

The physical environment may offer multiple destinations, such as shops, parks and other public open spaces, and recreational facilities, which support older adults' out-of-home mobility (Barnett et al., 2017; Sugiyama et al., 2012). Such destinations may increase daily total physical activity (Portegijs et al., 2015; Tsai et al., 2016), help maintain functional capacity and mobility and enhance quality of life (Satariano et al., 2012) and support social interaction (Chaudhury et al., 2016; Nathan et al., 2012) among older adults. Activity destinations where older adults can meet and engage with others provide opportunities for regular social interaction as well as enabling incidental social contacts (Nathan et al., 2012).

Previous studies have used various methods to identify destinations. These include combining travel diary data with a general classification of destinations, such as food outlets, parks, and shops (Chudyk et al., 2015; Nathan et al., 2012), using structured questionnaires with a predetermined list of destinations (Perchoux et al., 2019) or using publicly available spatial destination datasets (King et al., 2015). While such studies have mainly gathered objective information about the number and presence of destinations in the local area, less research has focused on destinations that are meaningful to older adults, their actual use of destinations, and in what kinds of environments and how far from home these destinations are located.

A few research have studied older adults' activity destinations with diaries or questionnaires. According to the results, older adults reported an average of six to seven destinations per week (Barnett et al., 2015; Chudyk et al., 2015; Perchoux et al., 2019). Previous studies have also found that older adults' most common reasons for making trips were shopping, social visits and exercising (Barnett et al., 2015; Chudyk et al., 2015; Winters et al., 2015). Chudyk et al. (2015) showed that grocery stores, restaurants/cafes, and health facilities were the most commonly reported destinations for older adults. Laatikainen et al., (2017) showed that older adults reported positive places where they spent time in close proximity to home. These places were strongly characterized by green and blue spaces and retail areas. Distance to reported destinations has also been associated with older adults' activity behavior. Portegijs et al. (2020) found that reporting destinations, such as nature, parks and services, at distances beyond 500m was associated with higher physical activity. Perchoux et al. (2019) found that over half of the reported destinations were located within a 20-minute walk from home. However, older adults tend to travel outside their neighborhood area, especially when visiting grocery stores (Hirsch et al., 2016; Prins et al., 2014). Thus, it is possible that the traditional neighborhood buffer zones such as 500m to one kilometer, may not accurately capture all of the activity behaviors of older adults (Hirsch et al., 2016).

Several studies have found associations between the objectively measured presence and proximity of destinations and utilitarian and recreational walking

(Sugiyama et al., 2012). The presence of destinations can increase daily activity and decrease the early onset of walking difficulties (Sugiyama et al., 2018). According to a previous study, the presence of several different destinations in the neighborhood area was associated with walking frequency and physical activity (King et al., 2015). The most common such destinations were cafés, transport stops and small food stores while supermarkets and sports facilities were located further away (King et al., 2015). McCormack et al., (2008) similarly found that the presence and mix of destinations was especially associated with transport-related physical activity.

2.3.2 Participatory mapping for measuring activity destinations

A variety of methods exist to collect spatial information on an individual's mobility, such as questionnaires (Hasanzadeh, 2022) and global positioning systems (GPS) (Hasanzadeh, 2022; Kerr et al., 2011). Participatory mapping approaches have become more popular in health-related research in the last two decades (Hasanzadeh, 2022; Hinrichs et al., 2020). This approach is usually referred to as Public Participation Geographic Information Systems (PPGIS) or SoftGIS (Laatikainen et al., 2017; Rantanen & Kahila 2009). The PPGIS approach, which was developed to collect spatial information for research and participatory planning, has various urban, regional, and environmental applications (Brown & Kyttä, 2014). Participatory methods, such PPGIS, are convenient tools to investigate the person-environment relationship (Brown & Raymond, 2014; Schmidt-Thomé et al., 2014). Online participatory mapping methods combine an internet-based map with the traditional questionnaire (Brown & Kyttä, 2014; Hasanzadeh, 2022). PPGIS can utilize a wide range of visual tools, such as digital maps and satellite imagery (Hasanzadeh, 2022). The most commonly used marking methods in map-based data collection are points, lines or polygons on the map (Brown & Fagerholm, 2015).

The place-based approach provides insights into the environments in which individuals choose to spend their time (Laatikainen et al., 2017). These methods allow the combination of qualitative data, e.g., purpose of visiting a specific location, and objective geographic system data, e.g., street network and land use data (Fagerholm et al., 2021; Hasanzadeh, 2022; Hinrichs et al., 2020). This gives a possibility to study spatial associations between individuals, specific destinations, and physical features of the environment (Hasanzadeh, 2022). Various methods of analysis can be used to study features related to mapped attributes (Fagerholm et al., 2021). For instance, by using a circular buffer at certain distances around mapped destinations, it becomes possible to study land use types and other GIS variables that can help describe the destination's location in the urban structure (Laatikainen et al., 2017).

The PPGIS method offers the ability to study location-based values and perceptions (Brown & Raymond, 2014; Fagerholm et al., 2021), the quality of the environment (Kyttä et al., 2013), and perceived barriers (Raymond et al., 2016). In addition, it is possible to investigate spatial behavioral patterns and everyday activities, including daily mobility patterns, places visited, and the frequency of visits (Fagerholm et al., 2021; Laatikainen et al., 2017, Portegijs et al., 2021). The mapping of individual experiences and behaviors attaches individuals to a specific physical environmental context (Kyttä et al., 2013). PPGIS has made it possible to study the actual use of destinations and mobility patterns instead of studying the nearest service available (Laatikainen et al., 2015). Laatikainen et al. (2015) showed that, for example, proximity to the nearest water area does not seem to have a clear influence on the actual use of this type of destination.

The most commonly used map-based questionnaires are Maptionnaire & VERITAS (Hasanzadeh, 2022). Maptionnaire is an advanced example of the PPGIS methodology that allows the mapping of environmental experiences and daily behaviors (Kahila-Tani et al., 2019). It has been used in academic research projects and public participation processes (Kyttä et al., 2023). The VERITAS application (Visualization and Evaluation of Route Itineraries, Travel Destinations, and Activity Spaces) has been used in a few studies conducted in Canada, France, and Luxemburg (Kestens et al., 2018; Perchoux et al., 2019). Unlike Maptionnaire, it requires a data collection procedure administered through face-to-face meetings (Chaix et al., 2012). Both applications enable study of participants' destinations, routes, modes of transportation, and related social dimensions (Hasanzadeh, 2022; Kestens et al., 2016).

The quality of PPGIS data depends on many different factors, such as assistance, accuracy, mapping efforts, type of collected spatial data (Brown & Kyttä, 2014; Kahila-Tani et al., 2019) and participation rates (Brown & Kyttä, 2018). Respondents' time and effort may also bring some limitations (Fagerholm et al., 2021). Participants' cognitive challenges, including poor concentration, spatial abilities, and memory deficiencies, may vary (Gottwald et al., 2016). For example, mapping place-related activities and experiences may be cognitively less challenging than expressing place-related values or understanding of concepts (Brown, 2017). Previous studies have evaluated spatial quality as good enough for many purposes (Brown et al., 2015) and it also accurately describes where people move (Hasanzadeh, 2022; Laatikainen et al., 2018; Portegijs et al., 2020). Map-based questionnaires have been validated among older adults (Hinrichs et al., 2020), especially for distance-related life-space parameters (Hinrichs et al., 2020). However, the lack of a temporal component is major limitation of PPGIS data (Perchoux et al., 2014). Online participatory mapping provides a feasible and cost-effective way to collect person-based data that also imposes a low participant burden (Hasanzadeh, 2022; Laatikainen et al., 2018; Portegijs et al., 2020; Schmidt et al., 2019). Moreover, it enables data collection from large participant samples and provides user-friendly online applications (Brown & Kyttä, 2014).

2.4 Theoretical approach to understanding out-of-home mobility and environmental features

In research on person-environment interactions, the relationship between an individual and their surroundings is seen as a dynamic and interactive process, where behavior and experiences are influenced by the physical, social, and cultural context in which they occur (Laatikainen et al., 2017). Therefore, several socio-ecological models highlight the meaning of individual and environmental factors and their interactions as key factors affecting older adults' activity behavior. The present study framework was based on the ecological model of active living (Sallis et al., 2006), the ecological model of aging (Lawton & Nahemow, 1973), and the model of selective optimization with compensation (Baltes & Baltes, 1990).

Sallis et al. (2006) developed an ecological model of active living comprising four layers: intrapersonal, perceived environment, behavior, physical environment, and policy environment. The intrapersonal layer includes demographics and psychological and biological factors. The layer of perceived environment considers factors related to individuals' perceptions of the environmental features. The behavioral layer includes four domains of active living: active transport, occupational activities, household activities, and active recreation. The fourth layer, the physical environment, focuses on the objectively definable characteristics of the target environment. The final layer comprises factors related to regulating and organizing public services.

The ecological model of aging proposed by Lawton and Nahemow (1973), focuses on the interaction between personal and environmental features (Person-environment fit). According to the model, activity behavior is influenced by the competence and capabilities of the individual, such as physical function, and the demands of the living environment. In adaptive behavior, a balance between these two dimensions is normally reached when an individual engages in daily activities without giving a great deal of consideration to the environment. If the individual's competence and environmental press do not match, their behavior may be negatively affected and become maladaptive. This can reduce competence and lead to avoidance of certain activities. The model indicates that individuals with lower competence and declining capabilities are more vulnerable to the challenges presented by the environment than those with higher competence (Lawton & Nahemow, 1973).

A similar perspective on the adaptation of behavior is presented by Baltes & Baltes (1990) in the model of selective optimization with compensation (SOC). Individuals should optimize their resources and adapt their behavior to achieve their goals. According to the SOC model, older adults respond to functional decline and environmental demands through processes of selection, optimization, and compensation. Through these processes, individuals may be able to continue their activity behavior as their capabilities decrease. Selection refers to increased restrictions and losses in personal and environmental resources, such as moving, reducing activities, or avoiding walking outside the home. However, selection can also involve new or transformed goals. Optimization involves learning new ways and choosing the relevant means to achieve these goals by utilizing environmental resources as well as considering individual resources. Compensation refers to the response to losses of using alternative ways or external resources to maintain function or achieve goals (Baltes & Baltes, 1990).

The theoretical framework of this study is based on the above-mentioned theories which explore the person-environment relationship. The ecological model of active living suggests that out-of-home activities, such as leisure and physical activities, are conducted in specific environments and places throughout the day. Older adults are seen as playing an active role in the interplay between personal resources and environmental pressures and characteristics (Shoval et al., 2011). Older adults select their environments according to their needs and preferences. Therefore, studying meaningful places for older adults and the environmental features around them is important for promoting healthy aging. Using these models, the present dissertation research examined the associations between individual resources, environmental features, and activity behavior outside the home.

3 PURPOSE OF THE STUDY

The aim of this study was to examine individual resources and the environments and destinations that support older adults out-of-home mobility. This aim was approached by combining participants' activity behavior data and destinations with the geographical characteristics of their mobility environments. To study the relevance of different environmental features of the participants' neighborhood and walking ability for participation in out-of-home activities, the associations between neighborhood walkability, walking difficulties and participation in leisure activities were investigated. To explore the relationship between individual factors and out-of-home activity behaviors, the associations of walking difficulties with reported activity destinations were studied. Furthermore, to gain understanding of the role of participants' activity behavior on their use of the environment, the associations between their physical activity and the locations of their physical exercise destinations were explored. Finally, actual use of the environment and perceived opportunities were examined by counting activity destinations and levels of autonomy in outdoor participation. The specific research questions were:

1. How are neighborhood walkability and walking difficulties associated with older adults' participation in leisure activities? How is walkability and walking difficulties associated with participation at the four-year follow-up? (Study I)

2. Do older adults' reported activity destinations and distances to destinations differ according to their walking ability? (Study II)

3. How is older adults' physical activity level associated with the number of physical exercise destinations and the distance of these from their homes and with land use-type characteristics? (Study III)

4. How are numbers of activity destinations and the distance from home to these destinations associated with autonomy in participation outdoors

among older adults? Do numbers of reported activity destinations and distances to these destinations predict change in autonomy in participation outdoors at the four-year follow-up? (Study IV)

4 MATERIALS AND METHODS

4.1 Datasets and participants

This study is based on the results of two projects: Geographic Characteristics, Outdoor Mobility and Physical Activity in Old Age (GEOage) and Places of Active Aging (PAA). In these projects, open map data were combined with the data collected from participants. The GEOage project utilized participant data from the Life-Space Mobility in Old Age (LISPE) cohort study and the Mobility and Active Aging (MIIA) study which was a LISPE follow-up study. The Places of Active Aging project used participant data from the Active Aging – Resilience and External Support as Modifiers of the Disablement Outcome (AGNES) cohort study and follow-up study. The participants in both research projects were community-dwelling older adults. The datasets, study designs, and number of participants are summarized in Table 1.

TABLE 1 Summary of the datasets, study designs and participants.

Study	Dataset	Design	Participants	Age, years (mean ± SD)
I	LISPE & MIIA	Cross-sectional (baseline)	n = 848	80.6 ± 4.2
		Prospective (baseline and 4-year follow-up)	n = 206	80.0 ± 4.1
II & III	AGNES baseline	Cross-sectional	n = 901	78.6 ± 3.6
IV	AGNES follow-up	Prospective (baseline and 4-year follow-up)	n = 613	78.2 ± 3.3

4.1.1 Life-Space Mobility in Old Age (LISPE & MIIA, Study I)

Life-Space Mobility in Old Age (LISPE; Study I)
The LISPE project was a 2-year prospective cohort study conducted between the years 2012-2014 (Rantanen et al., 2012). The purpose of the study was to examine the associations of home and neighborhood characteristics with older adults' health, functioning, quality of life and life-space mobility. The study aimed to recruit older adults aged 75-90 living in Jyväskylä and Muurame in Central Finland. In 2012, Jyväskylä had around 133,500 inhabitants, making it the seventh largest city in Finland, while Muurame had about 9,500 inhabitants (Official Statistics of Finland, 2012). Both municipalities have a comparable urban structure, with the city and subcenters serving as residential and service areas. The outlying areas have varying population densities. A random sample of 2,550 persons was drawn from the Digital and Population Data Services Agency and informed about the study. Of these, 848 who met the inclusion criteria, expressed their willingness to participate, were living independently in the recruitment area, and were able to communicate were recruited for the study. The LISPE data were collected by face-to-face interviews in participants' homes using a structured questionnaire.

Life-Space Mobility and Active Ageing (MIIA; Study I)
The MIIA study was a follow-up to the LISPE study and was conducted in 2016. Participants were recruited from the 848 individuals who took part in the LISPE study. The MIIA sample size was designed to include only a small proportion of the original LISPE sample. According to power calculations conducted for primary outcomes such as life-space mobility, a sample size of 200 was sufficient to establish statistically significant correlations. Of the 298 individuals who were selected for the MIIA subsample, 77 declined to participate, and 15 could not be reached. The data were then collected through face-to-face home interviews with 206 community-dwelling individuals aged between 79 and 93. No differences in sex, number of chronic conditions, or years of education were observed between the MIIA participants (n = 206) and non-participants (n = 642) in the original LISPE cohort. However, the MIIA participants were slightly younger and had better cognition and physical performance.

Cross-sectional and longitudinal data from LISPE and MIIA were used in Study I. The cross-sectional analyses were conducted for all 848 participants. The associations between neighborhood walkability, walking difficulties, and participation in leisure activities were investigated. In addition, to study the associations between neighborhood walkability, walking difficulties, and participation in leisure activities over time, the analyses only included the individuals who had participated in the MIIA study (n = 206).

4.1.2 Active Aging – Resilience and External Support as Modifiers of the Disablement Outcome (AGNES, Studies II, III & IV)

AGNES baseline (Study II, III & IV)

AGNES was a population-based observational cohort study conducted between September 2017 and December 2018 (Portegijs et al., 2019; Rantanen et al., 2018). A random sample of 75-, 80-, and 85-year-old adults living in the city of Jyväskylä, a medium-sized city in Central Finland with a population of 141,305, was drawn from the Digital and Population Data Services Agency in Finland (Official Statistics of Finland, 2018a). The study area encompasses small hills and quiet residential streets, intersected by some busier streets. The city and its subcenters contain both service and residential areas. The inclusion criteria were living independently in the study area, being able to communicate, being willing to participate, and signing an informed consent. In total, 1,021 participants consented to a face-to-face structured interview in their own homes (Portegijs et al., 2019). At the end of the home interview, the assessments that were to take place in the research center were scheduled.

Subsequently, 908 of the home interview participants participated in the research center laboratory assessments, which included a map-based assessment. Map-based data were collected through an internet-based PP-GIS questionnaire (Maptionnaire, Mapita LTD, Helsinki, Finland) to obtain information on older adults' use and perceptions of their neighborhood environment and beyond. Participants were asked to locate on a map all the activity destinations they had visited at least once a week during the past month. A total of 901 participants, assisted by their interviewer, located their activity destinations on a digital map. Participants' home addresses were located on a map using the Digiroad dataset (Finnish Transport Infrastructure Agency, 2019) and then linked to participants' activity destinations using the Geographic Information System (GIS) software ArcMap 10.6.1 (Esri Inc.). Objectively assessed features of the environment around participants' homes and activity destinations were studied together with the AGNES participant data.

AGNES follow-up (Study IV)

The AGNES follow-up study was conducted between autumn 2021 and autumn 2022. At the follow-up, 904 of the AGNES cohort participants who were not deceased or had not withdrawn their consent and who had responded to the home interview at baseline were recruited for the study. Of these, a total of 663 participated in the face-to-face home interviews. In Study IV, the AGNES follow-up data were compared to the AGNES baseline data in order to investigate changes in autonomy in outdoor participation according to the participants' reported activity destinations. Of those who responded to the follow-up questionnaire, 613 had valid baseline data on reported activity destinations and were included in the longitudinal analyses.

4.2 Ethics

All the studies were conducted in accordance with the Declaration of Helsinki. The participants of the LISPE, MIIA and AGNES studies gave their written informed consent before the assessments. Participation in the studies was voluntary and participants were allowed to withdraw at any point. The ethical statements for the LISPE and MIIA studies were approved by the Ethical Committee of the University of Jyväskylä. The AGNES cohort and follow-up studies were approved by the Ethical Committee of the Central Finland Health Care District. All data were protected by passwords accessible solely to members of the research teams and stored on the university's server. The data were also pseudonymized for the purposes of analysis.

4.3 Participant measures

The details of all variables related to the study participants are summarized in Table 2.

TABLE 2 Summary of participant variables.

Variable	Study	Method and references
Ability to move		
Difficulties in walking 2 km	I, II & III	Self-reported (Mänty et al., 2007)
Activity		
Participation in leisure activities	I	Self-reported
Physical activity	III	Self-reported, Yale Physical Activity Survey (YPAS) (Dipietro et al., 1993)
Autonomy		
Autonomy in participation outdoors	IV	Self-reported, Impact on Participation and Autonomy (IPA), outdoors subscale (Cardol et al., 2001)
Activity destinations		
Physical exercise destinations	II, III, IV	Self-reported (Maptionnaire, Mapita LTD, Helsinki, Finland)
Attractive destinations	II, IV	
Regular destinations	II, IV	
Descriptive variables and covariates		
Age	I-IV	Digital and Population Data Services Agency
Sex	I-IV	Digital and Population Data Services Agency
Education	I-IV	Self-reported
Financial situation	II	Self-reported
Cognitive function	I-IV	Mini-Mental State Examination (MMSE) (Folstein et al., 1975)
Chronic conditions	I, III, IV	Self-reported
Lower extremity function	IV	Short Physical Performance Battery, SPPB (Guralnik et al., 1994)
Regular driving	II, IV	Self-reported

4.3.1 Difficulties in walking 2 km

Participants were asked if they had difficulty in walking 2 km using a validated question: "*Do you have difficulty walking 2 km?*"(Mänty et al., 2007) The response categories were: 1) able without difficulty, 2) able with some difficulty, 3) able with a great deal of difficulty, 4) unable without the help of another person, and 5) unable to manage even with help. Participants who reported being able to walk two kilometers were asked an additional question to identify those with walking modifications: *"Have you noticed any of the following changes when walking two km due to your health or physical functioning?"* The list of modifications included walking slower, resting during walking, using an aid, reducing their frequency of walking, and having given up walking distances of two kilometers. Participants were asked to indicate whether they used any walking modifications with 'Yes' or 'No'. In Studies I and II, based on their self-reported walking modifications and difficulty in walking 2 km, participants were categorized into three groups of walking difficulties: 1) intact walking (reporting no difficulty or modifications), 2) walking modifications (reporting no difficulty and ≥ 1 modifications) and 3) walking difficulty (reporting at least some difficulty). In Study III, the analyzed associations were adjusted for baseline self-reported difficulty in walking 2 km (yes vs. no).

4.3.2 Participation in leisure activities

Based on social context (group vs. individual or small group), participants were asked about their leisure activities requiring outdoor mobility as follows: 1) organized group activities, such as class, group or club activities (e.g., choir, physical activity class or church activities); (2) outdoor recreation (e.g., fishing, berry-picking, walking the dog, or gardening); and (3) cultural or other individual activities, such as participation in cultural events as a spectator and ad hoc activities (e.g., going to the theater, concerts or a coffee shop) (Rantanen et al., 2012). The participants were asked to indicate the frequency of their participation in each activity as follows: 1) daily or almost daily, 2) about once a week, 3) two to three times a month, 4) about once a month, 5) a few times a year, 6) rarely, and 7) never. In Study I, the frequency of participation was categorized as either frequent or rare based on the distribution and type of leisure activity. The category "frequent" was defined as participation at least once per week in outdoor recreation and organized group activities and at least once per month in cultural or other individual activities. In the follow-up analyses, the frequency categories for leisure activities remained consistent with those used in the baseline analyses.

4.3.3 Physical activity

Self-reported physical activity was assessed using the Yale Physical Activity Survey for older adults (Dipietro et al., 1993). Participants were asked about the frequency with which they had performed vigorous-intensity physical activity and leisure walking for at least 10 minutes during the past month. Subsequently, they were asked about the usual duration of the activity per occasion. The frequency response categories were as follows: 0 = not at all, 1 = 1–3 times/month, 2 = 1–2 times/week, 4 = 3–5 times/week, and 6 = 5+ times/week, and the categories for duration were: 20 = 10–30 minutes, 40 = 30–50 minutes, and 60 = 60+ minutes. The following formula was used to calculate the total minutes of vigorous physical activity and leisure-time walking: (frequency*duration)/7.

Finally, the physical activity time of at least moderate intensity was calculated by summing the mean daily minutes of vigorous physical activity and leisure walking (Portegijs et al., 2019). In Study III, level of physical activity was dichotomized into higher levels of physical activity (≥ 30 minutes/day) and lower levels of physical activity (< 30 minutes/day).

4.3.4 Autonomy in participation outdoors

Perceived autonomy in outdoor mobility was measured utilizing the "autonomy outdoors" subscale of the Impact on Participation and Autonomy (IPA) questionnaire (Cardol et al., 2001). The autonomy outdoors subscale describes an individual's self-rated sense of control over the decision about when, where, or how one goes out and participates in out-of-home activities. The domain consists of five items: 1) visiting relatives and friends, 2) making trips and traveling, 3) spending leisure time, 4) meeting other people, and 5) living life in the way one wants to. Each item is rated on a scale from 0 (very good) to 4 (very poor). The total score for all five items ranges from 0 to 20, with higher scores indicating a poorer sense of autonomy. The IPA is a validated measure for older adults that can be used as a whole or as subscales (Cardol et al., 2001; Kersten et al., 2007). In Study IV, autonomy in participation outdoors was a continuous outcome variable.

4.3.5 Activity destinations

Map-based data on activity destinations were collected using the interactive online Maptionnaire® tool (Mapita LTD). Participants were asked to locate on a map all the destinations which they had visited on several occasions during the past month. These destinations comprised 1) destinations for physical exercise, 2) destinations regarded as attractive, and 3) destinations for regular activities visited at least once a week (not related to physical exercise). Physical exercise destinations included outdoor and indoor sports facilities and outdoor recreational areas. Attractive destinations included destinations that facilitate older adults' outdoor mobility, such as nature settings, lakeside areas, services and events, resting places, and other infrastructure-related places. Regular destinations included essential destinations, e.g., grocery stores and other shops, food and health services, and destinations for self-selected activities such as organized activities and social visits.

