JYU DISSERTATIONS 573

Heidi Leppä

Walking Modifications as Facilitators of Mobility in Old Age

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF SPORT AND HEALTH SCIENCES

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ABSTRACT

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Mobility enables independent living, and it has multiple dimensions; mobility patterns, the ability to move, autonomy in mobility, and the extent of mobility. In old age, functional decline predisposes to walking limitations that are further accentuated by lack of environmental support. In addition, the extent of mobility declines which often coincides with diminished autonomy in mobility. This study explored the role of 2 km walking modifications (e.g., using an aid) in maintaining outdoor mobility among older people. The levels and changes in the extent of mobility and autonomy in mobility were followed over two years in two studies: prior to and during the coronavirus disease 2019 (COVID-19) pandemic restrictions. In addition, this dissertation explored the associations of accelerometer-based free-living walking and environmental features with walking modifications.

The data were drawn from two research projects: Life-Space Mobility in Old Age (2012; n = 848, and 2014; n = 761); and Active Ageing – Resilience and External Support as Modifiers of the Disablement Outcome (2017–2018; n = 1021, and 2020; n = 809). The participants in both longitudinal cohort studies were community-dwelling people aged 75 to 93. Participants' perceived environmental mobility barriers and facilitators, walking modifications and difficulty, life-space mobility, autonomy in participation outdoors, unmet physical activity need, and level of physical activity were assessed with self-reported measures, and free-living walking with accelerometers.

Daily walking minutes, walking bouts, and bout intensity and duration were lower and walking fragmentation was higher among those with walking difficulty and intermediate among those using walking modifications when compared to intact walkers. Outdoor mobility facilitators helped to use adaptive walking modifications, thereby potentially slowing down negative changes in life-space mobility, and contributing to the maintenance of autonomy in mobility and in physical activity. During the first wave of the COVID-19 pandemic, the life-space mobility and autonomy in mobility declined among older people despite the use of walking modifications. The findings of this study suggest that among older people the use of adaptive walking modifications and environmental features that support their use are important for both their extent of mobility and autonomy in mobility.

Keywords: adaptation, environment, outdoor mobility, autonomy, older adults

TIIVISTELMÄ (ABSTRACT IN FINNISH)

Leppä, Heidi
Kävelymodifikaatiot liikkumisen mahdollistajina vanhuudessa
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Arkisten asioiden hoitaminen ja itsenäinen elämä vaatii liikkumista paikasta toiseen ja useimmiten myös kotoa poistumista. Heikentynyt toimintakyky voi muuttaa iäkkäiden ihmisten liikkumisen tapoja, heikentää liikkumiskykyä ja liikkumisen mahdollisuuksia, sekä vähentää kodin ulkopuolisen liikkumisen määrää. Tässä tutkimuksessa selvitettiin kahden kilometrin kävelymodifikaatioiden (esim. apuvälineen käyttö) roolia ulkona liikkumisen ylläpitämisessä iäkkäillä ihmisillä. Elinpiirin, liikkumisen määrän ja autonomian muutoksia seurattiin kahden vuoden ajan kahdessa eri tutkimuksessa, joista toinen sijoittui COVID-19 pandemian ajalle. Tutkimuksessa selvitettiin myös kiihtyvyysanturilla mitattujen kävelyn piirteiden ja koettujen ympäristötekijöiden yhteyksiä kävelymodifikaatioihin.

Tutkimuksessa hyödynnettiin kahden tutkimusprojektin aineistoa: Iäkkäiden ihmisten liikkumiskyky ja elinpiiri -aineistoa (2012; n = 848, ja 2014; n = 761) ja Aktiivisuuden, terveyden ja toimintakyvyn yhteys hyvinvointiin vanhuudessa -aineistoa (2017–2018; n = 1021, ja 2020; n = 809). Tutkittavat olivat kummassakin kohorttitutkimuksessa kotona asuvia 75–93-vuotiaita henkilöitä. Tutkittavien koettuja ympäristötekijöitä, kävelymodifikaatioita, kävelyvaikeuksia, elinpiiriä, ulkona liikkumisen autonomiaa, tyydyttämätöntä liikunnantarvetta ja fyysisen aktiivisuuden määrää arvioitiin kyselyiden avulla. Kävelyn piirteitä ja määrää mitattiin kiihtyvyysantureilla.