The numbers of physical exercise, attractive, and regular destinations reported were counted separately and then summed to yield a total number of activity destinations. In Study II, the total number of activity destinations was used as a continuous variable. In Study III, reported outdoor and indoor physical exercise destinations were counted separately for each participant and summed to yield the total number of physical exercise destinations. A categorical variable was formed based on the type of the physical exercise destinations reported: (1) only indoor physical exercise destinations were reported; (2) only outdoor physical exercise destinations were reported; (3) both types of destinations were reported, and (4) no physical exercise destinations were reported. The total number of physical exercise destinations was used as a continuous variable and also as a categorical variable in Study III. In Study IV, the total number of destinations was categorized into three groups: the total number of all reported destinations was categorized into (1) ≤5, (2) 6-7, (3) ≥8 and the numbers of physical exercise, regular and attractive destinations were categorized into (1) 0-1, (2) 2, (3) ≥3. The diversity of destinations was then determined for each participant based on the number of destination types reported. A dichotomous variable was created based on the numbers of the types of activity destinations reported: all three destination types reported vs. two or fewer destination types reported.

4.3.6 Descriptive variables and covariates

The data on participants' age and sex were drawn from the Population Information System administered by the Digital and Population Data Services Agency (Studies I-IV). Years of education and perceived financial situation were used as indicators of socioeconomic status. Years of education was asked with the question: *"How many years of education have you had in total?"* (Studies I-IV). During the home interview, participants were asked to rate their perceived financial situation on a four-point scale ranging from very good to poor (Study II). Responses were re-coded as "good to very good" versus "poor to fair" Cognitive function was assessed using the Mini-Mental State Examination (MMSE) with scores ranging from 0 to 30 (Folstein et al., 1975) (Studies I-IV). Higher scores indicate better functioning.

The number of self-reported physician-diagnosed chronic diseases was collected using a list of 22 chronic conditions and an open-ended question (Study I). A similar list was used in Studies III & IV. Participants were asked to self-report chronic conditions using a list of 34 diseases in 10 categories (Rantanen et al., 2018). The number of chronic conditions was calculated as the sum of individual chronic conditions and ranged from 0 to 12 conditions. Lower extremity function was evaluated using the Short Physical Performance Battery (SPPB; range 0–12) which was performed during the home interview (Study IV). The SPPB comprised three components: standing balance, 3-m walking speed, and 5 times repeated sit-to-stand test (Guralnik et al., 1994). Higher scores indicate better function. Regular driving of a car was self-reported and asked with the question *"How often do you drive a car?"* Regular driving was divided into two groups: driving regularly (daily or weekly) vs. driving rarely (monthly or less frequently) (Studies II & IV).

4.4 Objectively assessed environmental measures

Geospatial datasets were used to investigate the objective environmental features of the participants' neighborhood area, which included neighborhood walkability and the population density of the home location. In addition, environmental features of activity destinations were studied, including distance to destinations from home, maintained sports facilities, and land use types around the reported destinations. Objective environmental variables were created in ArcMap and ArcGIS Pro software (Esri Inc.). The environmental features related to the study are listed and described in detail in Table 3.

TABLE 3 Environmental features and datasets used in the study.

Environmental feature	Study	Dataset	Dataset producer
Neighborhood features			
Neighborhood walkability	I		
Land use		Corine land cover 2012 national datasets (20 m)	Finnish Environment Institute (SYKE) (partly Metla, Mavi, LIVI, VRK, MML Topographic Database 05/2012)
Population density		Population grid data 2011 (1 km × 1 km)	Official Statistics of Finland
Street connectivity		Digiroad publication 1/2013	Finnish Transport Infrastructure Agency
Population density	II & IV	Population Grid Data 2018 (1 km × 1 km)	Official Statistics of Finland
Destination features			
Distance	II, III & IV	Digiroad Publication 1/2019	Finnish Transport Infrastructure Agency
Land use	III	Corine land cover 2018 national datasets (20 m)	Finnish Environment Institute (SYKE) (partly Metla, Mavi, LIVI, VRK, MML Topographic Database 01/2017)
Maintained sports facility	III	Lipas-data 2/2018	Lipas Sport Facility Database

4.4.1 Neighborhood walkability

Participants' homes were located on the map by geocoding their home addresses in a geographic information system (GIS) (Finnish Transport Infrastructure Agency, 2013). A walkability index, modified from Frank et al. (2005), was created in GIS and comprised of three factors: land use mix, street connectivity, and population density. The walkability index was calculated within a radius of one kilometer from the participant's home (Portegijs et al., 2017). The land use mix refers to the distribution of land use types within a one-kilometer buffer area (dry land area only) around the participant's home on (Portegijs et al., 2017). The land use mix value was based on forest and semi-natural areas (built and natural green spaces), residential areas, services, and sport and leisure facilities (Finnish Environment Institute, 2012). Street connectivity refers to the number of street intersections along walkable ways within a one-kilometer radius of the participants' homes. Only 3-way intersections or more were counted, and intersections located within 10 meters of each other were merged for the calculations. The road network analysis was based solely on walkable roads and thus excluded motorways, trails, winter roads, railroads, and ferries. The total number of residents living within one-kilometer squares of the study areas where the participants lived was used to calculate population density (Official Statistics of Finland, 2011). A walkability index was then calculated by summing the z-scores for land use mix, street connectivity, and population density. A higher index score indicates better walkability. In Study I, the walkability index was categorized into tertiles labeled as lowest, middle, and highest.

4.4.2 Population density

In Studies II and IV, a pupulation density variable was created in GIS to indicate service availability and the amount of outdoor mobility-enabling infrastructure. Information on population density was obtained using population grid data (1 km x 1 km) (Official Statistics of Finland, 2018b). The range of population density in the Jyväskylä area was divided into tertiles (lowest, middle, highest). Each participant was assigned to the population density tertile of their home location. Population density was used as a covariate in Studies II and IV.

4.4.3 Distance

Distances between participants' homes and their reported destinations were computed as road network distances (Studies II & IV) and as Euclidean distances (Study III) (expressed in meters) using the Digiroad dataset (Finnish Transport Infrastructure Agency, 2019) in GIS. For technical reasons, distances to 19 destinations, including islands and foreign locations, were manually defined using Google Maps. In Studies II and IV, the median distance from home to activity destinations was calculated for all reported activity destinations combined as well as separately for each activity destination type. The calculations were made individually for each participant. In Study II, the median distance to reported activity destinations was used as a continuous variable. In Study IV, to indicate whether the reported destinations were located close to (proximal, ≤ 2 km) vs. further away from home (distant, > 2 km), dichotomous variables based on the median distance were created for each destination type.

In Study III, the maximum distance between participants' homes and their physical exercise destinations was calculated. Thus, for each participant, the most distant physical exercise destination was used. A categorical variable based on the proximity of the most distant physical exercise destination was formed as follows: (1) destinations within 1 km from home, (2) destinations beyond 1 km from home, (3) destinations at both distances, and (4) no reported physical exercise destinations. Maximum distance was used as both a continuous variable and a categorical variable.

4.4.4 Land use

The predominant type of land use was defined in GIS using Corine Land Cover (CLC) raster data (Finnish Environment Institute 2018). To characterize the predominant land use type around the reported physical activity destinations, 150-m buffer areas surrounding each reported destination were formed. A range of 130 to 150 meters has been identified as a convenient indicator of the area surrounding a single location (Hasanzadeh et al., 2017). The original 49 land use classes of the Corine Land Cover dataset were re-coded into five categories, encompassing both natural and built environments. These categories were: (a) residential areas; (b) services, sports, and leisure facilities; (c) industrial units; (d) agricultural and private garden areas, forests, seminatural areas, marshes, and bogs; and (e) water bodies (Finnish Environment Institute, 2018). In Study III, two dichotomous variables were formed for each land use type: reporting at least one proximal (< 1 km) and at least one distant (> 1 km) physical exercise destination within the respective land use type (yes/no).

4.4.5 Maintained sports facility

To identify publicly maintained sports facilities in the Jyväskylä area, the LIPAS sport facilities dataset from 2018 was used in Study III (Lipas Sport Facility Database, 2018). LIPAS is Finland's national geographic information database on various sport facilities, such as indoor and outdoor gyms, sports and swimming halls, neighborhood sports areas, ball and athletics fields, as well as routes for outdoor activities and recreation areas. LIPAS data can be integrated with other objective data in GIS. The data and information contained in LIPAS are sourced by experts from municipal sport services, associations for recreational areas, and sports federations. In Study III, LIPAS data on sports facilities were linked with participant data and the locations of reported physical exercise destinations in GIS. If a reported physical exercise destination was found to be located within 150 meters of a LIPAS sports facility, it was considered as a maintained indoor or outdoor sports facility. Two dichotomous variables were created for each participant based on the maximum distance of the physical exercise destination: participant reported at least one proximal (< 1 km) or at least one distant (> 1 km) physical exercise destination identified as a maintained sports facility (yes/no).

4.5 Statistical analyses

All the statistical analyses were performed using IBM SPSS Statistics for Windows (versions 26.0-28.0; Armonk, NY: IBM Corp.). The results were regarded as statistically significant if the p-value was < 0.05 or the 95% confidence intervals did not include one in the Poisson log-linear regression and logistic regression analyses or did not include zero in the general linear model analyses.

Descriptive analyses
Participants' descriptive characteristics and the values of the features of their destinations were reported as median and interquartile ranges (IQR) for continuous variables and as frequencies and percentages for categorical variables. The Mann-Whitney U-test was used to compare distributions between two groups, the Kruskall-Wallis test to compare distributions between three or more groups, and the chi-square test to compare frequencies and proportions between groups.

Binary logistic regression
In Study I, binary logistic regression models were used to calculate odds ratios (ORs) and 95% confidence intervals (CIs) for participation frequency in leisure activities at baseline and the four-year follow-up. The models were conducted to study cross-sectional (n = 848) and longitudinal (n = 206) associations between neighborhood walkability, walking difficulties, and participation in leisure activities. Two models for both cross-sectional and longitudinal analyses were constructed for each leisure activity separately. To test the role of age, sex and walking difficulties, they were added to the first model. Finally, years of education, MMSE score, and number of chronic conditions were added to the final model. Cross-sectional binary logistic regression models were conducted with neighborhood walkability and walking difficulties and their interaction as independent variables and the leisure activity categories as dependent variables. Additionally, for the interaction analyses, nine groups based on the combined distribution of walking difficulties and the three neighborhood walkability areas were formed. The participants with walking difficulty and living in the lowest walkability tertile were assigned as the reference group. The interaction analyses were adjusted for age, sex, years of education, MMSE score, and number of chronic conditions. Participation frequency in leisure activities at follow-up was regressed on neighborhood walkability and perceived walking difficulties at baseline in the longitudinal logistic regression models.

In Study III, the association between level of physical activity and reported distant physical exercise destinations identified as maintained sports facility and located in residential areas, service areas, agricultural or forest areas, and water bodies were investigated. The predominant land use type and maintained sports facility variables were treated as dependent variables and physical activity as an independent variable. Logistic regression models were run separately for each land use-type variable and maintained sports facility variable. All analyses were adjusted for age, sex, walking difficulties, MMSE score, chronic conditions, and years of education.

Poisson log-linear regression
In Study II, Poisson log-linear regression was used to study associations between reported walking difficulties and number of activity destinations. The analyses were conducted separately for each activity destination type and for all destinations combined. Participants with walking difficulty were used as a reference group. Poisson loglinear regression models were adjusted for age, sex, perceived financial situation, years of education, MMSE score, regular driving, and population density.

General linear model
A general linear model was used in Studies II, III & IV. Study II investigated the associations between walking difficulties and the log-transformed median distance from home to the reported activity destination using the general linear model. Participants with walking difficulty were taken as a reference group. Analyses were run separately for each activity destination type and for all destinations combined. Analyses were adjusted for age and sex, perceived financial situation, years of education, MMSE score, regular driving and population density.

Study III explored the associations between the level of physical activity, the total number of physical exercise destinations, and the maximum distance from home to a reported destination. Separate analyses were conducted using the total number of physical exercise destinations and maximum distance from home as dependent variables. Analyses were adjusted for age, sex, walking difficulties, MMSE score, chronic conditions, and years of education. In Study IV, the number of destinations, median distance to destinations and destination diversity were studied as predictors of perceived sense of autonomy. Separate analyses were adjusted for age and sex, years of education, regular driving, number of chronic conditions, cognitive function, population density and SPPB score. Participants with no reported destinations were removed from the analyses between median distance to destinations and the sense of autonomy.

Generalized estimating equation analyses
Generalized estimating equation (GEE) models with an unstructured working correlation matrix were used in Study IV to examine the changes over time in the participants' autonomy scores according to the groups of destination variables. We tested the main effects of groups and time and the interactions between these at the 4-year follow-up. Destination feature variables included the number of destinations, median distance to destinations, and diversity of destinations. Participants with no reported destinations were removed from the analyses between median distance to destinations and the sense of autonomy. The GEE models were adjusted for age, sex, years of education, regular driving, number of chronic conditions, cognitive function, population density, and SPPB score.

Sensitivity analyses

In Study I, we conducted sensitivity analyses to determine if potential changes in participants' living environment, resulting from a permanent move, impacted any of the associations identified. Throughout the follow-up period, nine participants relocated, but only three of them experienced a change in walkability area. We found that excluding these three participants from the analyses did not significantly alter the results. In Study IV, we performed sensitivity analyses by categorizing the data based on regular driving habits. The stratified analysis indicated that the main models did not show substantial differences between drivers and non-drivers.

Missing data

In Study I, information on years of education was missing for eight participants. In Studies II, III and IV, years of education was missing for four participants and MMSE score was missing for three participants. In addition, four participants were missing information on SPPB score (Study IV) and financial situation (Study II). These participants were not included in the fully adjusted models. In Studies II and III, 14 participants were excluded from the analysis due to missing information on self-reported walking difficulties. In Study III, 17 participants had missing information on amount of physical activity and were excluded from the analyses. In Study IV, missing autonomy in participation outdoors scores at baseline or follow-up with only one missing item (n = 7) were imputed using the mean of the available items.

5 RESULTS

5.1 Participant characteristics

Baseline characteristics of the study participants in the LISPE (Study I), MIIA (Study I), AGNES baseline (Studies II, III & IV) and AGNES follow-up (Study IV) studies are described in Table 4. Overall, the AGNES participants were in slightly better health than the LISPE and MIIA participants. AGNES participants were younger and had more years of education, fewer chronic diseases, better cognitive and lower extremity function, and a greater sense of autonomy in participation outdoors than the LISPE and MIIA participants. Over half of the study participants were women. In the LISPE and MIIA studies, a lower proportion of the study participants had intact walking compared to counterparts in the AGNES studies. Over half had a very good or good financial situation in all studies. Over 70% of LISPE participants engaged in outdoor recreation weekly, 40% of older adults participated in organized group activities weekly and 33% at least once a month in cultural and other individual activities. In addition, those who participated in the follow-up studies were younger, had more years of education, had a lower number of chronic diseases and had better cognitive function compared to the full baseline samples. In the AGNES follow-up, over half reported driving a car regularly as compared to the corresponding percentage of only 44% in the whole sample.

Characteristics of neighborhood environments and destinations are presented in Table 5. The AGNES follow-up participants had a slightly higher number of destinations, and their destinations were located further away from home than those of the total AGNES baseline sample. Approximately, 50% of participants reported physical exercise destinations that could be classed as a maintained sport facility. Over half of the participants reported at least one physical exercise destinations located in residential, service, agricultural, or forest areas. Half of the AGNES participants lived in the lowest tertile of population density. The homes of the LISPE participants were evenly across the different walkability areas.

TABLE 4 Characteristics of study participants in the datasets used in this study.

Characteristics	AGNES baseline n = 901	AGNES follow-up n = 613	LISPE n = 848	MIIA n = 206
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Age (years)	78.6 ± 3.6	78.2 ± 3.3	80.6 ± 4.2	79.9 ± 4.1
Education (years)	11.6 ± 4.2	11.9 ± 4.3	9.6 ± 4.1	9.8 ± 4.3
Chronic conditions (number)	3.4 ± 2.0	3.3 ± 2.0	4.4 ± 2.4	4.3 ± 2.4
Cognitive function (MMSE, score)	27.3 ± 2.4	27.6 ± 2.1	26.1 ± 2.8	26.6 ± 2.3
Lower extremity function (SPPB, score)	10.1 ± 2.0	10.4 ± 1.8	9.6 ± 2.5	10.2 ± 1.8
Autonomy in participation outdoors (score)	5.2 ± 3.6	4.8 ± 3.6	6.2 ± 3.8	5.5 ± 3.5
	%	%	%	%
Men	43.1	42.5	38.0	43.7
Difficulties in walking 2km				
Intact walking	47.8	52.1	30.0	34.5
Walking modifications	18.8	17.7	28.1	31.1
Walking difficulty	33.4	30.2	42.0	34.5
Higher level of PA, ≥ 30 minutes/day (vs. lower level of PA, <30 min/day)	52.0	55.5	-	-
Good or very good financial situation (vs. bad or poor)	60.3	61.2	50.4	51.0
Driving regularly (vs. rarely)	44.4	58.6	37.6	44.7
Participation in leisure activities				
Organized group activities at least once a week (vs. rare)	-	-	43.3	48.3
Outdoor recreation at least once a week (vs. rare)	-	-	77.4	83.5
Cultural or other individual activities at least once a month (vs. rare)	-	-	33.1	39.0

TABLE 5 Characteristics of participants' neighborhood environment and reported destinations.

Neighborhood features	AGNES baseline n = 901	AGNES follow-up n = 613	LISPE n = 848	MIIA n = 206
	%	%	%	%
Walkability tertiles				
Lowest	-	-	33.3	35.9
Middle	-	-	33.5	34.0
Highest	-	-	33.3	30.1
Population density				
Lowest	46.6	49.3	-	-
Middle	22.0	19.9	-	-
Highest	31.4	30.8	-	-
Destination features	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**
All destinations combined				
Number	6.0 (3.0)	7.0 (3.0)	-	-
Median distance (km)	1.8 (1.8)	1.9 (1.7)	-	-
Regular destinations				
Number	2.0 (1.0)	3.0 (1.0)	-	-
Median distance (km)	2.3 (2.5)	2.4 (2.5)	-	-
Attractive destinations				
Number	1.0 (1.0)	1.0 (1.0)	-	-
Median distance (km)	1.4 (5.1)	1.5 (6.3)	-	-
Physical exercise destinations				
Number	2.0 (2.0)	3.0 (2.0)	-	-
Median distance (km)	1.4 (1.8)	1.5 (1.9)	-	-
Maximum distance (km)	1.7 (3.0)	2.0 (3.4)	-	-
	%	%	%	%
Maintained sports facility	52.9	60.7	-	-
Land use type				
Residential areas	47.2	55.4	-	-
Service areas	50.8	59.3	-	-
Industrial units	5.0	10.8	-	-
Agricultural or forest areas	56.1	65.8	-	-
Water bodies	24.6	31.2	-	-

5.2 Neighborhood walkability, walking difficulties, and participation in leisure activities (Study I)

Study I examined the cross-sectional and longitudinal associations between neighborhood walkability, walking difficulties, and participation in leisure activities. Both the cross-sectional and longitudinal analyses revealed that neighborhood walkability was not statistically significantly associated with frequency of participation in organized group activities (e.g., choir, physical activity class or church activities) (Table 6). The participants living in the highest walkability index area had lower odds of frequent participation in outdoor recreation (e.g., fishing, berry-picking, walking the dog, or gardening) than those living in the lowest walkability areas (OR 0.61, 95% CI 0.40–0.94). The association remained statistically significant after adjusting for the covariates. At follow-up, living in a middle walkability neighborhood at baseline increased the odds of frequent participation in outdoor recreation at the four-year follow-up in the fully adjusted model (OR 2.92, 95% CI 1.03–8.30).

In terms of participating in cultural and other individual activities, the participants living in the highest (OR 1.62, 95% CI 1.12–2.35) or middle (OR 1.46 95% CI 1.01–2.11) walkability areas were more likely to be frequent attendees at cultural or other individual activities (e.g., going to the theater, concerts or a coffee shop) than those living in the lowest walkability area. However, when the models were adjusted for covariates, the associations became statistically nonsignificant. After all adjustments, the longitudinal analyses showed that the participants living in the highest (OR 2.96, 95% CI 1.25–7.02) or middle (OR 2.93, 95% CI 1.26–6.79) walkability area at baseline had higher odds at follow-up for frequent participation in cultural or other individual activities compared to those living in the lowest walkability neighborhood.

Participants with intact walking or walking modifications were more likely to attend all the studied leisure activities more frequently than those with walking difficulty. Older adults with intact walking at baseline had higher odds for frequent participation in outdoor recreation (OR 2.92, 95% CI 1.01–8.52) and cultural or other individual activities (OR 2.85, 95% CI 1.24–6.51) at the four-year follow-up than counterparts with walking difficulty. After adjustment for all covariates, the association between intact walking and participation in cultural or other individual activities remained statistically significant, while the association between intact walking and participation in outdoor recreation became statistically nonsignificant.

TABLE 6 Cross-sectional and longitudinal logistic regression analyses on neighborhood walkability, walking difficulties and frequent (vs. rare) participation in leisure activities at baseline (n = 848) and follow-up (n = 206).

	Participation in leisure activities at baseline (n = 848)						Participation in leisure activities at follow-up (n = 206)					
	Organized group activities		Outdoor recreation		Cultural or other individual activities		Organized group activities		Outdoor recreation		Cultural or other individual activities	
	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)
Walkability tertile												
Highest	1.22 (0.87–1.74)	1.07 (0.74–1.53)	**0.61 (0.40–0.94)**	**0.60 (0.39–0.94)**	**1.62 (1.12–2.35)**	1.34 (0.91–1.97)	1.61 (0.79–3.31)	1.48 (0.71–3.08)	1.49 (0.58–3.79)	1.37 (0.53–3.55)	**3.24 (1.41–7.43)**	**2.96 (1.25–7.02)**
Middle	1.10 (0.78–1.55)	1.04 (0.72–1.47)	0.82 (0.53–1.27)	0.82 (0.53–1.27)	**1.46 (1.01–2.11)**	1.38 (0.95–2.00)	0.73 (0.36–1.51)	0.72 (0.35–1.49)	2.59 (0.95–7.08)	**2.92 (1.03–8.30)**	**3.12 (1.39–7.00)**	**2.93 (1.26–6.79)**
Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Walking difficulties												
Intact walking	**2.07 (1.45–2.95)**	**2.43 (1.64–3.58)**	**5.97 (3.58–9.92)**	**6.23 (3.65–10.64)**	**2.93 (2.01–4.26)**	**2.83 (1.88–4.26)**	2.12 (0.99–4.56)	1.86 (0.81–4.27)	**2.92 (1.01–8.52)**	2.86 (0.90–9.13)	**2.85 (1.24–6.51)**	**2.83 (1.10–7.28)**
Walking modifications	**1.73 (1.23–2.45)**	**1.91 (1.33–2.75)**	**3.59 (2.33–5.53)**	**3.68 (2.37–5.73)**	**1.73 (1.19–2.52)**	**1.69 (1.14–2.49)**	1.47 (0.69–3.12)	1.34 (0.62–2.93)	1.87 (0.74–4.74)	1.86 (0.70–4.92)	1.43 (0.62–3.32)	1.36 (0.55–3.38)
Walking difficulty	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Men (vs. Women)	**0.63 (0.47–0.84)**	**0.63 0.47–0.86**	0.96 (0.67–1.39)	0.96 (0.93–1.01)	**0.72 (0.53–0.99)**	**0.67 (0.48–0.93)**	0.80 (0.43–1.49)	0.77 (0.41–1.46)	0.97 (0.42–2.27)	0.85 (0.35–2.03)	0.70 (0.35–1.39)	0.64 (0.31–1.32)
Age	1.00 (0.96–1.04)	1.01 (0.97–1.05)	0.97 (0.93–1.01)	0.97 (0.93–1.01)	0.98 (0.95–1.02)	0.99 (0.96–1.04)	0.98 (0.90–1.06)	0.98 (0.90–1.06)	**0.87 (0.79–0.97)**	**0.88 (0.79–0.98)**	0.94 (0.87–1.03)	0.93 (0.85–1.02)
Years of education		1.02 0.98–1.06		1.01 (0.97–1.06)		**1.06 (1.02–1.11)**		1.00 (0.94–1.08)		1.06 (0.96–1.17)		1.01 (0.93–1.09)
MMSE score		**1.09 (1.03–1.15)**		0.98 (0.91–1.05)		**1.06 (1.00–1.13)**		1.05 (0.91–1.21)		0.94 (0.79–1.12)		**1.32 (1.10–1.60)**
Number of chronic conditions		**1.09 (1.03–1.16)**		1.03 (0.95–1.01)		1.02 (0.95–1.09)		0.99 (0.87–1.13)		0.98 (0.83–1.15)		1.03 (0.88–1.19)

Note. OR = odds ratio, CI = confidence interval, MMSE = Mini-Mental State Examination. Bolded values indicate that the 95% CI does not contain the value 1, $p < 0.05$. Binary logistic regression models were run separately for each outcome variable.

To examine whether the association between walking difficulties and participation in leisure activities differed by neighborhood walkability, interaction analyses were conducted (Figure 1). For the interaction analyses, nine groups were formed based on the combined distribution of walking difficulties and the three neighborhood walkability areas. Participants with walking difficulty living in the lowest walkability tertile were assigned as the reference group. Individuals with walking difficulty were consistently the least likely to participate frequently in any activity, regardless of the walkability of their neighborhood. Thus, older adults with intact walking had the highest odds for frequent participation in most activities. Participants with walking modifications living in the lowest walkability areas had the highest odds for frequent participation in organized group activities and those living in the middle walkability area the highest odds for frequent participation in cultural activities.

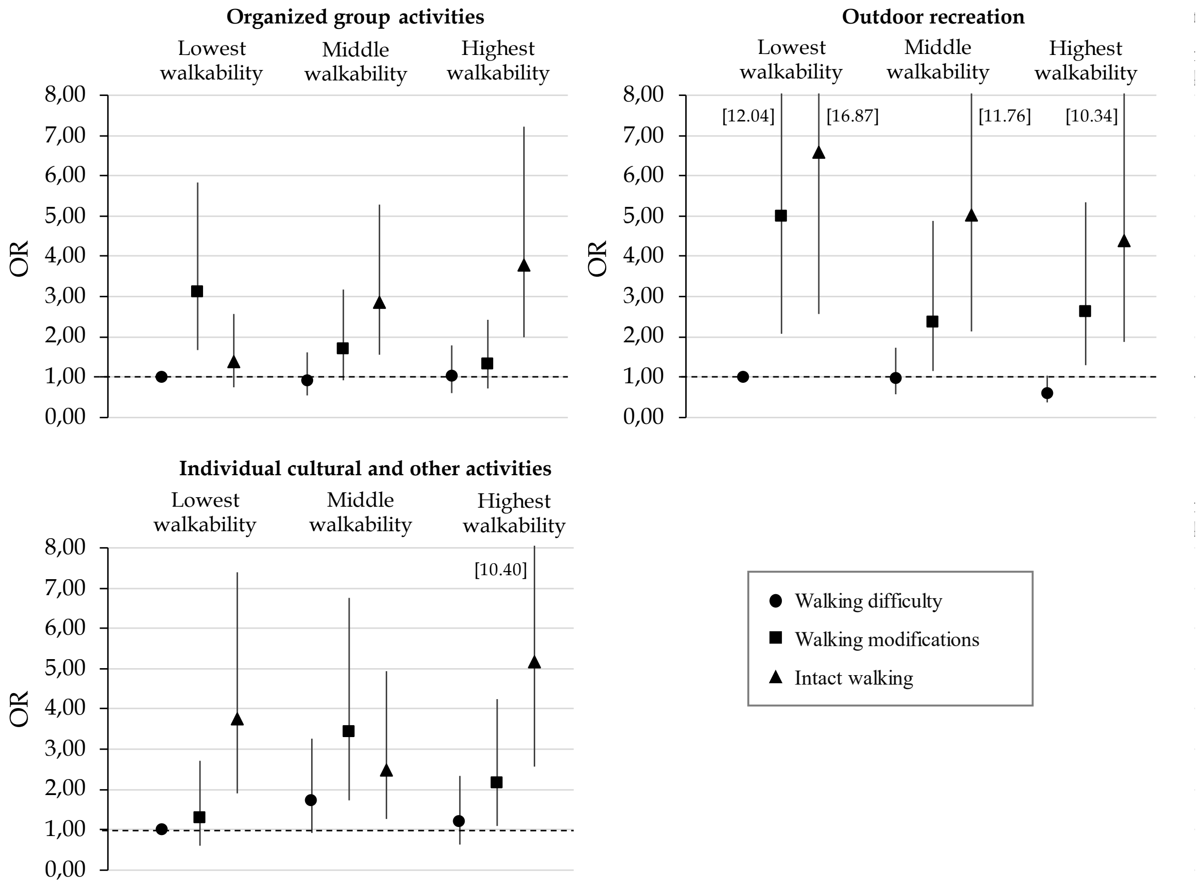

FIGURE 1 The odds ratios (ORs) and the 95% confidence intervals (CIs) for frequent (vs. rare) participation in leisure activities at baseline by interaction of neighborhood walkability and perceived walking difficulties (n = 848). Modified from Study I.

5.3 Walking difficulties and activity destinations (Study II)

In Study II, the number of reported destinations and the distance to those destinations were compared between those reporting intact walking, those reporting walking modifications, and those reporting walking difficulty. Figure 2 presents the incidence rate ratios and 95% confidence intervals for the number of activity destinations according to the walking difficulties. Participants with intact walking had greater IRRs for all destinations combined (IRR 1.20, 95% CI 1.13–1.28), physical exercise destinations (IRR 1.45, 95% CI 1.31–1.61) and attractive destinations (IRR 1.23, 95% CI 1.09–1.40) than those with walking difficulty. In turn, participants using walking modifications had greater IRRs for all destinations combined (IRR 1.09, 95% CI 1.01–1.18) and for physical exercise destinations (IRR 1.23, 95% CI 1.08–1.40) than those with walking difficulty.

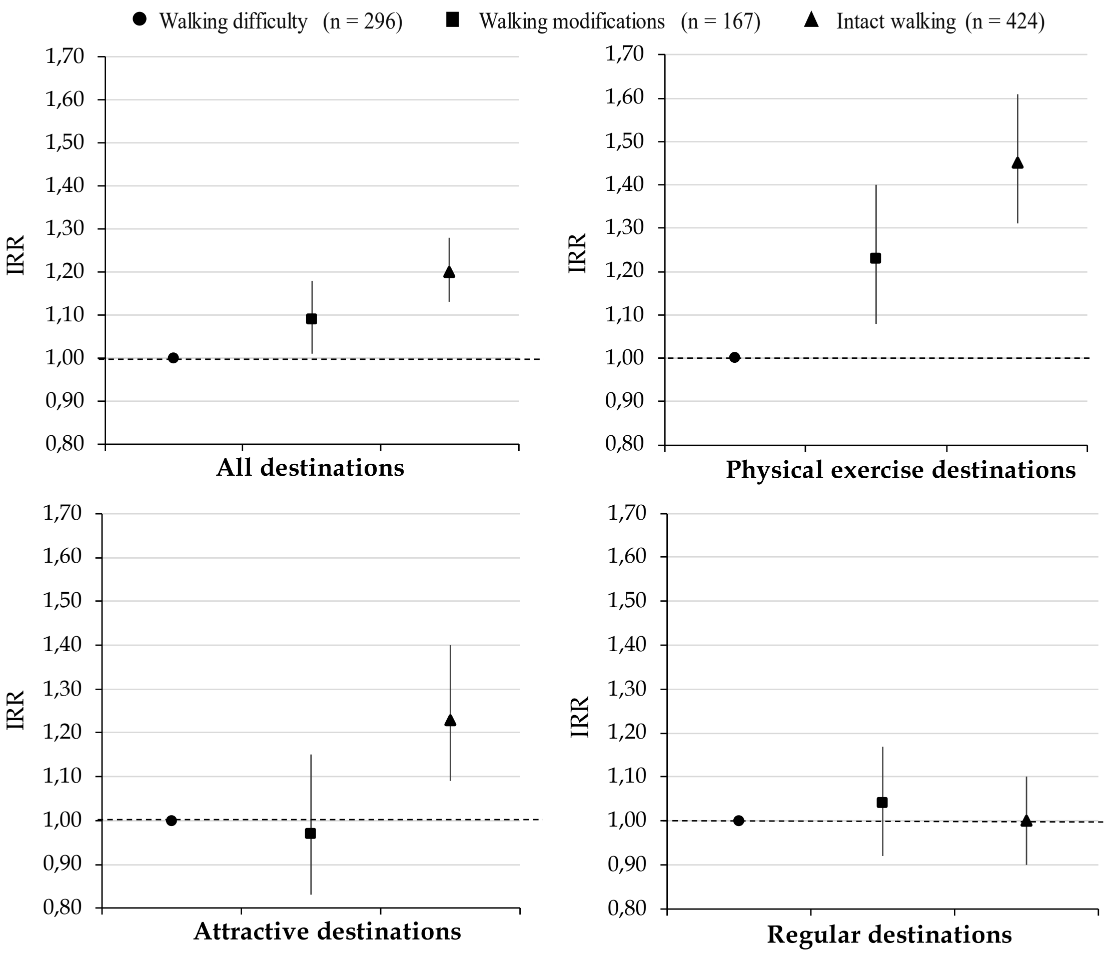

FIGURE 2 The incidence rate ratios (IRRs) and the 95% confidence intervals (CIs) for the number of reported activity destinations with different groups of walking difficulties (n = 887). The results are considered statistically significant when the 95% confidence intervals do not include one. Modified from Study II.

Table 7 shows the associations between participants' walking difficulties and median distance to their reported activity destinations. Participants who had intact walking reported a greater median distance to all destinations (b 0.13, 95% CI 0.07–0.19), physical exercise destinations (b 0.58, 95% CI 0.44–0.71), and attractive destinations (b 0.46, 95% CI 0.20–0.71) than those with walking difficulty. In turn, participants who used walking modifications reported a greater median distance to their physical exercise destinations than those with walking difficulty (b 0.41, 95% CI 0.25–0.58). However, the associations between walking difficulties and median distance to regular destinations were all non-significant.

TABLE 7 Associations between walking difficulties and median distance to reported activity destinations (n = 887).

	Distance to all destinations	Distance to physical exercise destinations	Distance to attractive destinations	Distance to regular destinations
	b (95% CI)	b (95% CI)	b (95% CI)	b (95% CI)
Intact walking (vs. walking difficulty)	**0.13 (0.07–0.19)**	**0.58 (0.44–0.71)**	**0.46 (0.20–0.71)**	0.04 (-0.05–0.13)
Walking modifications (vs. walking difficulty)	0.05 (-0.01–0.12)	**0.41 (0.25–0.58)**	-0.10 (-0.33–0.30)	0.05 (-0.06–0.16)
Men (vs. women)	**0.10 (0.04–0.15)**	-0.00 (-0.14–0.71)	0.05 (-0.16–0.30)	0.01 (-0.02–0.13)
Good or very good financial situation (vs. poor to fair)	0.01 (-0.04–0.07)	0.04 (-0.08–0.17)	0.05 (-0.16–0.30)	0.03 (-0.06–0.11)
Age	**-0.02 (-0.03– -0.01)**	**-0.02 (-0.04– -0.00)**	-0.02 (-0.05–0.01)	-0.01 (-0.02–0.00)
Years of education	-0.01 (-0.01–0.00)	0.00 (-0.01–0.02)	0.00 (-0.03–0.03)	**-0.02 (-0.03– -0.00)**
MMSE score	-0.01 (-0.01–0.02)	0.03 (-0.01–0.05)	0.02 (-0.03–0.07)	0.00 (-0.00–0.03)
No regular driving (vs. regular driving)	**-0.12 (-0.12– -0.06)**	-0.06 (-0.20–0.08)	0.03 (-0.19–0.28)	**-0.23 (-0.32– -0.13)**
Lowest tertile of population density (vs. highest tertile)	**0.17 (0.12–0.23)**	0.08 (-0.06–0.22)	**-0.33 (-0.59– -0.07)**	**0.23 (0.14–0.32)**
Middle tertile of population density (vs. highest tertile)	**0.15 (0.08–0.21)**	0.08 (-0.09–0.24)	-0.12 (-0.42–0.19)	0.05 (-0.06–0.16)

Note. b=regression coefficient, CI=confidence interval, MMSE=Mini-Mental State Examination. Bolded values indicate that the 95% CI does not contain the value 0, $p < 0.05$. The general linear models were run separately for each outcome variable.

5.4 Physical activity and features of physical exercise destinations (Study III)

Study III investigated the associations between physical activity level, land use type surrounding destinations, and distance to reported physical exercise destinations. Overall, 89% of the study participants reported outdoor physical exercise destinations and 47% reported indoor physical exercise destinations. The older adults with higher levels of physical activity were more likely to report both indoor and outdoor destinations whereas those with lower activity only one or the other of these. Those with higher physical activity also reported distant physical exercise destinations more often than those with lower levels of physical activity. Those in the higher physical activity group also reported a higher number of all destinations (b 0.74, 95% CI 0.54–0.94) as well as destinations further from home (b 0.36, 95% CI 0.23–0.49) than those in the lower physical activity group (Table 8).

TABLE 8 Associations of physical activity level with the number of physical exercise destinations and maximum distance to those destinations (n = 883).

	Number of physical exercise destinations	Maximum distance to physical exercise destinations
	b (95% CI)	b (95% CI)
Higher physical activity (vs. lower physical activity)	**0.74 (0.54–0.94)**	**0.36 (0.23–0.49)**
Age	0.01 (-0.02–0.04)	**-0.02 (-0.04– -0.00)**
Men (vs. women)	**0.40 (0.21–0.59)**	-0.03 (-0.16–0.09)
Intact walking (vs. walking difficulty)	**0.47 (0.25–0.67)**	**0.41 (0.26–0.56)**
MMSE score	**0.09 (0.05–0.13)**	**0.04 (0.01–0.07)**
Chronic conditions	-0.05 (-0.10–0.01)	-0.01 (-0.04–0.03)
Years of education	0.02 (-0.01–0.04)	0.01 (-0.01–0.02)

Note. b = unstandardized regression coefficient; CI = confidence interval; MMSE = Mini-Mental State Examination. Bolded values indicate that the 95% CI does not contain the value 0, $p < 0.05$. Higher physical activity, ≥30 min/day; lower physical activity, <30 min/day. General linear models were run separately for each outcome variable.

Participants with lower physical activity tended to have their most frequently visited proximal destinations located in residential areas, whereas those with higher physical activity tended to visit proximal destinations predominantly characterized by agricultural or forest areas. Both groups were more likely to have distant physical exercise destinations in service areas. The fully adjusted logistic regression analyses revealed that participants with higher physical activity were more likely than those with lower physical activity levels to visit distant physical exercise destinations located in residential areas (OR 1.55, 95% CI 1.08–2.21), service areas (OR 1.81, 95% CI 1.33–2.47) and agricultural or forest areas (OR 1.63, 95% CI 1.19–2.24) (Figure 3). However, the association between participants' level of physical activity and their reporting of distant destinations predominantly characterized by water bodies was not statistically significant (OR 1.46, 95% CI 0.97–2.21). Individuals with higher physical activity levels were also more likely to visit distant physical exercise destinations that were identified as maintained sports facilities than those with lower physical activity levels (OR 2.07, 95% CI 1.51–2.82).

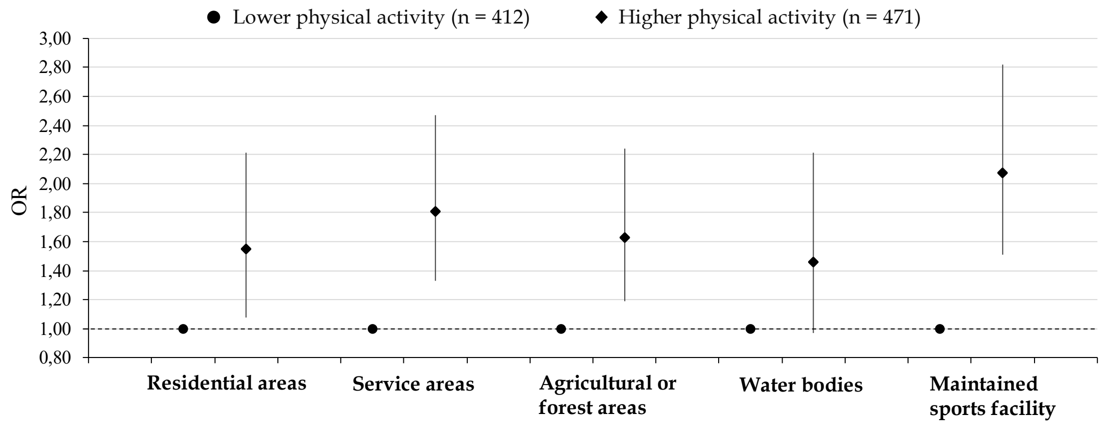

FIGURE 3 The odds ratios (ORs) and the 95% confidence intervals (CIs) for reporting at least one distant physical exercise destination identified as a maintained sports facility and according to the predominant land use type for those with higher physical activity (n = 471) vs. lower physical activity (n = 412). The results are considered statistically significant when the 95% confidence intervals do not include one.

5.5 Activity destinations and autonomy in participation outdoors (Study IV)

Study IV examined the association between the number of destinations, median distance to destinations, destination diversity and sense of autonomy in participation outdoors. The results showed that individuals who visited a lower total number of destinations (b 1.48, 95% CI 0.94–2.03), physical exercise destinations (b 1.56, 95% CI 1.01–2.11), or regular destinations (b 1.33, 95% CI 0.73–1.92) reported a lower sense of autonomy than those who visited more destinations (Table 9). After adjusting for potential confounders, these associations were somewhat attenuated but remained statistically significant. The number of attractive destinations reported was not associated with the sense of autonomy (b 0.34, 95% CI -0.27–0.96).

With respect to distance to destinations, participants who reported a shorter median distance to all destinations (b 0.59, 95% CI 0.11–1.08) or to physical exercise destinations (b 0.83, 95% CI 0.34–1.32) reported a more restricted sense of autonomy in participation outdoors than those who reported destinations further away. When potential confounders were added to the model, the associations became statistically nonsignificant. However, distance to regular (b 0.27, 95% CI -0.20–0.74) or attractive destinations (b 0.41, 95% CI -0.11–0.92) did not show a similar association with the sense of autonomy. The results also revealed that participants who visited all three types of destinations reported a higher sense of autonomy than those who visited only two or fewer types of destinations (b -0.89, 95% CI -1.39– -0.39). This association remained statistically significant after adjusting for all the confounders.

Overall, autonomy in participation outdoors worsened during the four-year follow-up (Table 10). Participants reporting the lowest number of all destinations at baseline perceived poorer autonomy in participation outdoors (mean 5.7, SD 3.9) than those reporting the highest number of all destinations (mean 4.4, SD 3.3), although the level of change between these two groups remained similar over time (B 0.08, SE 0.37, p=0.833). Similar associations were also found for the other destination variables. Thus, the rate of decline in autonomy in participation outdoors was similar irrespective of the number of activity destinations reported at baseline.

TABLE 9 Destination features (number of destinations, median distance and diversity of destinations) as separate predictors of perceived autonomy in participation outdoors at baseline (n = 899).

	Model 1		Model 2	
	b	95% CI	b	95% CI
Numbers of destinations (n = 899)				
All destinations				
≤ 5	**1.48**	**0.94–2.03**	**0.70**	**0.16–1.24**
6-7	0.55	-0.01–1.11	0.08	-0.46–0.62
≥ 8	Ref.		Ref.	
Physical exercise destinations				
0-1	**1.56**	**1.01–2.11**	**0.81**	**0.27–1.36**
2	0.46	-0.09–1.01	0.10	-0.43–0.63
≥ 3	Ref.		Ref.	
Attractive destinations				
0-1	0.34	-0.27–0.96	-0.05	-0.65–0.54
2	-0.14	-0.82–0.54	-0.21	-0.85–0.43
≥ 3	Ref.		Ref.	
Regular destinations				
0-1	**1.33**	**0.73–1.92**	**0.90**	**0.33–1.46**
2	0.30	-0.22–0.82	0.21	-0.28–0.70
≥ 3	Ref.		Ref.	
Median distance to[a]				
All destinations (n = 899)				
≤ 2 km	**0.59**	**0.11–1.08**	0.18	-0.30–0.65
> 2 km	Ref.		Ref.	
Physical exercise destinations (n = 835)				
≤ 2 km	**0.83**	**0.34–1.32**	0.37	-0.11–0.84
>2 km	Ref.		Ref.	
Attractive destinations (n = 687)				
≤ 2 km	0.41	-0.11–0.92	0.07	-0.43–0.56
> 2 km	Ref.		Ref.	
Regular destinations (n = 882)				
≤ 2 km	0.27	-0.20–0.74	0.11	-0.37–0.58
> 2 km	Ref.		Ref.	
Diversity of destinations (n = 899)				
Three types reported	**-0.89**	**-1.39– -0.39**	**-0.48**	**-0.96– -0.00**
Two or less types reported	Ref.		Ref.	

Note. b = unstandardized regression coefficient; CI = confidence interval. Bolded values indicate that the 95% CI does not contain the value 0, $p < 0.05$. GLM models were run for each destination variable separately. [a]Participants with no reported destinations were removed from the analyses. Model 1 adjusted for age, sex and Model 2 adjusted for age, sex, years of education, regular driving, number of chronic conditions, MMSE score, population density and SPPB score. Higher scores in autonomy in participation outdoors indicate a more restricted sense of autonomy (range 0-20).

TABLE 10 Perceived autonomy in participation outdoors scores at baseline and at the four-year follow-up by destination features, and with time, group, and group-by-time interaction effects tested with generalized estimating equation analysis (n = 613).

	Time		Group		Group x time	
	B (SE)	p	B (SE)	p	B (SE)	p
Numbers of destinations (n = 613)						
All destinations						
≤ 5	1.76 (0.24)	**<0.001**	0.61 (0.60)	0.307	0.08 (0.37)	0.833
6-7			-0.37 (0.54)	0.500	0.23 (0.34)	0.493
≥ 8			Ref.		Ref.	
Physical exercise destinations						
0-1	1.83 (0.18)	**<0.001**	1.11 (0.33)	0.079	0.27 (0.42)	0.484
2			-0.32 (0.36)	0.538	0.29 (0.35)	0.400
≥ 3			Ref.		Ref.	
Attractive destinations						
0-1	1.93 (0.34)	**<0.001**	-0.04 (0.62)	0.944	-0.23 (0.39)	0.533
2			-0.75 (0.70)	0.289	0.15 (0.45)	0.736
≥ 3			Ref.		Ref.	
Regular destinations						
0-1	1.90 (0.21)	**<0.001**	0.64 (0.61)	0.297	-0.15 (0.43)	0.697
2			0.53 (0.51)	0.300	-0.10 (0.32)	0.744
≥ 3			Ref.		Ref.	
Median distance to[a]						
All destinations (n = 613)						
≤ 2 km	1.81 (0.21)	**<0.001**	-0.01 (0.48)	0.985	0.08 (0.29)	0.789
> 2 km			Ref.		Ref.	
Physical exercise destinations (n = 578)						
≤ 2 km	1.83 (0.22)	**<0.001**	0.32 (0.46)	0.494	0.13 (0.30)	0.651
>2 km			Ref.		Ref.	
Attractive destinations (n = 472)						
≤ 2 km	1.74 (0.22)	**<0.001**	-0.31 (0.53)	0.563	0.40 (0.33)	0.232
> 2 km			Ref.		Ref.	
Regular destinations (n = 604)						
≤ 2 km	1.95 (0.19)	**<0.001**	0.28 (0.51)	0.578	-0.27 (0.30)	0.358
> 2 km			Ref.		Ref.	
Diversity of destinations (n = 613)						
Three types reported	1.63 (0.29)	**<0.001**	-0.89 (0.54)	0.102	0.32 (0.34)	0.345
Two or less types reported			Ref.		Ref.	

Note. B = unstandardized regression coefficient, SE = standard error. Statistically significant p-values are bolded. Bolded values indicate p < 0.05. GEE models were run for each destination variable separately. All analyses adjusted for age, sex, years of education, regular driving, number of chronic conditions, MMSE score, population density, and SPPB score. Higher scores in autonomy in participation outdoors indicate a more restricted sense of autonomy (range 0-20).
[a]Participants with no reported destinations were removed from the analyses.

6 DISCUSSION

The purpose of this dissertation research was to investigate the individual resources, environmental factors, and activity destinations that contribute to the out-of-home mobility of older adults. Participant-reported data on mobility patterns and map-based destinations were combined with the objective features of the participants' environments. The main findings were that older adults living in highly walkable neighborhoods tended to participate frequently in cultural activities, while those in less walkable areas were more likely to engage in outdoor recreation. Older adults with good walking ability and higher levels of physical activity reported visiting a wide range of destinations, including destinations outside their immediate neighborhoods. Despite experiencing challenges in walking, older adults visited destinations and engaged in out-of-home activities on a daily basis. The more physically active older individuals reported using a variety of sports facilities and exercise facilities located in areas characterized by different types of land use. For older adults, visiting activity destinations was also linked with a higher sense of autonomy in their perceived opportunities to participate in activities outside the home.