Kävelyvaikeuksia tai -modifikaatioita raportoiville iäkkäille ihmisille kertyi vähemmän kävelyminuutteja ja -jaksoja kuin heille, jotka eivät kokeneet kävelyvaikeuksia. Lisäksi heidän aktiivisuutensa kertyi useimmiten katkonaisemmin ja heidän kävelyjaksojensa intensiteetti oli pienempi ja kävelyjaksot lyhyempiä. Ulkona liikkumista houkuttelevat tekijät ovat yhteydessä adaptiivisten kävelymodifikaatioiden käyttöön, mikä puolestaan voi hidastaa elinpiirin pienentymistä ja ylläpitää ulkona liikkumisen autonomiaa. COVID-19 pandemian aikana iäkkäiden ihmisten ulkona liikkumisen määrä, laajuus ja koetut mahdollisuudet heikkenivät kävelymodifikaatioiden käytöstä huolimatta. Tulosten mukaan adaptiivisten kävelymodifikaatioiden käyttö ja ulkona liikkumista tukevien ympäristötekijöiden kokeminen voivat auttaa iäkkäitä ihmisiä ulkona liikkumisen ylläpitämisessä.

Asiasanat: adaptaatio, ympäristö, ulkona liikkuminen, autonomia, iäkkäät ihmiset

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ORIGINAL PUBLICATIONS AND AUTHOR CONTRIBUTION

The thesis is based on the following four original publications, which will be referred to by their Roman numbers. In addition, the thesis includes unpublished results.

I. Skantz, H., Rantalainen, T., Karavirta, L., Rantakokko, M., Palmberg, L., Portegijs, E., & Rantanen, T. (2021). Associations between accelerometer-based free-living walking and self-reported walking capability among community-dwelling older people. *Journal of Aging and Physical Activity*, *29*(6), 1018–1025. https://doi.org/10.1123/japa.2020-0389

II. Skantz, H., Rantanen, T., Rantalainen, T., Keskinen, K. E., Palmberg, L., Portegijs, E., Eronen, J., & Rantakokko, M. (2020). Associations between perceived outdoor environment and walking modifications in community-dwelling older people: a two-year follow-up study. *Journal of Aging and Health, 32*(10), 1538–1551. https://doi.org/10.1177/0898264320944289

III. Skantz, H., Rantanen, T., Palmberg, L., Rantalainen, T., Aartolahti, E., Portegijs, E., Viljanen, A., Eronen, J., & Rantakokko, M. (2020). Outdoor mobility and use of adaptive or maladaptive walking modifications among older people. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 75*(4), 806–812. https://doi.org/10.1093/gerona/glz172

IV. Leppä, H., Karavirta, L., Rantalainen, T., Rantakokko, M., Siltanen, S., Portegijs, E., & Rantanen, T. (2021). Use of walking modifications, perceived walking difficulty and changes in outdoor mobility among community-dwelling older people during covid-19 restrictions. *Aging Clinical and Experimental Research*, *33*(10), 2909–2916. https://doi.org/10.1007/s40520-021-01956-2

As the first author of these original publications, considering the comments from the co-authors, I drafted the study questions and designs, prepared the data for statistical analyses, performed the statistical analyses, and assumed the main responsibility for writing the manuscripts. In addition, I actively participated in the data collection of the Active Ageing – Resilience and External Support as Modifiers of the Disablement Outcome (AGNES) study by interviewing participants during the structured home interviews. AGNES data were used in Studies I and IV. I also used pre-existing data from the Life-Space Mobility in Old Age (LISPE) study in Studies II and III.

FIGURES

TABLES

ABBREVIATIONS

AGNES	Active Ageing – Resilience and External Support as Modifiers of the Disablement Outcome study
CES-D	Center for Epidemiologic Studies Depression Scale
COVID-19	Coronavirus disease 2019 caused by the SARS-CoV-2 virus
CI	Confidence interval
g	Gravity
GEE	General estimation equations
GPS	Global positioning system
ICF	International Classification of Functioning, Disability and Health
IPA	Impact on Participation and Autonomy questionnaire
km	Kilometre
LISPE	Life-Space Mobility in Old Age study
LSA	University of Alabama at Birmingham Study of Aging Life-Space Assessment
LSQ	Life-Space Questionnaire
MAD	Mean amplitude deviation
OR	Odds ratio
p	p-value
SD	Standard deviation
SE	Standard error
SOC	Selective optimization with compensation
SPPB	Short Physical Performance Battery

CONTENTS

1 INTRODUCTION

The number of people aged 60 years and older is increasing all over the world (World Health Organization, 2021). At the end of the year 2012, 453 000 people in Finland were aged 75 years or older whereas, at the end of the year 2021 the corresponding number was 576 000 (Official Statistics of Finland, 2022b). In the year 2050, this number is predicted to have risen further to around 915 000 (Official Statistics of Finland, 2022a). Currently 93 % of the older people aged 75 years and older are community-dwelling in Finland (National Institute for Health and Welfare, 2019), and hence legislation and various interventions are focusing on supporting the independent living of older people, in which mobility has an important role. While people aged 75 and older may experience deterioration in their physical functioning and health, they nevertheless form a heterogenous population of individuals differing widely in their health status (Nguyen et al., 2021). Some older people may even continue working and be involved in many out-of-home activities, whereas others mainly stay at home or within a close distance from their homes.

Mobility refers to all forms of movement, both self-powered and non-self-powered (e.g., automobiles, human-assisted movement) and is required for many valued activities, community life, and independent living (Guralnik, Ferrucci, et al., 1995; Rantanen, 2013). In this dissertation, movement is defined as the translation of the body through space from one point to another. Optimal mobility is reached when the individual can move when, where and as often as she or he wishes (Satariano et al., 2012). Mobility can be studied from at least four perspectives: mobility patterns (how a person moves or walks), the ability to move (what a person is able to do), autonomy in mobility (a person’s satisfaction with opportunities to go to places or exercise), and the extent of mobility (what the person does) (Rantanen, 2013; Satariano et al., 2012). With increasing age, older people’s mobility patterns change, and they experience a decline in their ability to move and in the extent of their mobility and autonomy in mobility (Ferrucci et al., 2016; Satariano et al., 2012; Shumway-Cook et al., 2005; Simonsick et al., 2008). The aging-related decline in physical functioning changes ambulation, which increases the risk for perceived walking difficulty (Verbrugge

& Jette, 1994), reduced possibilities to participate in out-of-home activities, and further decline in mobility (Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017). Therefore, maintenance of the ability to walk is one of the key factors in enabling venturing further from home, even when using a vehicle, and autonomy in mobility (Rantanen, 2013).

Traditionally, in epidemiological aging research, walking limitations have been studied as the presence vs. absence of self-reported difficulty in walking specific distances or by assessing walking speed (Chung et al., 2015). However, people who do not perceive walking difficulty vary widely in their mobility. Some may be highly active while others may already experience the early signs of functional decline, possibly manifesting, for example, as modifications in walking (Mänty et al., 2007). Walking modifications include such strategies as using an aid, lowering one's walking speed or resting in the middle of walking longer distances (Fried et al., 2000; Mänty et al., 2007). It has been established that older people who have modified their walking constitute an intermediate group in physical functioning between those with intact walking and those with walking difficulty (Fried et al., 2000). However, whether they have different accelerometer-based free-living walking is currently unknown.

At the same time, as well as indicating underlying physical vulnerabilities, walking modifications may also be adaptive and help the individual to maintain participation in out-of-home activities despite the decline in physical functioning (Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017). However, it is unknown whether all types of walking modifications relate to outdoor mobility in the same way, or whether particular walking modifications are associated with less or more activity (Weiss et al., 2007). Therefore, in addition to studying the determinants of using walking modifications or perceiving walking difficulty, this study also investigated adaptive walking modifications. To explore whether some walking modifications compensate for functional decline and help maintain outdoor mobility more favourably than others, self-reported modifications in walking a distance of 2 kilometres were categorized into adaptive (e.g., reduced pace, using an aid, resting in the middle of walking) and maladaptive (reduced frequency or giving up walking) walking modifications. This categorization was modelled on the ecological theory of aging (Lawton & Nahemow, 1973) and the model of selective optimization with compensation (SOC) (Baltes & Baltes, 1990). The distinction between adaptive vs. maladaptive walking modifications was based on the purpose of the modification: whether the adaptation allow the person to continue walking the distance in question but in a different way vs. whether the person has given up walking or reduced the walking distance in question.

The choice of walking modifications may be conscious or subconscious (Lien et al., 2015) and may reflect, e.g., a person's capabilities, access to resources, preferred approach to performing an activity, and environmental opportunities (Baltes & Baltes, 1990; Gitlin et al., 2017; Tomey & Sowers, 2009). While previous studies have shown that person-related factors, such as older age and poorer physical functioning, are associated with walking modifications (Freedman et al., 2016; Hoenig et al., 2006), little attention has been paid to the associations between the outdoor environment and walking modifications. More specifically, how perceived facilitators for and barriers to outdoor mobility relate to the use of walking modifications remains unknown.