Our study underlines the complexity of the relationship between individual resources, activity destinations and environmental factors in shaping the daily lives and well-being of older adults. By studying both subjective experiences and objective environmental data, we are able to gain a more holistic understanding of the factors influencing older adults' activity behavior. More specifically, this approach enabled the identification of environmental features and activity destinations that facilitate or hinder outdoor mobility and participation in leisure activities outside the home. This information has practical implications for urban planning, and community development aimed at the creation of a more age-friendly built environment and community. In particular, the findings of this research underscore the importance of creating walkable environments and offering diverse activity options to enhance the well-being and participation of older individuals, especially those with different walking abilities.

6.1 Associations between neighborhood environment and out-of-home-activity

The neighborhood environment is important for the activity of older adults. This study looked at the relationship between neighborhood walkability and self-reported participation in leisure activities. The main results showed that older adults' objective neighborhood walkability was differently associated with their participation in cultural activities vs. outdoor activities. Those living in the highest walkability neighborhoods participated more frequently in cultural and other individual activities, such as going to concerts, the theater, or coffee shops, than participants living in the lowest walkability areas. This is in line with previous findings of an association between neighborhood walkability and community participation, including out-of-home social and leisure activities (Vaughan et al., 2016). In high walkability areas, land use is diversified, the road network is coherent, and population density is high. Areas such as city centers are usually high-walkability areas that offer more services and possibilities to participate in a variety of activities, especially cultural activities. Hence, this result may be explained by the better accessibility to services and cultural activities in the highest walkability areas and greater likelihood of the availability of preferred activities. Previous studies have indicated that proximity to services is associated with higher participation in cultural activities or going to a café (Richard et al., 2009). In addition, the mere proximity of services may motivate older adults to go out and be physically active (Barnett et al., 2017).

The present study also found that older adults living in the highest walkability area had lower odds of frequent engagement in outdoor recreations. These included nature-based activities such as fishing, berry-picking and other activities such as walking the dog or gardening. Our results are in line with previous studies which have also found an association between lower neighborhood walkability and higher odds of reporting gardening (King et al., 2017). Outdoor recreation typically occurs in natural settings, where nature and green spaces can provide restorative experiences (Andkjær & Arvidsen, 2015; Hinrichs et al., 2019; Keskinen et al., 2018). It may be that outdoor activities are more relevant in lower walkability areas, where population density is lower and destinations fewer in number (King et al., 2017). While the peripheral areas of a city may offer better access to nature, cultural and other services concentrated in the city center may be a long distance away. It is also possible that older adults may have chosen to live in this particular area based on their preferences and travel needs (Mokhtarian & Cao, 2008). Finally, the results of this study showed nonsignificant associations between neighborhood walkability and participation in organized group activities, including classes and club activities. Previous studies have also found associations of walkability features, such as population density, with participation in club activities, although not with volunteering or attending meetings of organizations (Hand & Howrey, 2019). In Finland, activities of these kinds may be distributed across within municipality, while neighborhood areas may not be as important as an individual's capacity and preferences.

6.2 Individual resources and activity destinations

Individual factors such as walking difficulties and physical activity may significantly impact people's willingness and motivation to move around outside the home, including where and how far to go from home. The results of this study showed that older adults with walking difficulty were consistently the least likely to participate frequently in leisure activities, a finding also reported previous studies (Hand & Howrey, 2019; Siltanen et al., 2021). Older adults with walking difficulty also reported a lower number of activity destinations, with the exception of regular destinations, than older adults with intact walking. A low number of physical exercise destinations and attractive destinations may signal an overall reduction in recreational activities. In our study, older adults with walking difficulty tended to visit destinations that were close to home. Individuals with lower physical competence and decreasing capabilities are more vulnerable to environmental challenges, such as barriers, than those with higher competence (Lawton & Nahemow, 1973). Other factors such as older age, low socioeconomic and health status, and impaired physical function have also been shown to be linked with lower outdoor participation (Yang et al., 2018). According to the ecological model of aging, activity behavior is influenced by the combination of an individual's competence and capabilities, such as physical function, and the demands of their living environment (Lawton & Nahemow, 1973).

The present study found that using walking modifications helped participation in all the leisure activities investigated. Using modifications may help people to continue participating in activities outside the home even when preclinical difficulties have manifested. Older adults may respond to functional decline and environmental demands by modifying their walking behavior and in this way be able to continue their habitual activities despite their decreasing capabilities (Baltes & Baltes, 1990). However, we found that the association between walking modifications and activity destinations was somewhat more complex. Older adults who had modified their walking behavior reported a higher number of physical exercise destinations, and destinations that were also located further away than those with walking difficulty but unmodified walking behavior. Thus, our results complement earlier findings by showing that walking modifications allow older adults to continue visiting preferred physical exercise destinations. However, only a nonsignificant difference was observed in the number of destinations considered attractive, including natural places, between the older adults using walking modifications and those with walking difficulty. For people with walking difficulty, getting to sports facilities may alone require a good level of physical capacity and hence may restrict their visits to such places. On the other hand, making the effort may enable them to maintain their physical capacity. Neighborhood environments may, however, lack the facilitators older adults with walking difficulty need to support and motivate them to visit such places.

According to results of this study, the older adults with intact walking or using walking modifications reported destinations located further away from home, possibly indicating that they have the necessary physical reserves and are thus willing to travel further to a specific type of destination. Visits to regular destinations may be an important part of older individuals' community mobility, especially for those with reduced walking ability. This study also found that older adults, irrespective of walking modifications or walking difficulty, reported an equal number of regular destinations. Regular destinations included critical daily amenities, such as grocery stores, health services, and other shops. Despite having walking difficulty, older adults seen to demonstrate resilience in reaching necessary destinations for daily living, a finding that highlights the importance of creating accessible environments that can accommodate different levels of mobility.

The current study also revealed the diversity and location of older adults' activity destinations. Physical exercise and attractive destinations were located somewhat closer to home than regular destinations. Previous studies have shown that everyday destinations are regularly visited, even if they are further away from home, and by modes of transport other than walking (Hirsch et al., 2016; Nathan et al., 2012). Although in this study we were not interested in the modes of transportation used to access these destinations, it can be assumed that shopping trips, especially those involving grocery shopping, often require transporting multiple items and hence are more commonly made by car. A recent study found that almost all self-selected activities promote well-being (Rantanen et al., 2021). We also found that visiting fewer activity destinations and destinations located closer to home was associated with a lower perceived sense of autonomy in participation outdoors. Nevertheless, older adults with mobility challenges seem willing to venture outside their local area to access essential services and stores, thereby contributing to their everyday activity (Hillsdon et al., 2015) and well-being (Satariano et al., 2012). In sum, these findings indicate the crucial role played by the environment in meeting older adults' needs and maintaining their independence (Wahl et al., 2012).

In addition to individual factors such as walking ability, the results of this study showed that a higher level of physical activity was associated with a higher number of physical exercise destinations and that these destinations were located at some distance away from home. Older adults with higher physical activity reported more often both outdoor and indoor destinations than just one or the other which concurs with the findings of an earlier study (Kerr et al., 2012). Those with higher physical activity may visit a variety of different physical exercise locations to engage in preferred activities whereas individuals with lower physical activity may choose just one specific location for this purpose. Indoor physical exercise destinations may be more accessible and participation in the activities they offer may require fewer individual resources. For instance, uneven terrain in outdoor areas can create a sense of insecurity for people with mobility limitations.

This study found that physically active older adults were more likely than less active counterparts to choose exercise destinations that were at some distance away from home. Previous research has shown that older adults may be willing to travel further for exercise (McCormack et al., 2006), particularly to destinations that are important to them and located in a pleasant environment. Being physically active allows older adults to engage more easily in everyday activities, maintain themselves in better physical condition (Piercy et al., 2018), and enjoy a greater life space (Portegijs et al., 2015). This study also found that the group of older adults with higher physical activity were more likely to identify distant exercise destinations identified as maintained sports facilities. Physical exercise destinations were also located in differing environments characterized by different land use types. Maintained sports facilities have surroundings and facilities that are designed explicitly for physical activity. Older adults may be motivated to travel a considerable distance from home to reach sports facilities where they can participate in specific sports or otherwise be physically active. When selecting a place or facility for physical exercise, factors such as the distance from home and surrounding land use type are nevertheless important for older adults. The type of facility available and how far it is from home is likely to influence its use. In this study, older adults more frequently reported distant physical exercise destinations that were predominantly located in service areas and proximal destinations located in residential, agricultural, or forest areas. Older adults may choose certain destinations for physical exercise because they are close to other services and hence may be able to visit multiple destinations during the same trip. The results also suggest that natural or semi-natural environments can encourage physical activity. This finding emphasizes the importance for promoting public health of preserving and integrating green spaces located in urban areas.

6.3 Methodological considerations

This dissertation research utilized data from two larger cohort studies: LISPE and AGNES, and from their sub-studies MIIA and the AGNES follow-up study. The LISPE and MIIA studies were conducted in 2012 and 2016. The AGNES baseline data were gathered in 2017-2018. Thus, these data already existed when I started my doctoral research, requiring me to carefully familiarize myself with these studies research protocols before conducting my own analyses. The AGNES follow-up data were gathered in 2021-2022 during the initial years of my doctoral research. Hence, I was part of the AGNES research group and conducted home interviews with the study participants. All the research projects followed good scientific practice. Participants had the opportunity to request information and withdraw their consent at any time.

The LISPE and AGNES studies included large population-based samples of people over age 75, and very little information was missing. The study participants were relatively healthy and well-functioning older adults. Both studies included face-to-face home interviews. The AGNES study also included laboratory measurements accompanied by a map questionnaire. It has been reported that older individuals with poorer health and functioning are more likely to decline participation in studies that require more effort (Portegijs et al., 2019). Thus, the present findings may not be generalizable to older individuals with poorer health and function. Since all the participants lived in the same urban area of Jyväskylä and Muurame in Central Finland, the findings may have limited generalizability to areas with different geographical characteristics and cultures. The LISPE and AGNES datasets contained a wide range of variables related to individuals' functioning and health, physical activity, outdoor mobility, and autonomy, which enabled the finding of answer to the research questions. There were relatively few missing data as the self-reported information was gathered through face-to-face computer-assisted home interviews and map-based questionnaire information collected in connection with laboratory measurements.

In this study, both cross-sectional and longitudinal study designs were used. A strength of this study was the possibility to study the associations of neighborhood walkability, walking difficulties and participation in leisure activities over a four-year follow-up. This study design allowed for the examination of changes over time in the frequency of participation in leisure activities among older adults residing in areas with different levels of walkability and experiencing different walking difficulties (Study I). However, the relatively small study sample in the longitudinal analyses may limit the generalizability of the results, and the findings should be interpreted with caution. Older adults' activity destinations at baseline in relation to the changes in autonomy over time were also studied (Study IV). This study also used cross-sectional analyses from which causality cannot be inferred.

Older adults' out-of-home mobility was studied from multiple perspectives using a variety of mobility measures: perceived walking difficulties, level of physical activity, participation in leisure activities, activity destinations visited and sense of autonomy. This study did not specifically examine time spent outdoors, transportation to destinations, or aspects of the social environment, all of which may have influenced activity behaviors among older adults. Both self-reported data on individual resources and activity destinations and objective data on environmental features were used in this study. However, both assessment types have their strengths and weaknesses. Walking difficulties were measured using a validated question to capture the early signs of walking disability (Mänty et al., 2007). Such efforts typically focus on the most demanding physical activities, such as walking longer distances (Mänty et al., 2007; Weiss et al., 2007). As the participants were in general healthy older adults, a two-kilometer distance was deemed suitable for studying walking difficulties in this group. Categorizing walking difficulties allowed us to identify those who reported no difficulties but had modified their walking. However, this study did not focus on what kinds of modifications were used. The use of walking modifications is considered an indicator of preclinical disability (Mänty et al., 2007). By identifying people in the preclinical stage who may be at higher risk of future disability, the need for preventive measures and interventions can be targeted.

Participants were asked, among other things, about their engagement in three different leisure activities commonly pursued in Finland. The questions provided a broad understanding of the outdoor leisure activities that interest older adults. However, it is possible that some individuals participated in activities other than those they were asked about. A further weakness of this study is that the location of these leisure activities is unknown. The level of physical activity was self-reported which may lead to overestimates of the amount of physical activity (Steene-Johannessen et al., 2016). Daily minutes of self-reported leisure walking and vigorous-intensity physical activity were combined to capture the total time spent doing at least moderate-intensity physical activity and then coded as higher and lower physical activity. However, this categorization may result in a loss of information. The YPAS questionnaire combines low-intensity and vigorous-intensity physical activity and is considered a valid measure of older adults' physical activity (Dipietro et al., 1993). In future studies, combining subjective and objective methods could provide more information on physical activity among older adults.

A map-based questionnaire was used to study the activity destinations, which older adults' had visited on several occasions during the past month. These methods allow the combination of qualitative data and objective geographic system data, and hence the study of individuals' perceptions and values regarding specific locations. The map-based data were combined with the AGNES participant data and objective open data. A map-based questionnaire has been validated among older adults (Hinrichs et al., 2020) and proven to be a feasible and cost-effective method with a low participant burden. The strength of this method is also its the inclusive approach, in which older adults have an active role in locating the places on the map. In this study, map-based questionnaires were also used to collect data on a variety of destinations and obtain a comprehensive picture of the places used by older adults, especially those that are important to them. However, the PPGIS method used in this study has some limitations. Answering the questionnaire requires a certain level of cognitive ability. Moreover, the accuracy of the locations may vary. To minimize inaccuracy, the participants located destinations on a map together with a research assistant. There is also the possibility of recall bias with self-reported measures, in the present instance regarding the destinations visited. Despite its weaknesses, the PPGIS method can be useful in urban planning and decision-making processes. Using PPGIS, participants can indicate locations of relevance in their daily lives, thereby helping planners to target policies and actions. Combining different types of data, as in this study, can thus provide a comprehensive picture of the environment in which older adults live and the factors that influence it.

This study used various objective measures to examine the environmental features of the neighborhood and surrounding destinations. Neighborhood walkability was measured using a walkability index consisting of three components: land use mix, street connectivity, and population density. This type of walkability index has been widely used. However, it has not been standardized and may not fully capture individuals' perceptions of their neighborhood's environment (Koohsari et al., 2015). Other limitations related to neighborhood factors are that this study did not account for neighborhood self-selection, meaning that individuals may have chosen to live in a particular neighborhood (Mokhtarian & Cao, 2008). In addition, older adults may have been exposed not only to environmental factors in the neighborhood but also to various other environmental factors outside their neighborhood, which could have biased the results (Kwan, 2018). Distance was measured using road network distances and Euclidean distances. The distance from home to a reported physical exercise destinations was measured using the Euclidean distance formula (Study III), which may underestimate actual distances (Shahid et al., 2009) but correlates well with driving distances (Boscoe et al., 2012).

6.4 Implications and future directions

The results of this study showed that the home environment, walking ability, and physical activity play crucial roles in determining out-of-home mobility. This means that it is essential to consider the opportunities and facilities offered by the local environment. Neighborhoods with a better outdoor mobility infrastructure may provide more opportunities for older adults to engage in leisure activities, visit different places, and run daily errands compared to neighborhoods with a poorer infrastructure. However, despite the presence of favorable environment, it seems according to the results of this study, that walking ability itself remains a significant factor influencing the amount of outdoor activity, places visited, and distances traveled by older adults. Hence, local environments should be designed to promote and support mobility, even when walking ability has declined. The current study showed that while walking difficulties can reduce outdoor mobility, both walking modifications and the environment can help maintain it. In turn, individual-related factors such as social support, goals, and opportunities may also influence outdoor mobility. The results of this study also revealed that older individuals continued to travel further away from home, even when their walking ability was reduced.

The findings further demonstrated that physical activity has a positive impact on the utilization of exercise facilities in different settings. This points to the importance of promoting physical activity among older individuals and creating environments that motivate people to stay active. The availability of different locations for exercise can draw older adults to engage in physical activity, providing these places are meaningful to them. Thus, the needs and preferences of older age groups should be considered in urban planning. Given that diversity in land use can increase the range of activities available to older adults, investment in diverse land use is crucial, especially in urban areas, including areas outside the immediate city center.

The use of a combination of different types of data can yield a more comprehensive understanding of older adults' mobility. For example, a map-based approach enables individuals to connect their subjective experience of specific places with their geographic location. This method enables the consideration of older adults' needs and preferences and hence a better understanding of their activity behaviors. By integrating objective methods with subjective experiences, relevant characteristics of the environment and their impact can be compared across different groups. It is important to note that as individuals' subjective views of the environment may vary, the different methods used do not negate one another.

The study findings suggest several interesting areas for future research. For example, future studies could investigate how individuals' environmental preferences and exposures and individual resources, like motivation and social support, influence their participation in activities and choice of destinations. Understanding these relationships could support healthy and active aging. Engaging in leisure activities and visiting different destinations has numerous health benefits. It is, therefore, essential to examine the impact of destinations and leisure activities on overall physical activity and other health outcomes. Future studies could also explore the relationship between the locations of leisure activities and the home environment. A map-based approach could offer a more comprehensive understanding of older adults' recreational environments, as such methods allow people to be involved in the research and planning of their own mobility environments. Studying older adults' activity destinations provides information on where they spend their time outdoors. Future research could clarify how many times a person visits the same destination and the duration of each visit. It would also be interesting to study how the destinations change over time. This study focused on the connections between environmental characteristics, individual resources, and outdoor activities. More research remains to be done on how different physical and social environmental factors, both subjective and objective, influence the visits to destinations of different groups of older adults. Greater understanding of the individual and environmental factors affecting out-of-home mobility may contribute importantly to planning of more supportive and age-friendly environments.

7 MAIN FINDINGS AND CONCLUSIONS

The main findings of this study are:

1. The older adults living in the highest walkability area had higher odds for frequent participation in cultural and individual activities and lower odds for frequent participation in outdoor activities than those living in the lowest walkability area. Intact walking was associated with frequent participation in all the leisure activities studied. These findings emphasize the importance of achieving a good balance between environmental amenities and individuals' functional abilities to engage in preferred leisure activities.

2. Better walking ability was linked to a higher number of physical exercise and attractive destinations and to such destinations located further away from home. The association between the number of destinations for regular destinations, distance to these destinations and walking difficulties was not statistically significant. The results suggest that despite developing walking difficulty, older individuals do not easily give up accessing to essential daily destinations.

3. The older adults reporting higher physical activity used a larger variety of physical exercise destinations, including destinations located in different types of land use, different types of sports facilities, and destinations located further away from home than those with reporting lower physical activity. These findings highlight the importance of the availability of physical exercise destinations in different environments, including neighborhood areas, for older adults to be physically active.

4. The older adults reporting a lower number of activity destinations and destinations located closer to home also reported a more restricted sense of autonomy in participation outdoors than those reporting a higher number of destinations and destinations further away from home.

Moreover, those who reported more diverse destinations had a better sense of autonomy than those who reported less diverse destinations. This finding highlights the importance in of urban planning of providing community amenities that enhance well-being.

SUMMARY IN FINNISH

Fyysinen ympäristö, aktiivisuuden paikat ja ulkona liikkuminen ikääntyessä

Iäkkäillä henkilöillä on useita syitä lähteä kotoaan, kuten osallistuminen erilaisiin vapaa-ajan aktiviteetteihin ja käynti itselle merkityksellisissä paikoissa. Aktiivinen elämäntapa auttaa yksilöitä säilyttämään itsenäisyytensä sekä kognitiivisen ja fyysisen toimintakykynsä. Se antaa heille myös mahdollisuuden olla sosiaalisesti aktiivisia. Useat yksilöön liittyvät tekijät sekä fyysisen ympäristön tekijät voivat edistää tai haitata osallistumista kodin ulkopuolella tapahtuvaan toimintaan. Tutkimusta on kuitenkin vähän, millaisissa ympäristöissä iäkkäät henkilöt liikkuvat ja kuinka yksilölliset ja ympäristötekijät vaikuttavat iäkkäiden ulkona liikkumiseen.

Tämän tutkimuksen tarkoituksena oli tutkia yksilöllisiä tekijöitä, ympäristön piirteitä ja aktiivisuuden paikkoja, jotka tukevat iäkkäiden henkilöiden aktiivisuutta ja liikkumista kodin ulkopuolella. Tutkimuksessa yhdistettiin osallistujien tietoja aktiivisuuskäyttäytymisestä ja karttapohjaisista paikoista sekä liikkumisympäristöjen maantieteellisiä ominaisuuksia.

Väitöskirjassa käytettiin kahden tutkimusprojektin aineistoja. Iäkkäiden ihmisten liikkumiskyky ja elinpiiri (LISPE) -tutkimukseen osallistui 848 kotona itsenäisesti asuvaa 75–90-vuotiasta henkilöä Jyväskylän ja Muuramen alueelta. Tutkimus toteutettiin vuonna 2012. Neljä vuotta myöhemmin Elinpiiri ja aktiivisena vanheneminen (MIIA) -tutkimukseen osallistui 206 LISPE-tutkimuksen osallistujaa. Aktiivinen vanhuus (AGNES) -tutkimukseen osallistui 901 kotona itsenäisesti asuvaa 75-, 80-, ja 85-vuotiasta henkilöä vuosina 2017–2018 ja sen jatkotutkimukseen osallistui 613 henkilöä vuosina 2021–2022. Kotihaastattelulla selvitettiin tutkittavien terveydentilaa, kognitiivista ja fyysistä toimintakykyä, itseraportoitua kävelykykyä, fyysisen aktiivisuuden tasoa, autonomian tunnetta ja osallistumista vapaa-ajan toimintoihin. Karttapohjaisen kyselyn avulla tarkasteltiin iäkkäiden henkilöiden aktiivisuuden paikkoja, jotka sisälsivät liikuntapaikkoja, liikkumiseen houkuttelevia paikkoja ja säännöllisiä arkiasioinnin paikkoja. Lähiympäristön käveltävyys, maankäyttö paikkojen ympärillä ja etäisyys paikkoihin määritettiin paikkatietoaineistojen avulla.

Tulokset osoittivat, että ikääntyneet henkilöt, jotka asuivat korkeimmalla käveltävyyden alueella, osallistuivat suuremmalla todennäköisyydellä säännöllisesti kulttuuri- ja yksintehtäviin aktiviteetteihin ja pienemmällä todennäköisyydellä ulkoilutoimintaan kuin ne henkilöt, jotka asuivat matalimman käveltävyyden alueella. Ikääntyneiden hyvä kävelykyky edisti heidän säännöllistä osallistumistaan kaikkiin tutkittuihin vapaa-ajan toimintoihin. Lisäksi henkilöt, joilla oli hyvä kävelykyky, raportoivat enemmän liikuntapaikkoja ja liikkumiseen houkuttelevia paikkoja sekä nämä paikat sijaitsivat kauempana kotoa kuin niillä henkilöillä, jotka kokivat kävelyvaikeuksia. Iäkkäiden henkilöiden kävelykyvyn taso ei ollut yhteydessä vierailtujen säännöllisten paikkojen määrään tai etäisyyteen. Kävelykyvyn lisäksi fyysisen aktiivisuuden taso oli yhteydessä liikuntapaikkojen määrään, etäisyyteen sekä millaisessa ympäristössä raportoidut liikuntapaikat sijaitsivat. Korkeamman fyysisen aktiivisuuden tason raportoivilla iäkkäillä henkilöillä oli enemmän liikuntapaikkoja ja ne sijaitsivat kauempana kotoa, kuin niillä, joilla oli matalampi fyysisen aktiivisuuden taso. Korkeampi aktiivisuustaso oli myös yhteydessä liikuntapaikkojen monipuoliseen käyttöön, ja ne sijaitsivat monenlaisilla maankäytön alueilla. Paikkojen lukumäärä yhdistyi myös autonomian tunteeseen. Tulosten mukaan ikääntyneillä henkilöillä, joilla oli matalampi paikkojen määrä ja ne sijaitsivat lähempänä kotoa, oli rajoittuneempi autonomian tunne kuin niillä henkilöillä, joilla oli korkeampi paikkojen lukumäärä ja jotka sijaitsivat kauempana kotoa. Paikkojen monipuolisuus oli yhteydessä korkeampaan autonomian tunteeseen.

Tutkimuksen tulokset osoittivat, että kotiympäristöllä, kävelykyvyllä ja fyysisellä aktiivisuudella on merkitystä kodin ulkopuolella liikkumisessa. Ympäristön tarjoamat mahdollisuudet ja liikkumista tukeva infrastruktuuri voivat tarjota ikääntyneille henkilöille mahdollisuuksia vierailla eri paikoissa, hoitaa päivittäisiä asioita sekä osallistua vapaa-ajan toimintoihin. Suotuisasta ympäristöstä huolimatta näyttää kuitenkin tämän tutkimuksen tulosten mukaan siltä, että kävelykyky itsessään on edelleen merkittävä tekijä, joka vaikuttaa ikääntyneiden osallistumiseen aktiviteetteihin ja paikoissa käymiseen. Yhdistämällä yksilön kokemuksia ja objektiivisia ympäristöaineistoja, voidaan saada monipuolinen kuva tekijöistä, jotka vaikuttavat iäkkäiden henkilöiden ulkona liikkumiseen. Tutkimusta vielä kaivataan siitä, kuinka erilaiset fyysisen ja sosiaalisen ympäristön tekijät vaikuttavat iäkkäiden ihmisten liikkumiseen sekä kuinka aktiivisuuden paikat muuttuvat ajan myötä.