The purpose of this doctoral thesis was to investigate older people's use of walking modifications and how these are related to life-space mobility, autonomy in outdoor mobility and physical activity. The associations of the use of walking modifications with the extent of and autonomy in outdoor mobility were investigated during the normal aging process and during the COVID-19 restrictions when environmental support for outdoor mobility was reduced due to the closure of many destinations and amenities. While previous studies have focused on walking modifications as a sign of preclinical disability, this study broadens the concept by introducing the categorization into adaptive and maladaptive walking modifications. A further aim was to investigate the associations of the perceived outdoor environment and accelerometer-based free-living walking with the use of walking modifications and perceived walking difficulty. Investigating the personal and environmental characteristics that are associated with using walking modifications or perceiving walking difficulty furthers understanding of the complex relationships between personal capacity, the environment, and individuals' behaviour.

2 REVIEW OF THE LITERATURE

2.1 Mobility in old age

Mobility is a broad term that includes all forms of movement from one place to another, such as ambulation (i.e., gait, walking), walking for leisure, exercising, engaging in different activities or driving a car (Satariano et al., 2012; Szanton et al., 2015; Webber et al., 2010). Mobility can manifest as a means of transport to desired places (e.g., shopping, running daily errands) or as an activity in itself (e.g., walking, riding a bike) (Mollenkopf et al., 2006) and includes moving both in and out of home. It has been suggested that mobility is optimal, when an individual is able to travel when, where and how often they wish (Satariano et al., 2012). Optimal mobility is an important enabler for independent living, participation in valued activities and community life, and a hallmark of successful aging among community-dwelling older people (Anton et al., 2015; Guralnik, Ferrucci, et al., 1995; Rantanen, 2013; Simonsick et al., 2005).

Four aspects of mobility were considered in the present study: mobility pattern, autonomy in mobility, extent of mobility, and ability to movemobility pattern, autonomy in mobility, extent of mobility, and ability to move (Figure 1). *Mobility pattern* describes a person's way of moving, walking or accumulating physical activity. Assessing mobility from that perspective can be done for instance by using self-reported questionnaires inquiring about changes in walking, i.e., walking modifications, or by accelerometers that can capture walking and activity bouts. *Autonomy in mobility* refers to perceived satisfaction with one's opportunities to exercise or to go where one wants to go. Autonomy in mobility can be assessed for instance as individuals' perceptions of their possibilities to visit destinations outside their home when they so wish, and as a lack of autonomy, i.e., unmet physical activity need. *Extent of mobility* describes what the person does. The volume of physical movement and travel, its frequency, the distance travelled or walked, the area in which one moves or walks, or the accumulation of physical activity can be assessed for instance with life-space mobility or physical activity assessment methods, both of which can be based either on self-reports or monitoring. A person's *ability to move* describes what the person is able to do, and it is typically assessed as self-reported walking difficulty over certain distances or as walking speed.

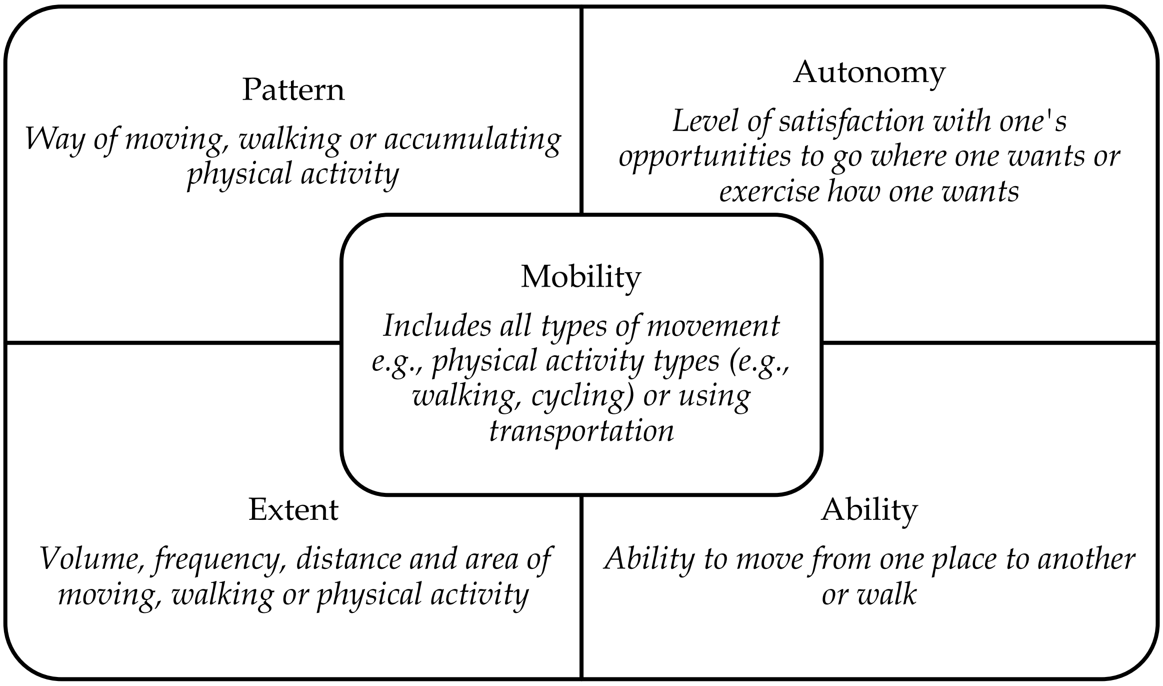

FIGURE 1 Mobility has multiple dimensions, such as pattern, autonomy, extent, and ability.

2.1.1 Importance of outdoor mobility

Outdoor mobility (i.e., out-of-home mobility) is an essential part of daily life in old age as it is at all ages, and can be defined as *locomotion in environments outside the home* (Patla & Shumway-Cook, 1999). Older people's main reasons for going outdoors are running daily errands, attending various events and making social visits (Davis et al., 2011; Tsai, Rantakokko, Rantanen, et al., 2016). Older people are more physically active on days when they leave their homes (Portegijs et al., 2015) and, vice versa, older people spend most of their sedentary time at home (Leask et al., 2015). It has also been shown that going outdoors at least once a week may slow the rate of functional decline among frail older people (Shimada et al., 2010). In sum, adequate outdoor mobility is essential for maintaining physical and mental health, quality of life and wellbeing in old age (Baker et al., 2003; Bentley et al., 2013; Rantakokko, Portegijs, et al., 2013; Rantanen et al., 2021).

In contrast, inability to access the outdoors and destinations outside one's home may lead to a higher risk for severe adverse health outcomes, such as increased risk for further functional decline (Shimada et al., 2010), nursing home admission (Sheppard et al., 2013), mortality (Boyle et al., 2010), and becoming entirely homebound over time (Gill et al., 2003). Being homebound is associated with dependency in self-care (Musich et al., 2015; Ornstein et al., 2015), depression (Ornstein et al., 2015), and a high mortality rate (Ankuda et al., 2021; Soones et al., 2017) making it a serious health risk. Many homebound older people report strong interests in participating in activities outside the home, including visiting friends and family, but their opportunities for doing so may be slight (Szanton et al., 2016) and thus they are at an increased risk for social isolation (Qiu et al., 2010). In addition to various health risks, restrictions in outdoor mobility potentially coincide with giving up activities that are meaningful for older individuals, such as visiting friends or relatives, which may predict decline in older people's quality of life (Rantakokko, Portegijs, et al., 2013).

2.1.2 The extent of mobility

Mobility refers to moving one's body position indoors and beyond the home using either the energy produced by muscles or with the help of a vehicle (Webber et al., 2010). Moving further away from home becomes especially more challenging with advancing age (Webber et al., 2010) and older people spend increasingly more time close to their homes. This manifests in a smaller life-space and lower levels of physical activity (Lounassalo et al., 2019; Rantakokko, Mänty, et al., 2013; Rantanen, 2013).

The extent of a person's mobility can be examined in relation to, for example, the different locations or zones in which the person moves, how far from home the person moves, and the number of trips away from home the person takes. The extent of mobility can be assessed using self-reported or map-based questionnaires, a global positioning system (GPS) or wearable devices, such as accelerometers (Taylor et al., 2019; Ullrich et al., 2022). Self-reported questionnaires are easy to implement, require low resources and provide valid assessments of both indoor and outdoor mobility (Ullrich et al., 2022). A GPS for instance enables calculation of the number of trips a person makes away from home and the total area travelled. Mode of travel, in turn, can be determined from the speed and place of travel (Taylor et al., 2019). Thus far, accelerometers have been used alongside a life-space mobility questionnaire to collect information on the amount of activity (Tsai et al., 2015).