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ORIGINAL PAPERS

I

NEIGHBORHOOD WALKABILITY, WALKING DIFFICULTIES, AND PARTICIPATION IN LEISURE ACTIVITIES AMONG OLDER PEOPLE: A CROSS-SECTIONAL STUDY AND 4-YEAR FOLLOW-UP OF A SUBSAMPLE

by

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Neighborhood Walkability, Walking Difficulties, and Participation in Leisure Activities Among Older People: A Cross-Sectional Study and 4-Year Follow-Up of a Subsample

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Abstract

Objectives: To study cross-sectional and longitudinal associations between objectively assessed neighborhood walkability, walking difficulties, and participation in leisure activities among older people. **Methods:** Self-reported 2 km walking difficulty (intact, modifications, difficulties) at baseline and participating in organized group, outdoor recreation and cultural activities at baseline and follow-up were studied in community-dwelling persons (*N* = 848) aged 75–90. A walkability index, calculated using a geographic information system, was categorized into tertiles (lowest, middle, highest). **Results:** Residence in the highest walkability areas was associated with higher participation in cultural activities and lower participation in outdoor recreation, while the latter was most frequently reported by residents in the lowest walkability areas. Those reporting no difficulties were more likely than those reporting difficulties to participate in all studied activities. Residence in the middle or highest walkability areas predicted higher participation in cultural activities at follow-up. **Discussion:** Older persons activity profiles associate with neighborhood walkability and walking difficulties.

Keywords

aging, walkability, walking difficulties, leisure activities, geographic information system

Introduction

Participating in meaningful leisure activities may provide pleasure, social support, artistic experiences, or a sense of being useful to others, all of which are essential elements of a fulfilling life, including in old age (Rantanen et al., 2021). Earlier research among older people has shown that participation in leisure activities is associated with higher well-being (Adams et al., 2011), better health behavior (Pollack and von dem Knesebeck, 2004), better quality of life (Adams et al., 2011; Silverstein and Parker, 2002), and decreased risk for functional limitations and mortality (Glass et al., 1999; Maier and Klumb, 2005). Leisure activities refer to activities which are pursued for enjoyment or well-being (Verghese et al., 2006) and not related to work or responsibilities of daily living (Verghese et al., 2006).

With increasing age, the match between a person's walking capacity and neighborhood amenities may become critical for going outside the home and attending activities further away (Skantz et al., 2020a, 2020b). The Selective optimization with compensation (SOC) model proposes that as people age, they must prioritize and optimize their resources to achieve goals while compensating their decreasing abilities (Baltes and Baltes, 1990). The Ecological model of aging by Nahemow & Lawton (1973) posits that an individual's ability to successfully complete an activity is influenced by the balance between their capabilities and the challenges presented by the environment. According to this model, older adults with fewer resources and declining

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capabilities are more vulnerable to challenges posed by the environment, which can impact their performance.

Research has shown that older adults with and without walking limitations may experience the same environmental features differently (Sakari et al., 2017; Vaughan et al., 2016; Yang and Sanford, 2012). Walking limitations and declining physical capacity increase individuals' vulnerability to challenging environmental features and reduce outdoor mobility (Laborde et al., 2022). Outdoor mobility, in turn, is necessary for participation in meaningful leisure pursuits, such as social, cultural, and physical activities (Leyden, 2003; Rantanen, 2013; Sallis, 2009). Outdoor mobility also supports good quality of life and health (Rantanen et al., 2021; Wahl and Weisman, 2003; Wiles et al., 2012). Older adults spend more time in their neighborhood environment than younger age groups (Levasseur et al., 2015). Consequently, the neighborhood environment may enhance or restrict older people's opportunities to be active outside the home (Sallis, 2009).

However, behavioral adaptations to the demands of their living environment may help older adults to continue engaging in valued activities (Laborde et al., 2022; Rantakokko et al., 2016; Skantz, Rantanen, Palmberg, et al., 2020). With increasing environmental pressure, older individuals may modify their walking to reduce its physiological demands rather than reducing it (Freedman et al., 2017; Nahemow and Lawton, 1973; Skantz, Rantanen, Palmberg, et al., 2020). The first modifications often concern the most challenging physical tasks, such as walking longer distances (Mänty et al., 2007; Weiss et al., 2007). While walking modifications, such as a slower walking pace, resting in the middle of walking, or using a walking aid, may help individuals continue walking to important destinations (Skantz, Rantanen, Palmberg, et al., 2020), they are often also the first signs of functional decline or preclinical disability (Fried et al., 2000). Mobility limitations, including fear of falling, the use of assistive devices (Nilsson et al., 2015) and difficulty walking (Hand and Howrey, 2019), as well as lower daily functional ability (Paillard-Borg et al., 2009; Strain et al., 2002), have been linked to reduced participation in leisure activities outside the home. Specifically, engaging in leisure activities that involve physical activity may be related to an individual's physical ability to perform such activities (Paillard-Borg et al., 2009; Pritchard et al., 2015).

Neighborhood walkability describes the environment's suitability for walking to different destinations. Walkability is often operationalized as three features, that is, land use, population density, and street connectivity (Frank et al., 2005; Lovasi et al., 2009). These are often combined to form a walkability index, with a higher value indicating better walkability (Frank et al., 2005). Walkable environments support older people's independence and mobility, give them an opportunity to maintain social networks, and promote their community engagement (Hassen and Kaufman, 2016). Earlier systematic review has found association between several environmental factors and community participation among older adults (Vaughan et al., 2016). Especially, factors related to walkability, such as high population density (Hand and Howrey, 2019), land use diversity (Beard et al., 2009), and proximity to destinations (Levasseur et al., 2011; Richard et al., 2013) have been associated with community participation and mobility outside the home. In addition, higher walkability has been found to be associated with higher physical activity among older adults (Portegijs et al., 2017; Saelens et al., 2003; Van Holle et al., 2014).

Thus far, only a few studies have focused on neighborhood walkability and participation in leisure activities (Vaughan et al., 2016), and no studies have explored the associations between neighborhood walkability, walking modifications and difficulties, and participation in leisure activities among older adults. While participation in leisure activities may be affected by environmental features, individual factors, such as functional limitations, also likely have a role. The aim of this study was to investigate (1) whether objectively assessed neighborhood walkability at baseline is associated with older adults' participation in leisure activities outside the home at baseline, (2) whether neighborhood walkability is associated with participation in leisure activities over a four-year follow-up, and (3) how walking difficulties are associated with participation in leisure activities among older people living areas differing in their walkability.

Methods

This study utilized baseline data gathered for a population-based study entitled "Life-space mobility in old age" (LISPE), which has previously been described in detail (Rantanen et al., 2012). Briefly, a random sample of 2 550 people was drawn from the Digital and Population Data Services Agency and informed about the study. Of these, 848 community-dwelling people aged 75–90 years and fulfilling the inclusion criteria took part. The inclusion criteria were living independently in the municipalities of Jyväskylä or Muurame in Central Finland, being able to communicate, and willingness to participate in the study. At the time of recruitment in 2012, Jyväskylä had about 133 500 inhabitants (the seventh largest city in Finland) and Muurame had about 9 500 inhabitants (Official Statistics of Finland, 2023). The two municipalities have a similar urban structure in which the city and subcenters form the service and residential areas, while the outlying areas vary in residential density. Participant data were collected from in-person at-home interviews in 2012. The LISPE participant data were linked with geographical data from a project entitled "Geographic characteristics, outdoor mobility and physical activity in old age" (GEOage). GEOage located the participants' home addresses at baseline on a map using the Digiroad dataset (Finnish Transport Agency, 2013) in Geographic Information System (GIS) software ArcMap 10.3 (Esri, Redlands, California, USA). Four years later, a random sample of 298 LISPE participants were invited to take part in the follow-up study MIIA. Of those invited, 77 declined to participate and 15 were not reached. The remaining 206 agreed to take part and thus supplied the four-year longitudinal data. When comparing the MIIA participants (n = 206) with the non-participants (n = 642) from the original LISPE cohort, there were no differences in terms of sex, number of chronic conditions, or years of education. However, the MIIA participants were found to be somewhat younger and had slightly better cognition and physical performance, as reported by Siltanen et al., (2019). This study combined and analyzed data on the participants and on their leisure activities and walking difficulties, using objectively defined neighborhood walkability.

The Ethical Committee of the University of Jyväskylä approved the study, which was conducted in accordance with the Declaration of Helsinki. Informed consents were obtained from all participants before the assessments.

Main Variables

Participation in Leisure Activities. Participation in leisure activities was self-reported. Activities requiring outdoor mobility were grouped by their social context (organized classes or group activities and clubs vs. individual or small group) (Rantanen et al., 2012) as follows: (1) organized group activities which included participation in class, group or club activities (e.g., choir, physical activity class or church activities); (2) outdoor recreation (e.g., fishing, berry-picking, walking the dog, or gardening); and (3) cultural or other individual activities, including participation in cultural events as a spectator and ad hoc activities (e.g., going to the theater, concerts or a coffee shop). For each question, the frequency response categories were: (1) daily or almost daily, (2) about once a week, (3) two to three times a month, (4) about once a month, (5) a few times a year, (6) rarely, and (7) never. For the cross-sectional and longitudinal analysis, participation frequency was dichotomized as frequently versus rarely based on the distribution and the type of the leisure activity. For outdoor recreation and organized group activities the category "frequently" was defined as participation at least once a week and for cultural or other individual activities at least once a month. The frequency response categories for leisure activities at follow-up were similar to those used at baseline.

Perceived Walking Difficulties. In the in-person interview, participants were asked "Do you have difficulty in walking 2 km?" The response categories were (1) able without difficulty, (2) able with some difficulty, (3) able with a great deal of difficulty, (4) unable without the help of another person, and (5) unable to manage even with help. To identify participants using walking modifications, participants who reported being able to walk two kilometers were asked an additional question: "Have you noticed any of the following changes when walking two km due to your health or physical functioning?". The walking modifications were walking slower, resting during walking, using an aid, having reduced the frequency of walking, and having given up walking distances of two kilometers. For each modification, the participant reported whether they were using that modification (yes/no). For the analyses, participants were categorized into three groups: (a) intact walking (reporting no difficulties or modifications), (b) walking modifications (reporting no difficulty and ≥1 modification), and (c) walking difficulty (reporting at least some difficulty).

Neighborhood Walkability. A walkability index, modified from Frank et al. (2004), was created in the GIS. The walkability index, which consisted of land use mix, street connectivity and population density, was calculated within a radius of one kilometer from the participant's home (Portegijs et al., 2017). The land use mix describes the heterogeneity in the distribution of land use types within the one km circular buffer area (dry land area only) around the participant's home (Portegijs et al., 2017). Residential areas, services, sport and leisure facilities, and forest and semi-natural areas (built and natural green spaces), were considered in defining the land use mix value (Finnish Environment Institute, 2012). Street connectivity was quantified as the number of intersections along walkable ways within a one-km buffer zone around the home (Finnish Transport Infrastructure Agency, 2013). Only three- or more-way intersections were included and street intersections within 10 m of each other were merged for the calculations. The road network analysis only included walkable ways and thus excluded motorways, trails, winter roads, railroads and ferries over water were excluded from the road network. Population density was defined as the absolute number of residents in the one-km squares of the study areas in which the participants resided (Official Statistics of Finland, 2011). To obtain the walkability index, z-scores were calculated for land use mix, street connectivity, and population density, and summed. Higher index scores indicate better walkability. For the analyses, walkability was categorized into tertiles as lowest, middle, and highest.

Covariates

Based on previous studies, variables considered likely to correlate with the independent and dependent variables were included as covariates. Participants' age and sex were obtained from the Digital and Population Data Services Agency as part of participant recruitment. During the home interview, participants were asked to report their total number of years of education. Years of education was used as an indicator of socioeconomic status. The number of self-reported physician-diagnosed chronic diseases was collected using a list of 22 chronic conditions and an open-ended question. Cognitive function was assessed using the Mini-Mental State Examination (MMSE) (Folstein et al., 1975). The MMSE contains 30 items and scores ranges from 0–30. A higher score indicates better function.

Statistical Analyses

Descriptive characteristics of the participants were compared between those living in the three different neighborhood walkability areas, using Kruskall–Wallis test or Chi-square test, depending on variable distribution. Similarly, participant characteristics were reported as medians and interquartile ranges (IQR) or as percentages. Logistic regression models were used to calculate odds ratios (OR) and 95% confidence intervals for participation in leisure activities at baseline and at the four-year follow-up. Cross-sectional binary logistic regression models were conducted with leisure activity categories as dependent variables and neighborhood walkability and walking difficulties and their interaction as independent variables. Three models were constructed for the cross-sectional and longitudinal analyses for each leisure activity category. In the cross-sectional analyses, the first model tested the association between walkability and participation in a leisure activity (Model 1). To test the role of walking difficulties, it was added to the model (Model 2). Finally, years of education, MMSE score, and number of chronic conditions were added to the model (Model 3). All models were adjusted for age and sex. In addition, the interaction between walkability and walking difficulties was tested and the analyses were adjusted for age, sex, years of education, MMSE score, and number of chronic conditions.

In the longitudinal regression models, participation frequency in leisure activities at follow-up was regressed on neighborhood walkability and perceived walking difficulties at baseline. In the first model, we tested how walkability predicted frequent participation in a leisure activity at follow-up (Model 1). In the second model, we included walking difficulties in the analyses (Model 2) and in the final model (Model 3) we added years of education, MMSE score, and number of chronic conditions. All models were adjusted for age and sex. Finally, sensitivity analyses were conducted to check whether potential changes in the participants' living environment due to a permanent move affected any associations found. During follow-up, nine participants moved but only for three participants walkability area changed. The results remained similar after excluding these three participants from the analyses (data not shown). SPSS Statistics for Windows (version 26.0; IBM Corp, Armonk, NY, USA) was used for all statistical analyses and statistical significance was set at $p < .05$ in all tests.

Results

Participant Characteristics

Characteristics of the full baseline sample and subsample are presented in Table 1. In the full baseline sample, participants living in the lowest walkability area were younger ($p = .003$), had a lower MMSE score ($p < .001$), had a lower level of education ($p < .001$), were more often men ($p = .001$) and more rarely participated in cultural or other individual activities outside the home ($p = .026$) than participants living in the middle or highest walkability areas. Of the 848 baseline participants, 206 participated in the follow-up four years later. At baseline, the subsample participants were younger and had a higher level of education, higher MMSE score, and fewer chronic diseases at the baseline than those who did not participate in the four-year follow-up. No differences were observed between the subsample participants living in the different walkability areas.

Cross-Sectional Associations of Neighborhood Walkability and Walking Difficulties With Participation in Leisure Activities

The logistic regression analyses (Table 2) revealed non-significant association between walkability and participation frequency in organized group activities. In Model 1, no statistically significant association was observed between walkability and participation in outdoor recreation. After controlling for the prevalence of walking difficulties, those living in the highest walkability index areas had lower odds for frequent participation in outdoor recreation than those in the lowest walkability areas (OR .61, 95% CI .40–.94). The association remained statistically significant after adjusting for the covariates (OR .60, 95% CI .39–.94). In Model 1, participants living in the highest (OR 1.65, 95% CI 1.15–2.38) or middle (OR 1.47, 95% CI 1.02–2.11) walkability areas were more likely to be frequent attendees at cultural or other individual activities than those living in the lowest walkability area. After controlling for walking difficulties, the associations weakened somewhat but remained statistically significant. Further adjustment for covariates attenuated the odds ratios and the associations became nonsignificant. Those with intact walking and walking modifications attended all the studied leisure activities more often than those with walking difficulties.

For the interaction analyses, we formed nine groups based on the combined distribution of walking difficulty and the three neighborhood walkability areas and assigned the participants with walking difficulties living in the lowest walkability tertile as the reference group. Figure 1 presents the fully adjusted odds ratios for frequent participation in leisure activities. Individuals with walking difficulties consistently had the lowest odds for frequent participation in any activity regardless of their neighborhood walkability tertile.

Table 1. Baseline Descriptive Characteristics by Walkability Tertiles at Baseline for the Full Baseline Sample (*n* = 848) and Subsample (*n* = 206).

	All at Baseline (*n* = 848)				Subsample at Baseline (*n* = 206)			
	Lowest Tertile *n* = 282	Middle Tertile *n* = 284	Highest Tertile *n* = 282		Lowest Tertile *n* = 74	Middle Tertile *n* = 70	Highest Tertile *n* = 62	
	Median (IQR)	Median (IQR)	Median (IQR)	*p*-Value	Median (IQR)	Median (IQR)	Median (IQR)	*p*-Value
Age (years)	79.9 (6.7)	79.7 (7.4)	81.3 (7.7)	**.003**[a]	79.9 (5.8)	79.3 (8.5)	80.5 (8.0)	.553[a]
Chronic conditions (*n*)	4.0 (3.0)	4.0 (3.0)	4.0 (3.3)	.987[a]	4.0 (3.0)	4.0 (3.3)	4.0 (4.0)	.610[a]
MMSE score	26.0 (4.0)	27.0 (3.8)	27.0 (3.3)	**<.001**[a]	27.0 (3.0)	27.0 (3.0)	27.0 (2.0)	.551[a]
Education (years)	8.0 (5.0)	9.0 (5.0)	9.0 (7.0)	**<.001**[a]	8.0 (5.0)	10.0 (5.0)	9.0 (5.0)	.105[a]
	% (*n*)	% (*n*)	% (*n*)		% (*n*)	% (*n*)	% (*n*)	
Men (%)	46.8 (132)	35.6 (101)	31.6 (89)	**.001**[b]	54.1 (40)	41.4 (29)	33.9 (21)	.055[b]
Walking difficulties (%)	—	—	—	.804[b]	—	—	—	.876[b]
Intact walking	30.5 (86)	31.3 (89)	28.0 (79)		31.1 (23)	37.1 (26)	35.5 (22)	
Walking modifications	27.7 (78)	26.1 (74)	30.5 (86)		31.1 (23)	28.6 (20)	33.9 (21)	
Walking difficulties	41.8 (118)	42.6 (121)	41.5 (117)		37.8 (28)	34.3 (24)	30.6 (19)	
Participation in leisure activities	—	—	—	—	—	—	—	—
Organized group activities (% at least once weekly)	40.1 (113)	43.5 (123)	46.5 (131)	.310[b]	44.6 (33)	47.8 (33)	53.2 (33)	.602[b]
Outdoor recreation (% at least once weekly)	81.1 (228)	78.2 (222)	73.0 (206)	.067[b]	83.8 (62)	82.9 (58)	83.9 (52)	.984[b]
Cultural or other individual activities (% at least once monthly)	27.0 (76)	35.2 (100)	37.0 (104)	**.026**[b]	28.4 (21)	47.1 (33)	42.6 (26)	.055[b]

Note. Statistically significant *p*-values are bolded. Bold values indicate $p < .05$. IQR = interquartile range; MMSE = mini-mental state examination [a]Kruskall–Wallis test, [b]Chi-square test.

For most activities, frequent attendance was most likely among those with intact walking and intermediate attendance among those with walking modifications. There were two exceptions to this: in the lowest walkability areas those with walking modifications had the highest odds for frequent participation in organized group activities, and in the middle walkability areas those with walking modifications had the highest odds for frequently attending cultural or other individual activities. Figure 1 also shows that the odds for frequent participation in outdoor recreation were the highest in the lowest walkability areas. In all, many of the 95% confidence intervals in Figure 1 overlap, indicating a need for interpretive caution.

Longitudinal Associations of Neighborhood Walkability and Walking Difficulties With Participation in Leisure Activities

No statistically significant associations between neighborhood walkability and frequent participation in organized group activities were observed at follow-up (Table 3). Living in a middle walkability neighborhood increased the odds for frequent participation in outdoor recreation at follow-up in the age- and sex-adjusted model (OR 2.79, CI 1.04–7.50) and in the fully adjusted model (OR 2.92, 95% CI 1.03–8.30). However, after adding walking difficulties into Model 2, the association was attenuated to borderline of significance. Older people living in the middle (OR 3.35, CI 95% 1.51–7.40) or highest (OR 3.42, 95% CI 1.52–7.23) walkability neighborhoods had higher odds for frequent participation in cultural or other individual activities compared those living in the lowest walkability neighborhood. The associations were somewhat attenuated but remained significant in all models. Intact walking at the baseline was associated with frequent participation in cultural or other individual activities (OR 2.85, CI 95% 1.24–6.51) and outdoor recreation (OR 2.92, CI 95% 1.01–8.52) at the four-year follow-up in the age- and sex-adjusted models. After adjusting with covariates, the association between intact walking and participation in cultural or other individual activities remained statistically significant whereas the association between intact walking and participation in outdoor recreation became nonsignificant.

Table 2. Cross-Sectional Logistic Regression Analyses on Neighborhood Walkability and Frequent (vs. Rare) Participation in Leisure Activities at Baseline (n = 848).

	Organized Group Activities						Outdoor Recreation						Cultural or Other Individual Activities					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Walkability tertile																		
Highest	1.26	.90–1.78	1.22	.87–1.74	1.07	.74–1.53	.70	.47–1.06	**.61**	**.40–.94**	**.60**	**.39–.94**	**1.65**	**1.15–2.38**	**1.62**	**1.12–2.35**	1.34	.91–1.97
Middle	1.10	.79–1.56	1.10	.78–1.55	1.04	.72–1.47	.87	.57–1.31	.82	.53–1.27	.82	.53–1.27	**1.47**	**1.02–2.11**	**1.46**	**1.01–2.11**	1.38	.95–2.00
Lowest	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—
Walking difficulties																		
Intact walking			**2.07**	**1.45–2.95**	**2.43**	**1.64–3.58**			**5.97**	**3.58–9.92**	**6.23**	**3.65–10.64**			**2.93**	**2.01–4.26**	**2.83**	**1.88–4.26**
Walking modifications			**1.73**	**1.23–2.45**	**1.91**	**1.33–2.75**			**3.59**	**2.33–5.53**	**3.68**	**2.37–5.73**			**1.73**	**1.19–2.52**	**1.69**	**1.14–2.49**
Walking difficulties			1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—
Men (vs. women)	**.69**	**.52–.92**	**.63**	**.47–.84**	**.63**	**.47–.86**	1.18	.84–1.68	.96	.67–1.39	.96	.93–1.01	.82	.60–1.11	**.72**	**.53–.99**	**.67**	**.48–.93**
Age	.977	.95–1.01	1.00	.96–1.04	1.01	.97–1.05	**.92**	**.89–.96**	.97	.93–1.01	.97	.93–1.01	**.95**	**.92–.98**	.98	.95–1.02	.99	.96–1.04
Years of education					1.02	.98–1.06					1.01	.97–1.06					**1.06**	**1.02–1.11**
MMSE score					**1.09**	**1.03–1.15**					.98	.91–1.05					**1.06**	**1.00–1.13**
Number of chronic conditions					**1.09**	**1.03–1.16**					1.03	.95–1.01					1.02	.95–1.09

Note. Values in bold; if the 95% CI does not contain the value 1, $p < .05$. OR = odds ratio, CI = confidence interval, MMSE = mini-mental state examination.

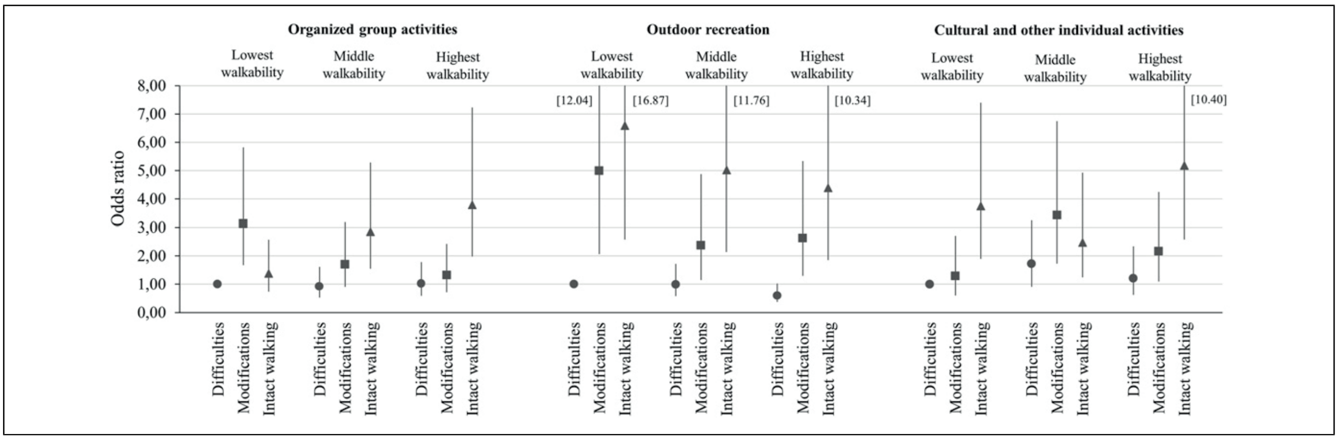

Figure 1. The odds for frequent (vs. rare) participation in leisure activities at baseline by interaction of neighborhood walkability and perceived walking difficulties (n = 848).