Life-space mobility

Life-space mobility describes the geographical area within which one moves and the frequency and independence of that movement, and is currently receiving more and more attention in aging research (Johnson et al., 2020). Investigating life-space mobility in the field of gerontology started in the 1980s when May and colleagues (1985) developed the first questionnaire to assess the extent and frequency of mobility among community-dwelling older people. They defined life-space as "the area through which the subject moved in each 24-hour period" (May et al., 1985). Since then, life-space has been commonly structured into various zones, for instance taking bedroom as the central zone and then outwards into moving other rooms, own yard, neighbourhood, town and outside the town (Johnson et al., 2020; Taylor et al., 2019).

Life-space mobility is a broader concept than physical activity, as it encompasses any type of movement, including the use of transportation in addition to walking or cycling, etc. However, these two concepts are also related to each other. Most older people accumulate physical activity when they participate activities that necessitate going outdoors. These activities include for instance running daily errands and visiting family and friends (Davis et al., 2011; Tsai, Rantakokko, Viljanen, et al., 2016). Older people are more physically active on days when they go out of their homes, and their physical activity increases further if their movement extends beyond their home to their neighbourhood and further afield (Portegijs et al., 2015). Even trips that include using motorized transportation increase an individual's physical activity (Davis et al., 2011; Portegijs et al., 2015). In contrast, older people with restricted life-space mobility also have lower levels of physical activity (Tsai et al., 2015). Moreover, lower step counts and low levels of moderate physical activity predict restricted life-space mobility over two years (Tsai, Rantakokko, Rantanen, et al., 2016).

Self-report questionnaires and GPS technology make it possible to gather information about movement across different life-space zones (Taylor et al., 2019). In aging research, life-space mobility has typically been measured by using various self-report questionnaires (Baker et al., 2003; Hashidate et al., 2013; Stalvey et al., 1999). Life-space mobility questionnaires, with a few discrepancies, give estimates of a person's movement across life-space zones over a given period of time. Therefore, life-space mobility assessments have focused on the activities performed and the spatial extent of a person's movement in each environment rather than simply the physical ability to move. Thus, older people whose level of physical functioning is similar may differ in their life-space mobility, according, for instance, to their different preferences, physical and cultural environment, and access to transport (Taylor et al., 2019).

Life-space mobility can be assessed among community-dwelling older people with or without cognitive impairment and also in a nursing home setting (Ullrich et al., 2022). Since most of the empirical studies on life-space mobility have focused on community-dwelling older people, less is known about life-space mobility among nursing home residents (Sverdrup et al., 2021). Stalvey et al. (1999) developed the Life-Space Questionnaire (LSQ) to assess mobility across nine life-space zones from the participant's room to traveling abroad. The LSQ enquired about life-space mobility in the preceding three days without, however, taking into account its frequency or independence. The Life-space Assessment (LSA), developed by Baker et al. (2003), assesses life-space mobility as the spatial area in which an individual has purposely moved in daily life during the preceding four weeks, along with the frequency of moving and the level of independence in moving and is thus a more detailed measure of life-space mobility than the LSQ. The LSA is currently the most widely used measure of life-space mobility among older people and has been translated into at least 13 languages (Taylor et al., 2019; Ullrich et al., 2022). The LSA has been demonstrated to be sensitive to change over a 6-month follow-up period as well as to stability over a brief follow-up of 2 weeks. The LSA is, therefore, a suitable measure for investigating changes in life-space mobility over time (Baker et al., 2003). The LSA inquiries about the participant's life-space mobility during the previous four weeks, which is a relatively long period. This may complicate its use in studies focusing on short-term changes or targeting participants with cognitive impairment (Ullrich et al., 2022).

Previous empirical studies have investigated the associations of socio-demographic variables and important measures of physical functioning and health with life-space mobility among community-dwelling older people. Older age, female gender, and lower level of education have been associated with lower LSA scores (Peel et al., 2005; Snih et al., 2012). LSA correlates strongly for instance with the short physical performance battery (SPPB) score and with gait speed. Higher scores in SPPB and faster gait speed indicates greater life-space mobility (Kuspinar et al., 2020; Portegijs, Rantakokko, et al., 2014). Driving and social support, together with walking speed, were found to be the most significant determinants of life-space mobility in the Canadian Longitudinal Study on Aging, which had over 12 000 participants (Kuspinar et al., 2020). Longitudinal studies have shown life-space mobility to be a predictor of cognitive decline (Silberschmidt et al., 2017), falls (Lo et al., 2016), mortality (Kennedy et al., 2017), and quality of life (Rantakokko, Portegijs, et al., 2013).

Whereas the LSQ and LSA have been used to study life-space mobility among community-dwelling older people, the Nursing Home Life-Space Diameter (NHLSD) and Life-Space at Home (LSH) questionnaires are examples of measures that can be used when investigating older people at home or in a nursing home setting (Hashidate et al., 2013; Taylor et al., 2019; Tinetti & Ginter, 1990). The NHLSD questionnaire was created by Tinetti & Ginter (1990) to assess the extent and frequency of mobility and designed for proxy documentation by nurses. Studies using the NHLSD have found, for instance, associations of younger age, good physical performance, less severe dementia, the availability of staff, and good lighting and cleanliness with wider life-space mobility in a nursing home setting (Jansen et al., 2017; Sverdrup et al., 2021). Hashidate et al. (2013) developed the LSH questionnaire to gather information on the distances travelled by homebound patients. As in the NHLSD, the LSH scores are dependent on external factors, such as availability of assistive services in addition to physical functioning (Taylor et al., 2019). The LSA (Baker et al., 2003) has been further modified for use with clinical populations, such as older people with cognitive impairment (Life-Space Assessment in Persons with Cognitive Impairment, LSA-CI) (Ullrich et al., 2019) and nursing home residents (Life-Space Assessment in Institutionalized Settings, LSA-IS) (Hauer et al., 2020). The LSA-CI and LSA-IS enquire about the extent of mobility over a shorter period than the LSA, and are thus more suitable measures for populations with cognitive impairment (Ullrich et al., 2022).

Physical activity

Physical activity refers to any bodily movement that results in energy expenditure including movements occurring during leisure, work or domestic activities (Caspersen et al., 1985). Therefore, any type of active movement during daily life accumulates physical activity. In turn, physical inactivity typically refers to a situation where the individual does not meet the physical activity guidelines, or performs an insufficient amount of physical activity (Sedentary Behaviour Research Network, 2012). The World Health Organization's current guidelines for physical activity suggest that older people should engage in at least 150–300 minutes of moderate-intensity or 75–150 minutes of vigorous aerobic physical activity per week. The guidelines also recommend strength training at least twice per week and multicomponent physical activity (e.g., a combination of balance, strength, endurance, gait and physical function training) at least three days per week (Bull et al., 2020).

Staying physically active and accumulating more physical activity minutes during the day is associated with multiple health benefits across the lifespan (Bull et al., 2020). Among older people, the specific benefits of physical activity include reduced risk for mortality, recurrent falls, fractures, breast and prostate cancer, dementia, Alzheimer's disease, and depression (Cunningham et al., 2020). Physical activity also helps to maintain better quality of life, physical and cognitive functioning and independence in old age (Cunningham et al., 2020; Hirvensalo et al., 2000) and prevent loss in mobility ability (Brown & Flood, 2013; Simonsick et al., 2005). For instance, a large intervention study (Rejeski et al., 2005) among sedentary older people showed that moderate physical activity (combination of aerobic, strength, balance and flexibility exercises) including center- and home-based sessions improved 400-meter walking speed and reduced the risk for major mobility disability (LIFE Study Investigators, 2006).

Despite these well-known health benefits, the proportion of people reaching the physical activity guidelines tends to decrease with advancing age. According to the latest Finnish national health examination study, 42 % of adults aged 18–64 years reach the physical activity guidelines, whereas only 26 % of people aged 65 and older reach the sufficient level of physical activity (Wennman & Borodulin, 2021). Moreover, older people tend to favour lighter physical activities over moderate to vigorous activities (Schrack et al., 2014) and their daily activity is often fragmented. A more fragmented activity pattern means shorter bouts of activity and more frequent shifting from the active to sedentary state compared to a less fragmented activity pattern (Schrack et al., 2019).