Discussion

Engagement in leisure activities differed between the participants living in the three different walkability living areas. The present findings showed that living in the highest walkability area, such as the city center, was associated with frequent participation in cultural or other individual activities but with lower participation in outdoor recreation. Participants with intact walking or using walking modifications were more likely than those with walking difficulties to participate frequently in leisure activities. In the four-year follow-up, living in a middle or the highest compared to the lowest walkability area predicted higher participation in cultural or other individual activities.

Previous studies have found an association between walkability and community participation, defined as leisure and social activities engaged in outside the home (Vaughan et al., 2016). In this study, older people living in the highest walkability area participated more frequently in cultural or other individual activities such as going to concerts, the theater, or coffee shops. In line with cross-sectional associations, living in the highest walkability area was associated with frequent participation in cultural or other individual activities over the four-year follow-up. Our results may be explained by better access to services and cultural activities in the highest walkability neighborhoods. Neighborhood walkability describes living environments assessed based on residents' ability to walk to destinations and services (Sallis et al., 2006). Areas such as city centers are typically high walkability neighborhoods as they may offer more services and a wide variety of cultural activities, and hence a greater likelihood of the availability of preferred activities. Access to services may motivate older adults to go out of home and be physically active (Barnett et al., 2017). The present results support those of a previous study which found that neighborhood factors, such as proximity to services and amenities was associated with higher participation of older adults in social activities, such as attending a cultural or sports event or going to a café (Richard et al., 2009).

Our study showed that living in the highest walkability area was associated with lower participation in outdoor recreation. Outdoor recreation typically occurs in natural settings and hence nature and green areas are important for restorative experiences (Andkjær and Arvidsen, 2015; Hinrichs et al., 2019; Keskinen et al., 2018). In our study, outdoor recreation included nature-based activities such as fishing and berry-picking, and other outdoor activities such as gardening and walking the dog. Nature areas may motivate older people to go outdoors and be physically active (Keskinen et al., 2018; Rantakokko et al., 2015). A previous study among older adults showed that lower walkability was associated with higher odds of reporting gardening (King et al., 2017). Outdoor activities, such as gardening, may be relevant in areas of lower walkability with lower residential density and fewer destinations (King et al., 2017). Moreover, these activities may be closer to home.

Previous research has found an association between walkability measures, such as population density, and participation in club activities but not between population density and volunteering or attending meetings of organizations (Hand and Howrey, 2019). However, we found nonsignificant associations between neighborhood walkability and participation in organized group activities, including classes and club activities. It may be that such activities are equally available around municipality, or that participation in organized activities is more dependent on individuals than on environmental features (Hand and Howrey, 2019).

The current findings accord with those of previous studies showing that walking difficulties are associated with lower participation in leisure activities (Hand and Howrey, 2019; Siltanen et al., 2021). In our study, those with intact walking or walking modifications had higher odds of participating frequently in leisure activities than those with walking

Table 3. Longitudinal Logistic Regression Analyses on Neighborhood Walkability and Frequent (vs. Rare) Participation in Leisure Activities at Follow-Up (n = 206).

	Organized Group Activities						Outdoor Recreation						Cultural or Other Individual Activities					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Walkability tertile																		
Highest	1.74	.86–3.54	1.61	.79–3.31	1.48	.71–3.08	1.75	.70–4.39	1.49	.58–3.79	1.37	.53–3.55	**3.42**	**1.52–7.23**	**3.24**	**1.41–7.43**	**2.96**	**1.25–7.02**
Middle	.79	.39–1.62	.73	.36–1.51	.72	.35–1.49	**2.79**	**1.04–7.50**	2.59	.95–7.08	**2.92**	**1.03–8.30**	**3.35**	**1.51–7.40**	**3.12**	**1.39–7.00**	**2.93**	**1.26–6.79**
Lowest	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—
Walking difficulties																		
Intact walking			2.12	.99–4.56	1.86	.81–4.27			**2.92**	**1.01–8.52**	2.86	.90–9.13			**2.85**	**1.24–6.51**	**2.83**	**1.10–7.28**
Walking modifications			1.47	.69–3.12	1.34	.62–2.93			1.87	.74–4.74	1.86	.70–4.92			1.43	.62–3.32	1.36	.55–3.38
Walking difficulties			1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—	1.00	—
Men (vs. women)	.91	.50–1.66	.80	.43–1.49	.77	.41–1.46	1.15	.51–2.60	.97	.42–2.27	.85	.35–2.03	.86	.45–1.64	.70	.35–1.39	.64	.31–1.32
Age	.96	.89–1.03	.98	.90–1.06	.98	.90–1.06	**.84**	**.76–.93**	**.87**	**.79–.97**	**.88**	**.79–.98**	**.92**	**.85–.99**	.94	.87–1.03	**.93**	**.85–1.02**
Years of education					1.00	.94–1.08					1.06	.96–1.17					1.01	.93–1.09
MMSE score					1.05	.91–1.21					.94	.79–1.12					**1.32**	**1.10–1.60**
Number of chronic conditions					.99	.87–1.13					.98	.83–1.15					1.03	.88–1.19

Note. Values in bold; if the 95% CI does not contain the value 1, p < .05. OR = odds ratio, CI = confidence interval, MMSE = mini-mental state examination.

difficulties. In addition, the older people reporting intact walking at baseline were also more likely to participate frequently in cultural or other individual activities four years later. Mobility limitations directly hinder going out or going further away from home and may eventually increase dependence on needed transportation. Among older people with mobility limitations, transportation is among the most common unmet needs that reduce access to out-of-home activities. (Casado et al., 2011; Shandra, 2021). Individuals are likely to choose activities that are suited to their physical capacity. According to the model of selection, optimization and compensation, older people need to select goals, optimize their resources to achieve those goals, and compensate to maintain functioning (Baltes and Baltes, 1990). Older adults may maintain their way of living by optimizing their mode of action when they start experiencing a decline in their mobility (Saajanaho et al., 2015; Siltanen et al., 2020). In line with this, we found in our earlier study that using modifications, such as assistive devices and slowing down the pace of walking, may help to maintain greater life-space mobility and autonomy in participation outside the home (Skantz, Rantanen, Palmberg, et al., 2020).

Features of the built environment may affect how older adults with mobility limitations experience their surroundings and are able to participate in activities outside the home (Hand and Howrey, 2019). The ecological model of aging highlights that older adults with declining capabilities are more vulnerable to challenges posed by the environment, which can impact their activity (Nahemow and Lawton, 1973). Older adults' living environment may be an especially important factor for their outdoor participation (Rasinaho et al., 2007). A previous study reported that those with walking difficulties and living in areas of low residential density were less likely to participate in social activities outside the home (Hand and Howrey, 2019), a finding corroborated by our study. Infrastructural mobility barriers, such as poor street conditions, lack of resting places and long distances may restrict older adults' outdoor mobility (Rantakokko et al., 2015). Living in a high walkability area, such as a city center, may especially support the outdoor mobility of those with walking modifications. Our study suggests that walking modifications may enable more frequent participation in leisure activities irrespective of neighborhood walkability. Environment may provide opportunities to participate in different leisure activities, but also older people may move living areas which offer pleasant activities and support their physical functioning.

The strengths of this study include a large population-based sample of people over age 75 and very little missing information. Moreover, subjective participant data were studied in relation to objective geographical data. A further strength is the longitudinal component with 4-year follow-up data on leisure participation frequency. As the participants were in relatively good health, the results cannot be generalized to community-dwelling adults with poor functioning. Additionally, the rather small study sample in the longitudinal analyses may limit the generalizability of the results and the results should be interpreted with caution. Neighborhood walkability was objectively assessed using data derived from open data sources. A walkability index, although widely used, may not fully reflect individuals' perspectives on their neighborhood's environment (Portegijs et al., 2017).

Conclusions and Future Directions

The present findings suggest that walk-friendly environments may provide opportunities for participation in cultural activities. Participation in cultural activities may be influenced by the availability of and distance to services whereas individual factors, such as mobility limitations, may be more meaningful in activities directly related to physical functioning. Walking modifications may maintain older adults' involvement in community activities when the environmental features supporting participation are present. It would be important to identify older adults experiencing the first signs of functional decline and find ways to keep them engaged in activity. Future studies could consider how personal environmental preferences and individual resources, such as motivational factors, affect participation and how different environmental factors support participation. In addition, it would be interesting to know more about the locations of leisure activities in relation to the home and its environment. In sum, leisure activities outside the home foster positive experiences and may help with maintaining fitness in old age, thereby underlining the importance of a achieving a good balance between environmental amenities and a individuals' interests and functional abilities.

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Declaration of Conflicting Interests

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Ethical Approval

The Ethical Committee of the University of Jyväskylä approved the study, which was conducted in accordance with the Declaration of Helsinki.

Informed Consent

Informed consents were obtained from all participants before the assessments.

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II

ASSOCIATIONS BETWEEN WALKING LIMITATIONS AND REPORTED ACTIVITY DESTINATIONS AMONG OLDER ADULTS

by

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ORIGINAL INVESTIGATION

Associations between walking limitations and reported activity destinations among older adults

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Abstract
In old age, walking difficulty may reduce opportunities to reach valued activity destinations. Walking modifications, e.g., slower pace or using a walking aid, may enable individuals to continue going where they wish, and hence postpone the consequences of the onset of walking difficulties. We studied visited activity destinations (type, distance) among older people with varying degrees of walking limitations. Community-dwelling 75–85-year-old people living in Jyväskylä ($N = 901$) were asked to state whether they had no difficulty walking 2 km, had modified their walking, or had difficulty walking. On a digital map, participants located physical exercise, attractive, and regular destinations they had visited during the past month. Destination counts and median distance to destinations from home were computed. Participants with intact walking reported higher counts of physical exercise (IRR = 1.45, 95% CI [1.31, 1.61]) and attractive destinations (IRR = 1.23, 95% CI [1.10, 1.40]) than those with walking difficulty and also visited these destinations further away from home than the others ($b = 0.46$, 95% CI [0.20, 0.71]). Those with walking modifications reported higher counts of physical exercise destinations than those with walking difficulty (IRR = 1.23, 95% CI [1.09, 1.40]). Counts of regular destinations and distance traveled were not associated with walking limitations. Walking modifications may help people with walking difficulty reach destinations further away from home, potentially contributing to their sense of autonomy. For those with walking difficulty, a low count of destinations other than regular destinations, e.g., shops or healthcare facilities, may signal their abandonment of recreational activities and a decrease in their life space, potentially leading to reduced well-being.

Keywords Mobility limitation · Activity destination · Aging · Participation · Built environment · Spatial mobility

Introduction

Mobility outside the home is important for healthy aging and the maintenance of older adults' independence (Satariano et al. 2012). Mobility refers to the ability to move within one's community environments either independently or by using assistive devices or vehicles (Webber et al. 2010). The most common reasons for older people making regular trips outdoors are running daily errands, shopping, walking, and meeting other people (Davis et al. 2011; Tsai et al. 2016; Chudyk et al. 2015). Visiting different destinations may increase daily physical activity (Tsai et al. 2016; Portegijs et al. 2015), maintain functional capacity and mobility, and enhance quality of life among older adults (Satariano et al. 2012).

The socio-ecological model posits that individual, social, and environmental factors influence older people's possibilities to be active outside the home (Sallis et al. 2006; Chudyk et al. 2015). Functional decline may increase older people's

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risk of developing walking difficulties and hence reduce their possibilities to participate in activities outside the home (Verbrugge and Jette 1994; Hoenig et al. 2006; Freedman et al. 2017; Rantakokko et al. 2009; Leppä et al. 2021) and carry out essential activities of daily living (Sugiyama et al. 2018). The most common reason preventing older people from engaging in outdoor activities is difficulty in walking (Wilkie et al. 2007). Walking limitations have been associated with decreased participation in leisure activities outside the home (Hand and Howrey 2019; Tuomola et al. 2023). Decreasing walking abilities also render older adults more vulnerable to environmental factors (Portegijs et al. 2017).

According to the ecological model of aging, walking abilities can be maintained by reducing task demands, increasing personal capacity, or lowering environmental demands (Lawton and Nahemow 1973). Older adults may modify their walking behavior when environmental demands increase relative to their physiological capacity (Freedman et al. 2017; Skantz et al. 2020a, b). The selective optimization with compensation (SOC) model proposed by Baltes and Baltes (1990) takes a similar approach. According to the model, older people need to select goals, optimize their resources to achieve those goals, and compensate for their reduced abilities to maintain functioning (Baltes and Baltes 1990). When older adults start experiencing a decline in their walking stamina, they may optimize their mobility by modifying their way of walking (Saajanaho et al. 2015; Siltanen et al. 2020). Such modifications, including walking at a slower pace, resting in the middle of walking, or using assistive devices, may help individuals continue walking to important destinations, at least in the earlier phases of physical capacity decline (Rantakokko et al. 2016; Skantz, Rantanen, Palmberg, et al. 2020). Thus, adaptive walking modifications often are the first signs of functional decline or preclinical disability (Fried et al. 2000).

The neighborhood environment may offer multiple destinations, such as shops and other commercial destinations, parks and other public open spaces, and recreational facilities that support older adults' outdoor mobility (Sugiyama et al. 2012; Barnett et al. 2017). Such destinations provide opportunities for older people to be both physically active and interact with other people (Van Cauwenberg et al. 2018; Chaudhury et al. 2016; Nathan et al. 2012). Several studies have found that having walkable destinations in their neighborhood not only motivates older adults to walk (Nathan et al 2012; Gauvin et al. 2012; Barnett et al. 2017) and be physically active (King 2008; Barnett et al. 2017), but also slows down the development of walking difficulties (Eronen et al. 2013; Sugiyama et al. 2018). It is noteworthy that the type of destination may also influence the distance individuals are ready to travel (McCormack et al. 2006).

Online participatory mapping methods, such as the Public Participation Geographic Information System (PPGIS), provide an affordable and user-friendly way to examine the relationship between individuals and their environment (Laatikainen et al. 2018). The PPGIS allows researchers to collect information from a large group of individuals while minimizing the burden on participants (Hasanzadeh et al. 2017; Laatikainen et al. 2018; Portegijs et al. 2020; Schmidt et al. 2018). Previous studies have shown that PPGIS can achieve reasonable spatial accuracy when mapping physical features of the environment (Brown and Kyttä 2014) and validity in measuring frequently visited destinations and distance-related features (Hinrichs et al. 2020; Shareck et al. 2013). Locating destinations on a map has shown acceptable usability among older adults (Gottwald et al. 2016). Map-based questionnaires can provide information on people's destinations and the locations in which they move (Kestens et al. 2017) and on their motives to visit specific destinations (Portegijs et al. 2021). Self-reports can yield information about personally meaningful environmental features (Portegijs et al. 2020). Map-based questionnaires allow investigation of older adults' spatial behavior (Laatikainen et al. 2018) and the precise distances to their activity destinations (Portegijs et al. 2020).

We know relatively little about activity destinations that support older adults' activity behavior outside the home, especially those of older adults with different kinds of walking limitations. The purpose of this study was to gain an understanding of how people in the earlier (preclinical walking modifications) and later (manifest difficulty walking) phases in the walking disablement process are reporting different activity destinations compared to those with intact walking ability. Hence, this study explored the associations of older adults' walking limitations with destination counts and distances to activity destinations. Data on activity destinations were obtained with the PPGIS questionnaire and included regular destinations, physical exercise destinations, and attractive destinations.

Methods

This study forms part of the Places of Active Aging project which links participant data on the "Active aging—resilience and external support as modifiers of the disablement outcome" (AGNES) study with map-based data. As described previously, the AGNES baseline data were collected during 2017–2018 (Rantanen et al. 2018). A random sample of community-dwelling 75-, 80-, and 85-year-old adults living in the city of Jyväskylä in Central Finland was drawn from the Digital and Population Data Services Agency in Finland (Rantanen et al. 2018). The inclusion criteria for the study were living in the study area and being community-dwelling, willingness to participate, and the ability to communicate and provide an informed consent. All participants lived in

Jyväskylä, a medium sized city with 141 305 inhabitants (Official Statistics of Finland 2023). Our study area has small hills and quiet residential streets, with some busier streets intersecting them. City and subcenters form the service and residential areas and most of the shops and other services are concentrated in the city center. A total of 1 018 respondents participated in structured home interviews (Rantanen et al. 2018), of whom 908 participated in physical assessments in the research center, including a map-based assessment of their perceived environment. Of the participants in the map-based assessments, 901 located their activity destinations on a digital map with the assistance of an interviewer (Portegijs et al. 2021). Participants' home addresses were also located on a map using the Digiroad dataset (Finnish Transport Infrastructure Agency 2019) in Geographic Information System (GIS) software ArcMap 10.6.1 (Esri Inc.). Participants had better health and mobility than nonparticipants (Portegijs et al. 2019). The study was conducted in accordance with the Declaration of Helsinki. The Ethical Committee of the Central Finland Health Care District approved the study. All participants gave their written informed consent at the start of the home interview.

Main variables

Walking limitations were assessed based on self-reported walking difficulties and walking modifications. In the in-person interview, participants were asked the question "Do you have difficulty walking 2 km?". The response categories were (1) able without difficulty, (2) able with some difficulty, (3) able with a great deal of difficulty, (4) unable without the help of another person, and (5) unable to manage even with help. To identify participants using walking modifications, participants who reported being able to walk two kilometers without difficulty (response category 1) were asked an additional question: "Have you noticed any of the following changes when walking two kilometers due to your health or physical functioning?" The walking modifications listed were walking slower, using an aid, resting during walking, reduced the frequency of walking, and given up walking distances of two km. For each modification option, participants indicated whether they were using that modification (yes/no). For the analyses, participants were categorized into three groups: (a) intact walking (reporting neither difficulty nor modifications), (b) walking modifications (reporting no difficulties and ≥ 1 modification), and (c) walking difficulty (reporting at least some difficulty).

A map-based internet questionnaire on *activity destinations* was administered using the interactive online Maptionnaire® tool (Mapita LTD). Participants were asked to locate on a map three types of activity destinations which they had visited several times during the past month. These predefined activity destination types were 1) destinations for physical exercise, 2) destinations regarded as attractive for other out-of-home activity, and 3) destinations for regular activities (not related to physical exercise). Physical exercise destinations included outdoor and indoor sports facilities and outdoor recreational areas. Attractive destinations included destinations which served as motivators for older people to engage in out-of-home activities (other than physical exercise), such as nature settings, lakeside areas, services, and events, places to rest and other infrastructure-related places. Regular destinations included essential destinations, e.g., grocery stores and other shops, food and health services, and destinations for self-selected activities such as organized activities and social visits.

To reflect diversity in destinations for each participant, the reported number of physical exercise, attractive, and regular destinations was counted for each respective category and summed to yield a total count of activity destinations. Distances between participants' homes and their reported destinations were computed as road network distances (expressed in meters) using the Digiroad dataset (Finnish Transport Infrastructure Agency 2019). For technical reasons, distances to 19 destinations (e.g., an island or abroad) were defined manually using Google Maps. The median distance was calculated for all reported activity destinations combined as well as separately for each activity destination type.

Covariates

Age, sex, perceived financial situation, years of education, cognitive function, regular driving, and residential density were used as covariates in the analyses based on existing knowledge of variables that correlate with out-of-home mobility. Participants' age and sex were drawn from the Digital and Population Data Services Agency in the context of their recruitment. Perceived financial situation and years of education, which were used as indicators of socio-economic status, were obtained during the home interview. Participants were asked to rate their perceived financial situation on a four-point scale ranging from very good to poor, and responses were recoded as "good to very good" versus "poor to fair." Educational level was self-reported as years of full-time education. Cognitive function was measured using the Mini-Mental State Examination during the home interview (MMSE; Folstein et al. 1975). The MMSE score ranges from 0 to 30, with a higher score indicating better function. Regular driving was assessed with the question "How often do you drive a car yourself?" For the analyses, driving a car was divided into two groups: driving regularly (daily or weekly) versus driving rarely (monthly or less frequently). Residential density was used as an indicator of the availability of services and the amount of infrastructure for outdoor mobility. The range of residential density in the

1 km × 1 km squares in the study area (Population Grid Data 2018) was categorized in tertiles (lowest, middle, highest). Each participant was assigned to the population density tertile of their home location.

Statistical analyses

Descriptive statistics by the walking limitation categories were reported in percentages for categorical variables and as medians with interquartile range (IQR) for continuous variables. Differences between groups were tested with a Chi-square test or the Kruskal–Wallis test. The associations between reported walking limitations and counts of activity destinations were assessed cross-sectionally using Poisson loglinear regression analysis. General linear model analyses were used to investigate the associations between walking limitations and the log-transformed median distance from home to the reported activity destination. In all analyses, those with walking difficulty were used as a reference group. Analyses were run separately for each activity destination type and for all destinations combined. The Poisson loglinear regression models were adjusted for age, sex, perceived financial situation, years of education, MMSE score, regular driving, and residential density. General linear models were first adjusted for age and sex and then for age, sex, perceived financial situation, years of education, MMSE score, regular driving, and residential density.

Of the 901 participants, 14 were excluded from the analysis due to missing information on self-reported walking limitations, and hence, the analysis was conducted for 887 participants. Information was missing on years of education for four participants, MMSE score for three participants, and financial situation for four participants. These 11 participants were not included in the fully adjusted models in the Poisson loglinear regression and general linear model analyses. We did additional sensitivity analyses stratifying the data based on regular driving. In stratified analyses, the main models did not materially differ between drivers and non-drivers (data not shown). The results were regarded as statistically significant if the p value was < 0.05 or 95% confidence intervals did not include one in the Poisson loglinear regression analyses or did not include zero in the general linear model analyses. SPSS Statistics for Windows (version 26.0; IBM Corp.) were used for statistical analyses.

Results

The participants' median age was 78.9 (IQR = 4.7) years and 57.1% ($n = 506$) of the participants were women. Participants with intact walking were statistically significantly more often male, younger, drove regularly and had a higher education, better financial situation, and higher MMSE score than those with walking difficulties ($p \leq 0.002$ for all; Table 1).

Count of activity destinations

The most commonly reported physical exercise destinations were outdoor sports facilities, while the most reported attractive destinations were service or event venues and nature settings (Appendix 1). The most commonly reported regular destinations were grocery and other stores. The characteristics of the participants' activity destinations by walking limitations are summarized in Table 2. The results showed that the median count of destinations reported by

Table 1 Participants characteristics by walking limitations ($N = 887$)

	Intact walking $n = 424$ Median (IQR)	Walking modifications $n = 167$ Median (IQR)	Walking difficulty $n = 296$ Median (IQR)	p value
Age, years	75.7 (4.4)	79.4 (4.6)	79.6 (8.6)	**< 0.001**[a]
Education, years	11.0 (6.0)	10.0 (7.0)	10.0 (6.0)	**0.002**[a]
MMSE, score	28.0 (2.0)	28.0 (3.0)	27.5 (3.0)	**0.002**[a]
Men, % (n)	49.1 (208)	43.1 (72)	34.1 (101)	**0.001**[b]
Good or very good perceived financial situation % (n)	69.5 (294)	54.5 (91)	51.5 (151)	**< 0.001**[b]
Regular driving % (n)	64.2 (272)	55.7 (93)	43.6 (129)	**< 0.001**[b]
Tertile of residential density % (n)				0.218[b]
Lowest	48.1 (204)	40.7 (68)	49.0 (145)	
Middle	20.0 (85)	28.1 (47)	20.6 (61)	
Highest	31.8 (135)	31.1 (52)	30.4 (90)	

Statistically significant p values are bolded. Bold values indicate $p < 0.05$. *IQR* interquartile range, *MMSE* Mini-Mental State Examination

[a]Tested with Kruskal–Wallis test. [b] Tested with Chi-square test

Table 2 Characteristics of reported activity destinations by walking limitations ($N=887$)

	Intact walking $n=424$ Median (IQR)	Walking modifications $n=167$ Median (IQR)	Walking difficulty $n=296$ Median (IQR)	p value
Count				
All destinations	7.0 (3.0)	6.0 (3.0)	6.0 (4.0)	**< 0.001**[a]
Physical exercise destinations	3.0 (2.0)	2.0 (2.0)	2.0 (2.0)	**< 0.001**[a]
Attractive destinations	2.0 (1.0)	1.0 (2.0)	1.0 (2.0)	**0.003**[a]
Regular destinations	2.0 (1.0)	3.0 (1.0)	2.0 (1.0)	0.410[a]
Median distance (km)				
All destinations	2.1 (1.7)	1.6 (1.6)	1.4 (1.6)	**< 0.001**[a]
Physical exercise destinations	1.9 (1.8)	1.3 (1.4)	0.9 (1.4)	**0.001**[a]
Attractive destinations	2.0 (10.4)	1.1 (3.7)	0.9 (2.9)	**< 0.001**[a]
Regular destinations	2.5 (2.8)	2.2 (2.5)	2.1 (2.4)	**0.048**[a]

Statistically significant p values are bolded. Bold values indicate $p<0.05$. *IQR* interquartile range, *MMSE* Mini-Mental State Examination

[a]Tested with Kruskal–Wallis test. [b] Tested with Chi-square test

the participants with intact walking was seven, whereas the corresponding count reported by those with walking difficulty was six ($p<0.001$; Table 2). In addition, compared to participants with walking difficulty, those with intact walking reported a higher count of physical exercise destinations (median = 3, IQR = 2 vs. median = 2, IQR = 2; $p<0.001$) and attractive destinations (median = 2, IQR = 1 vs. median = 1, IQR = 2; $p<0.001$). No statistically significant differences were observed in regular destination counts between the walking limitations categories ($p=0.410$).

Figure 1 presents the fully adjusted incidence rate ratios (IRR) and 95% confidence intervals (CI) for the activity destination counts for those with walking limitations. Compared to the participants with walking difficulty, the IRR for the count of all destinations combined for those with intact walking was 1.20 (95% CI [1.13, 1.28]). Thus, the total count of destinations reported by those with intact walking was 21% higher than that reported by those with walking difficulty. Intact walkers had greater IRRs for the counts of physical exercise destinations (IRR = 1.45, 95% CI [1.31, 1.61]) and attractive destinations (IRR = 1.23, 95% CI [1.09, 1.40]) than those with walking difficulty. Participants with walking modifications were estimated to report a 9% higher count of all destinations combined (IRR = 1.09, 95% CI [1.01, 1.18]) and a 23% higher count of physical exercise destinations (IRR = 1.23, 95% CI [1.08, 1.40]) than those with walking difficulty. However, the association between using walking modifications and reporting attractive destinations was nonsignificant. The results also showed that having walking limitations was

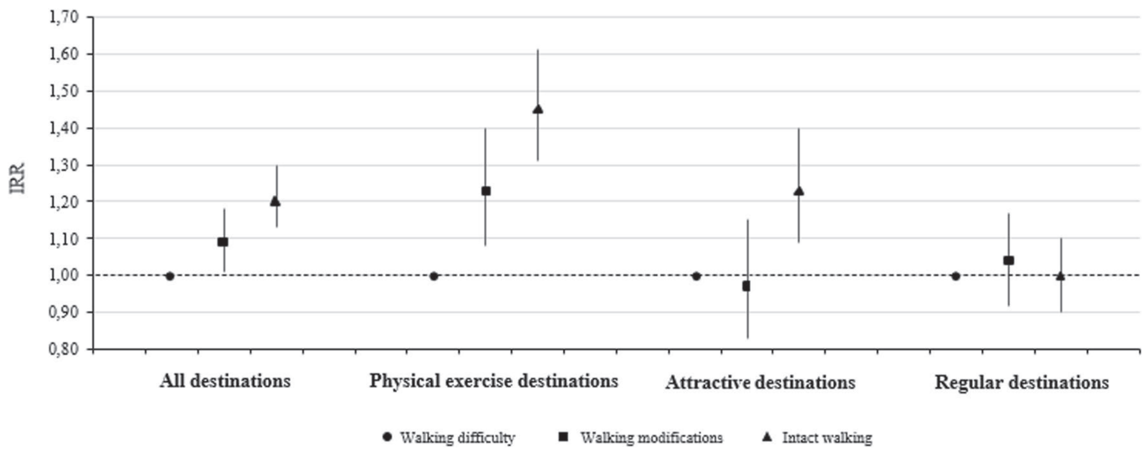

Fig. 1 The incidence rate ratios (IRR) and 95% confidence intervals (CI) for the count of activity destinations in Poisson loglinear regression models with walking limitations ($N=887$). The results were considered statistically significant when the 95% confidence intervals did not include one

not statistically significantly associated with the reported count of regular destinations.

Median distance to activity destinations

Table 2 reveals that, when all destinations were considered, older people with intact walking reported destinations approximately 700 m further from their homes than those with walking difficulty ($p<0.001$). The physical exercise destinations reported by intact walkers were located one kilometer ($p=0.001$) and the attractive destinations 1.1 km ($p<0.001$) further than those reported by those with walking difficulty. The difference in the median distance of regular destinations between participants with intact walking and those with walking difficulty was 400 m ($p=0.048$). In general, the linear models using loglinear transformation showed that the older people with intact walking reported a greater median distance to all destinations combined ($b=0.13$, 95% (CI) [0.08, 0.19]), physical exercise destinations ($b=0.61$, 95% CI [0.47, 0.74]), and attractive destinations ($b=0.51$, 95% CI [0.26, 0.77]) than those with walking difficulty (Table 3). After adjusting with covariates, the associations were somewhat attenuated but remained significant in all models. In addition, participants using walking modifications ($b=0.42$, 95% CI [0.25, 0.59]) reported a greater median distance to physical exercise destinations than participants with walking difficulty. The association remained statistically significant after adjusting with covariates. However, the association between walking limitations and median distance to regular destinations was nonsignificant.

Discussion

In this study, use of a map-based PPGIS method enabled us to obtain new information about activity destination counts and locations relative to the homes of older adults. Compared to the participants with walking difficulty, the older adults with intact walking reported higher counts of physical exercise and attractive destinations and also destinations that were located further away from their homes. Those using walking modifications, indicative of early limitations, reported a higher count of physical exercise destinations than those with walking difficulty. However, the association between distance to destinations for regular activities and walking limitations was nonsignificant. As far as we know, this is the first study to examine the associations between manifest and early walking limitations and different types of activity destinations among older adults. The validity of these findings is supported by previous results, indicating that destinations may motivate older adults to participate in out-of-home activities and that older adults have multiple reasons for visiting places outside the home (Tsai et al. 2016; Chudyk et al. 2015). However, earlier studies have also shown that having walking limitations may restrict people's participation in activities outside the home (Hand and Howrey 2019; Tuomola et al. 2023), as we also found in relation to the destinations visited by our participants.

The ecological model of aging suggests that when older people encounter environmental challenges that exceed their physical capabilities, they may adjust their walking behavior, e.g., by reducing their walking pace, using assistive devices, or taking breaks to reduce the physiological demands of walking (Freedman et al. 2017; Skantz et al. 2020a, b). This aligns with the model of selection, optimization, and compensation, which suggests that older individuals use these strategies to continue engaging in activities that are important to them (Baltes and Baltes 1990). Walking adaptations enable older adults to maintain a sufficient level of community mobility (Skantz, Rantanen, Palmberg, et al. 2020). Our results complement earlier findings by showing that walking modifications allow older people to continue visiting destinations where activities meaningful to them take place. In the current study, although the older adults who had modified their walking behavior reported more physical exercise destinations than those with walking difficulty, the two groups showed only a nonsignificant difference in counts of destinations regarded as attractive, including nature locations. A possible explanation might be that their neighborhood environments may lack the kinds of facilitators that support and motivate older people with walking limitations to visit such places. Older people with walking difficulties experience environmental features differently from intact walkers (Sakari et al. 2017; Skantz et al. 2020a, b). Lack of resting places, long distances to destinations, or hilly terrain may further encumber their mobility (Rantakokko et al. 2012; Keskinen et al. 2020).

In our study, the most commonly reported destinations that people regarded as regular were grocery and other stores. As daily routines, visits to regular destinations (Chudyk et al. 2015; Davis et al. 2011) may form a major part of people's community mobility, especially for older people with reduced walking ability. This was also evident in our data. Older adults reported an equal count of regular destinations irrespective of the presence or absence of walking modifications or difficulty even though those with walking difficulty reported a lower count of other activity destinations. A low count of physical exercise and attractive destinations may signal a reduction in recreational activities, leading to decreased life-space and reduced well-being in old age.

Interestingly, regular destinations were located further away from home than physical exercise and attractive destinations. This is most likely because they were critical, such as grocery stores, health services, and other shops. It has previously been established that critical destinations may be

Table 3 General linear model analyses of the associations between walking limitations and median distance to reported activity destinations ($N = 887$)

	Distance to all destinations				Distance to physical exercise destinations				Distance to attractive destinations				Distance to regular destinations			
	Crude[a]		Fully adjusted[b]		Crude[a]		Fully adjusted[b]		Crude[a]		Fully adjusted[b]		Crude[a]		Fully adjusted[b]	
	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI
Intact walking (vs. walking difficulty)	**0.13**	**0.08, 0.19**	**0.13**	**0.07, 0.19**	**0.61**	**0.47, 0.74**	**0.58**	**0.44, 0.71**	**0.51**	**0.26, 0.77**	**0.46**	**0.20, 0.71**	0.05	−0.05, 0.14	0.04	−0.05, 0.13
Walking modifications (vs. walking difficulty)	0.05	−0.02, 0.12	0.05	−0.01, 0.12	**0.42**	**0.25, 0.59**	**0.41**	**0.25, 0.58**	0.05	−0.26, 0.36	−0.10	−0.33, 0.30	0.04	−0.08, 0.15	0.05	−0.06, 0.16
Men (vs. women)	**0.17**	**0.12, 0.22**	**0.10**	**0.42, 0.15**	0.01	−0.10, −0.13	−0.00	−0.14, 0.71	0.04	−0.18, 0.26	0.10	−0.15, 0.36	**0.20**	**0.12, 0.28**	0.01	−0.02, 0.13
Good or very good perceived financial situation (vs. poor to fair)			0.01	−0.04, 0.07			0.04	−0.08, 0.17			0.05	−0.16, 0.30			0.03	−0.06, 0.11
Age	**−0.02**	**−0.03, −0.02**	**−0.02**	**−0.03, −0.01**	**−0.02**	**−0.04, −0.01**	**−0.02**	**−0.04, 0.00**	−0.02	−0.05, 0.01	−0.02	−0.05, 0.01	**−0.01**	**−0.02, −0.00**	−0.01	−0.02, 0.00
Years of education			−0.01	−0.01, 0.00			0.00	−0.01, 0.02			−0.00	−0.03, 0.03			**−0.02**	**−0.03, −0.00**
MMSE score			−0.01	−0.01, 0.02			0.03	−0.01, 0.05			0.02	−0.03, 0.07			0.00	−0.00, 0.03
No regular driving (vs. regular driving)			**−0.12**	**−0.12, −0.06**			−0.06	−0.20, 0.08			0.03	−0.19, 0.28			**−0.23**	**−0.32, −0.13**
Lowest tertile of residential density (vs. highest tertile)			**0.17**	**0.12, 0.23**			0.08	−0.06, 0.22			**−0.33**	**−0.59, −0.07**			**0.23**	**0.14, 0.32**

Table 3 (continued)

	Distance to all destinations				Distance to physical exercise destinations				Distance to attractive destinations				Distance to regular destinations			
	Crude[a]		Fully adjusted[b]		Crude[a]		Fully adjusted[b]		Crude[a]		Fully adjusted[b]		Crude[a]		Fully adjusted[b]	
	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI	b	95% CI
Middle tertile of residential density (vs. highest tertile)			**0.15**	**0.08, 0.21**			0.08	−0.09, 0.24			−0.12	−0.42, 0.19			0.05	−0.06, 0.16

b Regression coefficient, *CI* confidence interval, *MMSE* Mini-Mental State Examination. General linear models adjusted for: [a]age and sex; [b]age, sex, perceived financial situation, years of education, MMSE score, regular driving, and residential density. Values in bold; if the 95% CI does not contain the value 0, $p<0.05$

located further away from home and still be visited regularly, although also using other modes of transport than walking. (Hirsch et al. 2016; Nathan et al. 2012). According to a previous study, passive modes of transportation such as cars or public transportation were commonly used for daily trips to services and shops (Sugiyama et al. 2019). Shopping trips, in particular, often involve carrying groceries and are more likely to be traveled by car. In our study, the median distance to regular destinations was from 2.1 to 2.5 km. This suggests that older adults with walking limitations travel outside their neighborhood to access services and shops, which contributes to their daily activity (Hillsdon et al. 2015) and well-being (Satariano et al. 2012). Our recent study indicated that almost all self-selected activities promote well-being (Rantanen et al. 2021). This study suggests that the environmental characteristics of the living environment, such as the residential density of the neighborhood, can influence how far older adults travel to visit different places. Urban areas may offer more destinations that are closer to home. Older adults may walk instead of driving if the meaningful destinations are located nearby (Rosso et al. 2013; Chudyk et al. 2015).

We also found associations between the extent of walking limitations and distances to specific destinations. Those with intact walking and those using modifications reported physical exercise destinations further from home than those with walking difficulty. This may suggest that they have more physical reserves and are thus willing to travel further to a specific type of destination. Previous studies have shown that mobility restrictions are associated with a smaller activity range (Iveson et al. 2023) and lower life-space mobility (Dunlap et al. 2022), indicating that older adults with mobility limitations may have more limited use of their environment (Iveson et al. 2023). The physical exercise and attractive destinations reported by those with walking difficulty were all within one kilometer from home. This underlines the importance of the local siting of services and other important destinations.

The strengths of this study include a population-based sample of individuals aged 75–85 who were interviewed face-to-face using an online participatory mapping method, the PPGIS, to study the out-of-home activity destinations of older adults. We studied road network distances to these locations rather than straight-line distances. This study provided a comprehensive picture of older adults' activity destinations including not only destinations for daily errands but also those for physical exercise and enjoying outdoor mobility. In addition, our sample size was relatively large and missing data were few. However, the study has its limitations. The cross-sectional design limits the ability to infer causality. This study was also conducted in one country, Finland, and therefore generalization to different cultural and geographic contexts must be carefully considered. Moreover, our study population comprised relatively healthy and well-functioning older people. We cannot rule out variation in the accuracy of the identified locations, although previous research has shown that the spatial quality of the PPGIS may be adequate for mapping daily mobility (Laatikainen et al. 2018).

Conclusions

Participants with intact walking reported more physical exercise destinations and attractive destinations than participants with walking difficulty. Moreover, intact walkers' destinations were located further away from home. Walking modifications, such as resting and using a walking aid, may help individuals to continue visiting meaningful destinations, especially physical exercise destinations, despite functional decline. Our study suggests that despite the onset of walking difficulties, older people do not readily give up accessing destinations necessary for daily living. Such destinations may not only encourage older people to go outdoors but also give them an opportunity to be socially active. However, walking difficulties seem to decrease participation in recreational activities. Understanding the diversity of activity destinations and environments that are relevant for older adults without and with walking difficulties or early signs of walking limitations is important for designing age-friendly environments. These environments may encourage older people to be physically active despite early signs of walking difficulties. More research is needed on how environmental factors facilitate outdoor mobility and influence older people's decisions about which destinations to visit. It would also be important to study the role of destinations in relation to overall physical activity and other health outcomes.

Appendix 1: Percentages and counts of reported reasons to visit activity destinations by destination type

Physical exercise destinations	% (*n*)
Outdoor sports facilities	58 (1350)
Indoor sports facilities	25 (575)
Outdoor recreational areas	17 (383)

Attractive destinations	% (*n*)
Services and events	28 (595)
Nature	15 (326)
Appealing landscape	12 (254)
Waterbody or lake	11 (237)
Park or other green area	8 (162)
Good walkways or routes	7 (147)
Resting place	3 (57)
Even sidewalks	2 (49)
Other	14 (298)

Regular destinations	% (*n*)
Grocery store	44 (1397)
Other store	16 (507)
Home of Friend/relative	9 (272)
Other service	6 (201)
Organized activity	6 (182)
Health service	5 (163)
Food service	4 (132)
Events	3 (104)
Church/parish	1 (37)
Cemetery	1 (32)
Other	5 (158)

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Availability of data and materials Data will be made available on request. To request the data, please contact Professor Taina Rantanen (taina.rantanen@jyu.fi).

Declarations

Ethics approval and consent to participate The ethical statement has been provided by the Ethical Committee of the Central Finland Health Care District which was conducted in accordance with the Declaration of Helsinki. All participants gave their written informed consent at the start of the home interview.

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III

OLDER ADULTS' SELF-REPORTED PHYSICAL ACTIVITY AND DISTANCE TO AND LAND USE AROUND REPORTED PHYSICAL EXERCISE DESTINATIONS

by

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Older adults' self-reported physical activity and distance to and land use around reported physical exercise destinations

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Suggested running head: Physical activity & physical exercise destinations

Older adults' self-reported physical activity and distance to and land use around reported physical exercise destinations

Abstract

Little is known about older adults' physical exercise destinations. We studied associations between physical activity (PA) level and physical exercise destinations (total number and surrounding environment) in community-dwelling 75–85-year-old people living in Central Finland. Participants (N=901) reported the amount of at least moderate intensity PA and physical exercise destinations. Distance from home, land use and locations of sport facilities were defined using a geographic information system. General linear model showed that older adults with higher PA reported higher numbers of physical exercise destinations and destinations further away from home than those reporting lower PA. Binary logistic regression showed that higher PA increased the odds of reporting a distant destination identified as a sports facility and of reporting destinations located in residential, service, forest and water body areas respectively. Physical exercise destinations in different environments may attract older people to go out and be more physically active.

Keywords: sports facility, active aging, built environment, geographic information system

Introduction

Outdoor environments that enhance older people's physical activity ideally consist of diverse facilities, destinations and walking trails near home (Sugiyama et al., 2012). Specific physical exercise destinations may encourage older people to go outdoors and spend time in these locations. Sport and physical exercise destinations include, for example, outdoor and indoor sports facilities such as sports grounds, public parks, outdoor gyms, swimming halls and gyms (Gul et al., 2016).

Knowledge on the associations between older adults' physical activity levels and use of physical exercise destinations is quite sporadic and mostly focused on neighborhood environments (Bonaccorsi et al., 2020). The general idea is that older adults prefer easily accessible destinations near home which provide opportunities for physical and social activities, such as parks, trails and recreational centers, swimming halls and gyms (Chaudhury et al., 2016; Gough et al., 2021; Moran et al., 2014; Van Cauwenberg et al., 2018). Streets, local squares and parks have been reported as recreational physical activity locations (Liu et al., 2021). Reporting a range of physical exercise destinations correlated with accumulating higher PA (Kerr et al., 2012). For example, older people who reported outdoor exercise destinations or both indoor and outdoor physical exercise destinations accumulated more moderate-to-vigorous physical activity than those who reported only indoor physical exercise or no regular physical exercise destinations (Kerr et al., 2012).

Environmental factors of neighborhood, such as walkability, residential density, greenery, land use mix and access to destinations, have been positively associated with older adults' physical activity (Bonaccorsi et al., 2020). Furthermore, physical activity was higher among older people reporting destinations that attract them to move outdoors, such as nature, parks and services, especially when destinations were located further away from home (over 500m) (Portegijs et al., 2020). Older people may prefer to travel outside their neighborhood to use specific physical exercise destinations (McCormack et al., 2006). Among younger adults, those who participated in vigorous physical activity traveled further to use recreational destinations than those who didn't do any vigorous activities (McCormack et al., 2006). Going to physical exercise destinations further away from home may be related to environmental characteristics around these destinations (Liu et al., 2021; McCormack et al., 2006; Vale & Pereira, 2016). There is limited understanding about how far from home older adults' physical exercise destinations are typically located and what type of land use is surrounding these destinations.

Online participatory mapping provides an inexpensive method with low participant burden and moderate data computation requirements while it accurately describes where people move (Hasanzadeh et al., 2017; Laatikainen et al., 2018; Portegijs et al., 2020; Schmidt et al., 2019). Self-reported destinations on an interactive map can provide representative descriptions of locations where people move around (Kestens et al., 2017). Online participatory mapping is also feasible in large interdisciplinary studies with extensive participant samples. Map-based questionnaires enable asking participants about motives for visiting the destination or the type of activity carried out there (Portegijs et al., 2021) and location data enables it to be combined with geospatial data on physical features of the environment (Rantanen & Kahila, 2009).

This research focuses on studying older adults' physical activity, physical exercise destinations of choice, and distance to and land use type around the physical exercise destinations. We study the associations between older people's physical activity level and the number of the self-reported physical exercise destinations, and their distance from home and land use type characteristics assessed based on a geographic information system.

Methods

Study design

This study is part of the Places of Active Aging project, which studies older people's exercise destinations and the physical environment around the destination. Participant data on health and function are derived from the "Active aging – resilience and external support as modifiers of the disablement outcome" (AGNES) cohort study. As described previously AGNES baseline data were collected from September 2017 to December 2018 (Rantanen et al., 2018). A random sample of 75-, 80-, and 85-year-old adults living in the city of Jyväskylä in Central Finland was drawn from the Digital and Population Data Services Agency in Finland (Rantanen et al., 2018). The inclusion criteria were being resident in the study area, living independently, being able to communicate and willing to participate. At baseline, 1018 (Rantanen et al., 2018) respondents participated in structured interviews at their home and 908 of them participated in physical assessments in the research center, which included a map-based assessment. Of those who participated in map-based assessments, 901 participants located their physical exercise destinations on a digital map with the assistance of an interviewer (Portegijs et al., 2019, 2021). The interviewer assisted participants technically with the orientation on the map and navigation to desired location. Seven of the respondents were unable to locate physical exercise destinations due the lack of time, health problems or limited cognitive function. Altogether 883 participants reported physical activity and completed map-based assessment. Participants' home addresses were derived from the population register and addresses were geocoded using the Digiroad dataset (Finnish Transport Infrastructure Agency, 2019).

The study was conducted in accordance with the Declaration of Helsinki. The ethical statement has been provided by the Ethical Committee of the Central Finland Health Care District. Study participants gave a written informed consent at the start of the home interview.

Main measures

Physical activity time of at least moderate intensity was self-reported using the Yale Physical Activity Survey for older adults (Dipietro et al., 1993). Participants were asked about the frequency and the usual duration per occasion of performing vigorous intensity physical activity as well as walking for at least 10 min during the past month. Response categories for frequency were (0) not at all, (1) 1–3 times per month, (2) 1–2 times per week, (4) 3–4 times per week and (6) 5+ times per week and for activity duration (20) 10–30 minutes, (40) 30–60 minutes, (60) over 60 minutes. Using these frequency and duration categories daily minutes were computed using the following formula [(frequency*duration)/7] for each separate activity and then summed to create total time in at least moderate intensity physical activity (Portegijs et al., 2019). For subsequent analyses, the responses were dichotomized into higher physical activity (≥30min/day) and lower physical activity (<30min/day).

Information about physical exercise destinations was collected using the interactive online Maptionnaire ® tool (Mapita LTD, Espoo, Finland). Participants were asked to locate physical exercise destinations, which they had visited several times in the past month. Physical exercise destinations included indoor sports facilities, and outdoor sports facilities and recreational areas. For each participant, reported outdoor and indoor physical exercise destinations were counted separately, and summed for the **total number** of reported physical exercise destinations. Participants were categorized into four groups according to **destination type**; only indoor physical exercise destinations, only outdoor physical exercise destinations, both destination types and no physical exercise destinations reported.

Participants' physical exercise destinations were linked to their home addresses using the geographic information system software ArcMap 10.6.1 (Esri Inc, Redlands, CA, USA). Distances between participants' homes and their located physical exercise destinations were computed as Euclidean distances (expressed in meters). The **maximal distance** from home to any of their physical exercise destinations was determined. For each participant, we used the distance of the most distant located physical exercise destination. Participants were categorized into four groups according to **distance** to only proximal physical exercise destinations (<1 km from home), only distant physical exercise destinations (>1 km from home), destinations at both distances, and no physical exercise destinations reported.

The data of land use (Finnish Environment Institute 2018) and Lipas sports facilities (Lipas sport facility database, 2018) was integrated with the participant data and the locations of reported physical exercise destinations. To characterize the predominant **land use type** around reported physical activity destinations we created 150-m buffer areas around each reported destination. According to Hasanzadeh et al. (2017), 130–150 m has been identified as a convenient estimation to indicate the surroundings of a single location. For the analyses, the original 49 land use classes of the Corine Land Cover dataset were reclassified into five land use types, which included natural and built environments: (1) residential areas, (2) services and sports and leisure facilities (3) industrial units, (4) agricultural and private garden areas, forest and semi-natural areas or marshes and bogs, (5) water bodies (Finnish Environment Institute 2018). For the analyses, we formed two variables for each land use type: reporting at least one proximal and at least one distant physical exercise destination at the respective land use type (yes/no).

We identified **sports facilities** from secondary data source “Public geographical information system for sports facilities in Finland” (Lipas sport facility database, 2018). This database contains information on publicly maintained sports facilities (such as indoor and outdoor gyms, sports and swimming halls, neighborhood sports areas, ball and athletics fields and tennis courts etc.), routes for outdoor activities and recreation areas. The information and data of Lipas is produced by experts of municipal sport services and by associations for recreational areas and sports federations. If a reported physical exercise destination was located within 150 m of a sports facility, it was considered to be the respective maintained indoor or outdoor sports facility. For the analyses we formed two variables for each participant: reported at least one proximal and at least one distant physical exercise destination identified as maintained sports facility (yes/no).

Covariates

Age, sex, years of education, chronic conditions, cognitive function, and difficulty walking were considered as covariates in the analyses. Participants’ age and sex were derived from the Digital and Population Data Services Agency recruitment. Education was described as years of full-time education (range from 0 to 33). Sociodemographics, such as gender, may affect older adults’ physical exercise destination choices (Liu et al., 2021). During the home interview, self-reported chronic conditions were queried using a list of ten categories including 34 diseases (Rantanen et al., 2018). Number of chronic conditions was calculated as the sum of individual chronic conditions varying from 0 to 12 diseases. Cognitive function was measured using the Mini-Mental State Examination (MMSE) (Folstein et al., 1975). The MMSE score ranges from 0 to 30 and a higher score indicates better function. Difficulty in walking two kilometers was asked about with a 5-point response scale ranging from “no walking difficulty” to “unable even with help of another person”. A dichotomous variable of difficulty walking 2 km was created (no difficulty vs. at least some difficulty or unable). Previous studies have shown that low physical functioning may decrease mobility outdoors (Kerr et al., 2012; Liu et al., 2021).

Statistical analyses

Descriptive characteristics of participants and values of the destination's features were compared between participants with lower and higher physical activity levels using Mann Whitney U test or Chi-square test. In addition, participants who reported physical exercise destinations were compared with those who did not report physical exercise destinations. Participant characteristics and environment features were reported as medians and interquartile ranges (IQR) or as percentages depending on variable distribution.

A general linear model was used to study associations between physical activity level and total number of physical exercise destinations and maximum distance from home to a reported destination. Separate analyses were conducted using the total number of physical exercise destinations and maximum distance from home as dependent variables. Analyses were first adjusted for age, sex and then difficulty walking, MMSE, chronic conditions and years of education. Logistic regression models were used to study the association between physical activity and reported distant physical exercise destinations located in residential areas, service areas, agricultural or forest areas and water bodies. In addition, logistic regression models were utilized to study associations between physical activity and reported distant physical exercise destinations identified as a sports facility. In these models, predominant land use type and sports facility variables were used as dependent variables and physical activity as an independent variable. Separate logistic regression models were run for each land use type variable and sports facility variable. Analyses were adjusted for age, sex, difficulty walking, MMSE, chronic conditions and years of education. SPSS Statistics for windows (version 26.0; IBM Corp., Armonk, NY, USA) was used for all statistical analyses and statistical significance was set at $p < 0.05$ in all tests.

Results

Overall, 89% percent of participants reported 1 to 8 outdoor physical exercise destinations and 47% 1 to 4 indoor physical exercise destinations, while 7% did not report any destinations for physical exercise. The 61 participants who reported not to use any physical exercise destinations were less physically active and had more difficulty walking than those who reported physical exercise destinations (median = 17.1 min, IQR = 22.9 vs. median = 34.3 min, IQR = 22.9; $p < 0.001$; 68.3% vs. 20.8%; $p < 0.001$, respectively), but they did not differ in any other variables. Table 1 shows descriptive characteristics of participants reporting lower ($N = 412$) and higher ($N = 471$) physical activity. Participants with lower physical activity were older, had fewer years of education, more walking difficulties, and diseases.

Those who had higher physical activity reported more physical exercise destinations than those with lower physical activity (median = 3.0, IQR = 2.0 vs. median = 2.0, IQR = 2.0; $p < 0.001$) (Table 1). The maximum distance of physical exercise destinations was longer for those who reported higher physical activity compared to those with lower physical activity (median = 3.4 km, IQR = 560 m vs. median = 3.1 km, IQR = 850 m; $p = 0.001$).

Older adults with higher physical activity more often reported both indoor and outdoor destinations for physical exercise and those with lower physical activity, only one of these (Figure 1a). There weren't statistically significant group differences in reporting indoor physical exercise destinations. Those with lower physical activity more frequently reported solely proximal physical exercise destinations than those who reported higher physical activity (Figure 1b). Whereas those who reported higher physical activity more frequently reported distant physical exercise destinations than did those who reported lower physical activity.

Participants reporting lower physical activity more frequently reported proximal physical exercise destinations in environments predominantly characterized by residential areas than those who reported higher physical activity (Figure 2a). The differences between groups were not statistically significant ($p = 0.068$). Whereas those who had higher physical activity more frequently reported proximal destinations in environments characterized by agricultural or forest areas, which was also statistically significantly more often than in the low physical activity group. Both physical activity groups more frequently reported at least one distant physical exercise destination in environments predominantly characterized by service areas (Figure 2b). Distant destinations in environments predominantly characterized by residential, service, agricultural or forest and water bodies land use types were reported more often by those who had higher physical activity. There were no significant differences between physical activity groups in reporting destinations characterized by industrial land type.

Those who reported higher physical activity more often reported distant physical exercise destinations identified as sports facilities than did those who reported lower physical activity ($p < 0.001$) (Figure 2b). There were no group differences in reporting proximal sports facilities (Figure 2a).

Table 2 shows those with higher physical activity reported higher numbers of physical exercise destinations (b = 0.95, 95% confidence interval [CI] 0.75–1.14) and destinations further from home (b = 0.49, 95% CI 0.37–0.62) compared to older adults in the lower physical activity group. The associations weakened somewhat, but remained statistically significant after adjusting for age, sex, difficulty walking, MMSE, chronic conditions and years of education.

The logistic regression analysis showed that those who reported higher physical activity had over twofold higher odds for reporting at least one distant physical exercise destination identified as a sports facility compared to those who reported lower physical activity (Table 3). The association remained significant after adjusting for age, sex, difficulty walking, MMSE, chronic conditions and years of education.

Higher physical activity increased the odds for reporting more distant physical exercise destinations in environments characterized by residential areas (Odds ratio [OR] 1.71, 95% CI 1.23–2.39). Reporting higher physical activity showed twofold higher odds for reporting more distant physical exercise destinations in environments characterized by service, agricultural or forest areas and water bodies. Adjusting for difficulty walking, MMSE, chronic conditions and years of education, the associations were attenuated somewhat and rendered the association between physical activity and physical exercise destinations located in areas with predominantly water bodies non-significant.

Discussion

The main results showed that older people reporting higher physical activity reported more physical exercise destinations, and their destinations reported were located further from home compared to those with lower physical activity. In addition, higher physical activity increased the odds of reporting one distant physical exercise destination identified as a sports facility and of reporting destinations predominantly located in all types of land use. Proximal physical exercise destinations were more frequently reported at locations predominantly characterized by residential and agricultural or forest areas whereas distant destinations were located in service areas.

A previous study in working-age adults has shown that higher self-reported leisure time physical activity was associated with a higher amount of sports facilities in the neighborhood and visiting indoor and outdoor sports facilities more often (Kajosaari & Laatikainen, 2020). The current results showed similar associations among older adults. Older adults reporting higher physical activity reported more physical exercise destinations. Those who are physically more active may use a larger variety of indoor and outdoor physical exercise destinations whereas those who have lower physical activity may choose a specific location where they visit multiple times. In line with previous research (Kerr et al., 2012), older adults who reported higher physical activity more often reported both indoor and outdoor destinations than only one of them. Furthermore, it was previously suggested that different recreational destinations may promote older adults' physical activity (Barnett et al., 2017). In our study, older adults reported more outdoor physical exercise destinations than indoor physical exercise destinations. Participants were quite active which may affect choices of physical exercise destinations. Older people with lower activity or walking difficulties may not be able to access outdoor destinations and may prefer indoor destinations.

Different neighborhood environment factors have been associated with older people's physical activity (Barnett et al., 2017). The physical environment may encourage older people to go outdoors and visit different kinds of destinations (Sugiyama et al., 2012). When choosing a physical exercise destination, distance from home and type of land use around destinations may be relevant, but also, different kind of destinations use by older people regardless of environmental features. For example, distance may affect the use of physical exercise destinations, as does the type of exercising possibilities at the destination. The distance to physical exercise destinations may be connected to the use of those destinations, and specific destinations may encourage people to travel further away from home (McCormack et al., 2006), which is in line with the present study. According to our study older adults may travel further for exercise purposes. When moving further away from home, older people may choose physical exercise destinations, which are important to them and in a pleasing environment potentially motivating them to be physically active. In our study, physically more active persons reported more distant physical exercise destinations. Physically active older adults can participate more easily in daily activities, they have better physical condition (Piercy et al., 2018) and their life-space may be greater (Portegijs et al., 2015). Regular physical activity may improve physical function and decrease the risk of developing cardiovascular and metabolic diseases (McPhee et al., 2016). In addition to environmental features, various individual-level factors may be associated with physical activity, such as age, sex, and self-rated health (Rai et al., 2019). In our study, older people reporting lower physical activity were older, had fewer years of education, had more walking difficulties and diseases, which may affect their destinations of choice, that is, they may favor destinations closer to home.

The neighborhood area is important for physical activity, especially for older adults (Chaudhury et al., 2016). The availability of recreational destinations and land use mix has been associated with older people's physical activity (Barnett et al., 2017). Parks and small green areas near home comprise a low-threshold to being physically active (Van Cauwenberg et al., 2015). According to a study by Kajosaari & Laatikainen, (2020), adults' green and built public spaces, such as parks and forests, were located closer to home compared to indoor and outdoor sports facilities. In our study, older people more frequently reported proximal physical exercise destinations predominantly characterized by residential and agricultural or forest land types, and more distant destinations were more often located in service-dominated areas. Different kinds of services may motivate older people to go out and be active (Barnett et al., 2017). Older people may use specific physical exercise destinations because these are near other services, and they can visit multiple destinations during the same trip. In our study, those with higher physical activity more frequently reported distant physical exercise destinations identified as sports facilities. Maintained sports facilities have surroundings and facilities that are built for physical activity. Older people may be motivated to travel further from home to reach sports facilities where they can be physically active and participate in different sports. The built environment of green areas may be more important for physical activity than the built environment of sports facilities where individual factors, such as social support and self-efficacy, may have a greater role (Kajosaari & Laatikainen, 2020).

The strengths of this study include a population-based sample of older adults above 75 years that contributes relevant information on the association between physical activity and reported physical exercise destinations. By combining environmental datasets and subjective methods, such as a map-based questionnaire, we were able to study the environmental context where older people are active. Map-based questionnaires are a suitable way to study older adults' mobility (Laatikainen et al., 2018). This is one of the first studies looking at associations between older people's physical activity, physical exercise destinations and environmental features around these destinations. We had few missing data and participants had a relatively good health condition. Overall, study participants were relatively physically active.

The following limitations should be noted when interpreting results. Participants with lower physical activity had more walking difficulties than those with higher physical activity, which may be one reason why people with lower activity reported fewer destinations and destinations closer to home. This study was conducted in Finland and therefore generalization to different cultural and environmental contexts should happen with caution. Responsibility for updating the Lipas database lies with experts of municipal sports services and associations for recreational areas and sports federations, which may lead to inaccuracies regarding the sports facilities listed or delays in reporting changes.

In addition, there are a few limitations concerning variables. Physical activity and physical exercise destinations were both self-reported. Self-reported physical activity may be overestimated (Steene-Johannessen et al., 2016). Daily minutes of self-reported walking bouts and vigorous physical activity were summed and categorized to describe the overall physical activity level. Categorization of an originally continuous variable may result in loss of some information. Older adults reported only physical exercise destinations, which they had visited several times during the past month, and thus, excluding single visits. Distance from home to physical exercise destination was measured with the

Euclidean distance, which may underestimate actual distances (Shadid et al., 2009) but correlates well with driving distances (Boscoe et al., 2012). The accuracy of locating destinations should be also noted. Older adults located their physical exercise destinations on a digital map with the assistance of an interviewer. The accuracy of the located destinations is unknown and may to some extent affect the environmental analyses in the 150-m buffer area used around the participant's reported destinations. However, we took this into account by requiring a sufficiently detailed zoom level for locating destinations in the map-based questionnaire app.

Conclusions

In the current study, older adults reporting higher physical activity used a larger variety of physical exercise destinations (i.e., locating in different types of land use and type of sports facility) and destinations located further away from home than did those with lower physical activity. Proximal destinations located in residential and forest areas may be important especially for those with lower activity and walking difficulties. Especially among older people with higher physical activity, willingness to travel further away from home and to physical exercise destinations in various land use types indicates the importance of these destinations to the persons visiting them. Information on physical exercise destinations and surrounding environments could help to create a more comprehensive picture of older adults' activity behavior outside the home and the meaning of activity locations. Further research is needed to study how specific physical exercise modes affect older adults' destination choices. In addition, it will also be interesting to find out how older adults' physical activity and use of physical exercise destinations change over time.

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Table 1. Descriptive characteristics and reported physical exercise destinations of participants with higher vs. lower physical activity (*N* = 883)

	Lower physical activity[a] *N* = 412 Median (IQR)	Higher physical activity[b] *N* = 471 Median (IQR)	*p* value
Age (years)	79.4 (4.8)	76.0 (4.5)	**0.003**[c]
Chronic conditions (n)	4.0 (3.0)	3.0 (2.0)	**<0.001**[c]
MMSE score	28.0 (3.0)	28.0 (3.0)	**0.017**[c]
Education (years)	10.0 (6.0)	11.0 (6.0)	**0.004**[c]
Number of reported exercise destinations	2.0 (2.0)	3.0 (2.0)	**<0.001**[c]
Maximum distance to reported exercise destinations (km)	3.1 (0.9)	3.4 (0.6)	**0.001**[c]
Men, % (n)	39.8 (164)	45.6 (215)	0.088[d]
Difficulty walking, % (n)	51.1 (208)	18.1 (85)	**<0.001**[d]

IQR, interquartile range; MMSE, Mini-Mental State Examination
[a] Lower physical activity, <30 min/day
[b] Higher physical activity, ≥30 min/day
[c] Mann-Whitney U test
[d] Chi-Square test

Table 2. The association between physical activity level and the number of and maximum distance to reported physical exercise destinations (*N* = 883)

	Number of physical exercise destinations				Maximum distance to physical exercise destinations (km)			
	Crude[a]		Fully adjusted[b]		Crude[a]		Fully adjusted[b]	
	b	95% CI	b	95% CI	b	95% CI	b	95% CI
Higher physical activity (vs. Lower physical activity)	**0.95**	**0.75–1.14**	**0.74**	**0.54–0.94**	**0.49**	**0.37–0.62**	**0.36**	**0.23–0.49**
Age	-0.01	-0.04–0-01	0.01	-0.02–0.04	**-0.04**	**-0.06–-0.02**	**-0.02**	**-0.04– -0.00**
Men (vs. Women)	**0.35**	**0.16–0.54**	**0.40**	**0.21–0.59**	-0.07	-0.19–0.06	-0.03	-0.16–0.09
Difficulty walking (vs. No difficulty walking)			**0.47**	**0.25–0.67**			**0.41**	**0.26–0.56**
MMSE score			**0.09**	**0.05–0.13**			**0.04**	**0.01–0.07**
Chronic conditions			-0.05	-0.10–0.01			-0.01	-0.04–0.03
Years of education			0.02	-0.01–0.04			0.01	-0.01–0.02

Note. Values in bold; If the 95% CI does not contain the value 0, $p < 0.05$. b = Regression coefficient, CI = confidence interval
General linear models adjusted for [a]age, sex, [b]age, sex, difficulty walking, MMSE, chronic conditions and years of education. Higher physical activity, ≥30 min/day; lower physical activity, <30 min/day.

Table 3. Odds ratios (95% CI) for reporting at least one distant physical exercise destination identified as a sports facility and according to predominant land use type for those with higher physical activity (vs. lower physical activity) (*N*=883)

Dependent variable	Crude[a]		Fully adjusted[b]	
	OR	95% CI	OR	95% CI
Sports facility	**2.51**	**1.87–3.36**	**2.07**	**1.51–2.82**
Residential areas	**1.71**	**1.23–2.39**	**1.55**	**1.08–2.21**
Service areas	**2.12**	**1.59–2.82**	**1.81**	**1.33–2.47**
Agricultural or forest areas	**2.17**	**1.62–2.91**	**1.63**	**1.19–2.24**
Water bodies	**2.14**	**1.44–3.17**	1.46	0.97–2.21

Note. Values in bold; If the 95% CI does not contain the value 1, $p < 0.05$. Lower physical activity as a reference category. Logistic regression model adjusted for [a]age, sex, [b]age, sex, difficulty walking, MMSE, chronic conditions and years of education. Reporting distant physical exercise destination in industrial land use type was too rare to compute valid logistic regression, and thus omitted from the table.

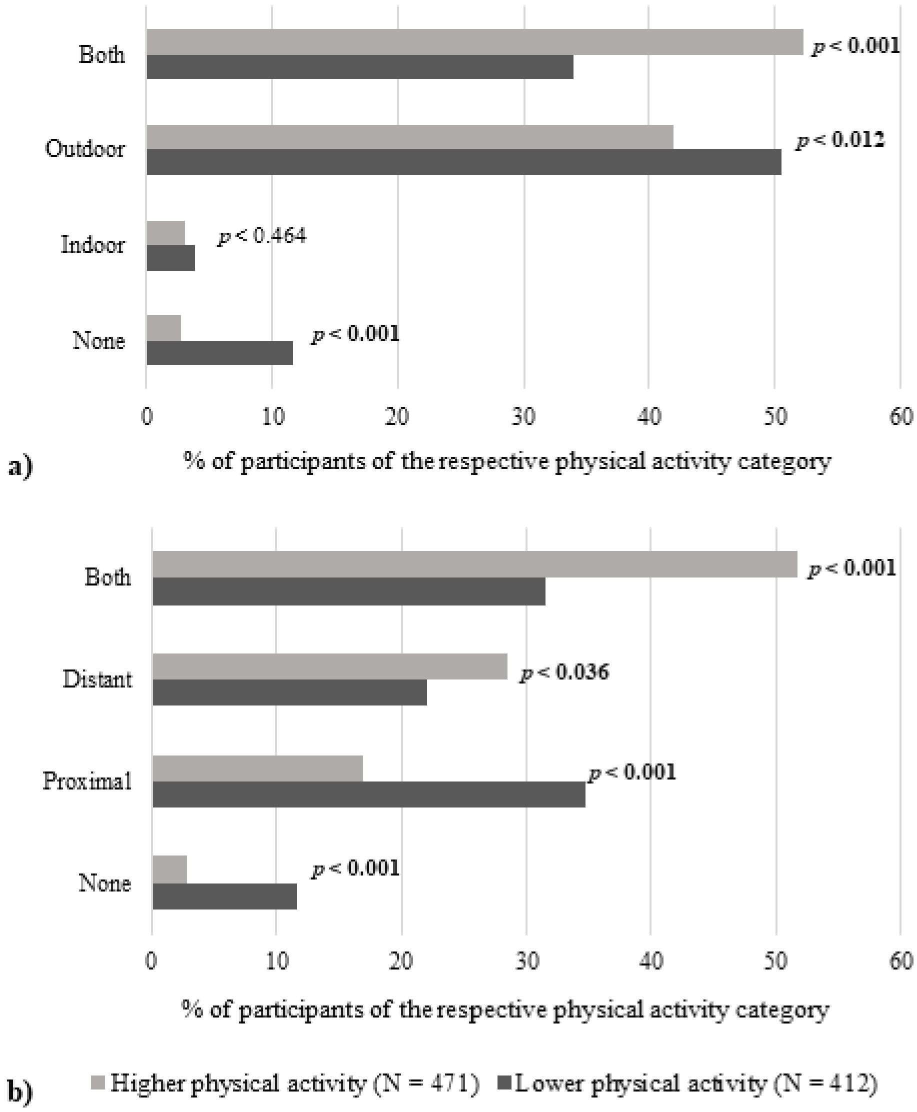

Figure 1. Proportions of participants reporting physical exercise destinations by (a) type and (b) distance according to physical activity group (%; $N = 883$). Statistical significance between physical activity groups in Chi-square test are indicated in the figure.

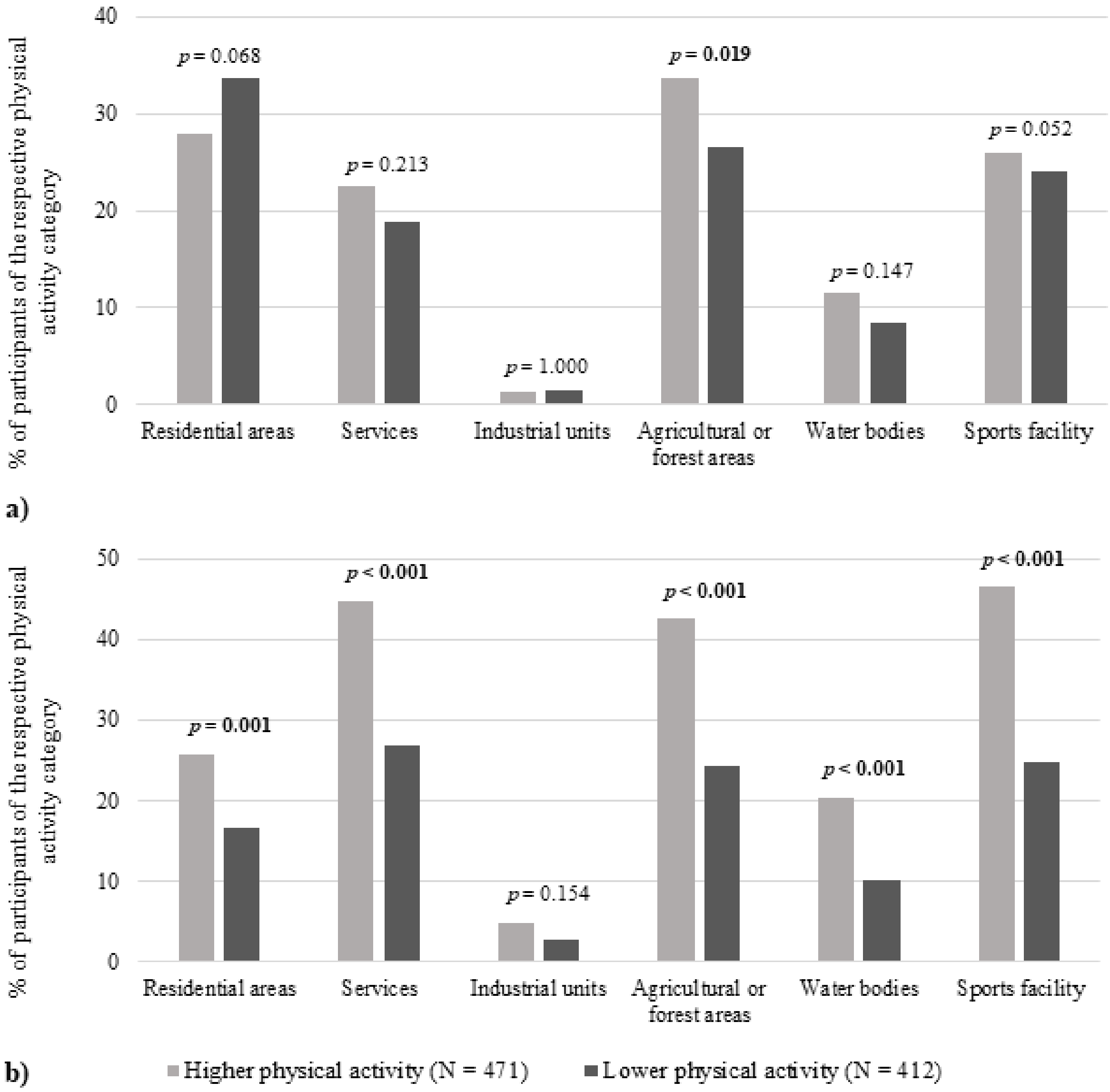

Figure 2. Proportion of participants reporting at least one (a) proximal and (b) distant physical exercise destination in predominant land type or identified as sports facility according to physical activity group (N = 883). Statistical significance between physical activity groups in Chi-square test are indicated in the figure.

IV

VISITED ACTIVITY DESTINATIONS AND SENSE OF AUTONOMY IN OUTDOOR ACTIVITIES AMONG OLDER PEOPLE

by

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Submitted for publication.

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