Assessing physical activity requires information on the type, frequency, duration and/or intensity of physical activity (Kowalski et al., 2012; Strath et al., 2013). Assessments can be made for instance with self-report questionnaires and/or accelerometers (Kowalski et al., 2012; Schrack et al., 2016). Among older people, deficits in cognitive and physiological functioning challenge the assessment of physical activity. Therefore, choosing the appropriate tool for older people may be complex (Kowalski et al., 2012). Self-report measures rely on individuals' memory, as they typically enquire about the type of activity, along with its frequency, duration and intensity during a certain period of time (Dipietro et al., 1993; Strath et al., 2013), and hence the usability of such measures is questionable among people with cognitive impairments (Kowalski et al., 2012). However, questionnaires are widely used because they are not only practical and easy to administer in large study populations but also cost-efficient (Kowalski et al., 2012; Sylvia et al., 2014).

The use of accelerometers has become popular in studies targeting older people in recent decades (Kowalski et al., 2012). Accelerometers typically register acceleration in three planes (anteroposterior, mediolateral, and vertical). This information can be used to calculate bouts of movement and non-movement in free-living conditions (Sylvia et al., 2014). Accelerometers can provide information about variables, such as how many minutes a person accumulates light, moderate and vigorous physical activity or about the accumulation pattern of daily activity (Palmberg et al., 2020; Schrack et al., 2019; Skotte et al., 2014). However, accelerometer-based assessments of physical activity present certain methodological challenges. While accelerometer-recorded signals can be used to infer a wide range of different types of activity and the intensity of body-weight resistance activities, they have limited value in classifying activities that are not body-weight resistant, such as swimming and strength training. However, an advantage of accelerometers compared to self-reports is that, accelerometers can be used to identify the accumulation of light physical activity that is typical among older people and that has proven difficult to reliably recall (Schrack et al., 2016).

2.1.3 Autonomy in mobility

Autonomy can be defined as the *feeling that one is the origin of one's own behaviours* (Ng et al., 2012) and it is one of the basic psychological needs of humans (Ryan & Deci, 2000). The satisfaction of basic psychological needs is related to a higher quality of life and improved physical health (Ryan & Deci, 2000). Overall, autonomy contributes to the maintenance of life satisfaction, and thus autonomy is an essential goal of rehabilitation (Berg et al., 2006; Cardol et al., 2002). Autonomy is related to participation that can be described as *the involvement of an individual in life situations* (World Health Organization, 2002). Making decisions on own daily life is important for the health and wellbeing of older people (Flick et al., 2003).

Whilst older people's autonomy have been studied, for instance as perceived autonomy in residential care (Moilanen et al., 2021), fewer studies have addressed autonomy in mobility. Autonomy in mobility refers to a person's level of satisfaction with their opportunities to move and participate in out-of-home activities as they wish. Therefore, autonomy in mobility can be considered as optimal, when individuals perceive that they have control over making decisions concerning their mobility and possibilities to live their life as they want (Cardol et al., 2001). Among community-dwelling older people, deficits in autonomy most commonly concern physical activity, and especially mobility outside the home, due to decline in their physical and cognitive functioning (Wilkie et al., 2006). In some cases, restrictions on autonomy are preventable, and thus it is important to investigate the factors affecting autonomy in mobility among older people.

As autonomy in mobility refers to individuals' preferences, perceptions of their possibilities to move, and meeting their needs of movement (Berenschot & Grift, 2019; Cardol et al., 2002), it is often assessed by asking people how satisfied they are with specific situations in their lives. People perceiving restrictions in their autonomy in mobility are not generally satisfied with their current situation and would wish to increase their mobility. Therefore, a person's wishes and opportunity to move are important aspects of autonomy in mobility. In the present study, the autonomy outdoors subscale of the Impact on Participation and Autonomy (IPA) questionnaire (Cardol et al., 2001) and a questionnaire on unmet physical activity need (Rantakokko et al., 2010) were applied to assess autonomy in mobility.

The IPA questionnaire was originally developed in the Netherlands for investigating participation and autonomy as a rehabilitation goal in people with chronic diseases (Cardol et al., 2001). Empirical studies investigating autonomy in participation have mainly targeted people with disabilities, such as stroke, spinal cord injury, or multiple sclerosis (Fallahpour et al., 2011; Karhula et al., 2019; Palstam et al., 2019; Piatt et al., 2016). The IPA is a generic questionnaire with 31 items and five subscales that covers relevant life domains, such as domestic tasks, mobility, social life, and self-care. The autonomy outdoors subscale focuses on individuals' satisfaction with their ability to plan and pursue activities out of home. In the outdoors domain, individuals' are asked to evaluate their satisfaction with their possibilities to visit relatives and friends, make trips and travel, spend leisure time, meet other people, and live life the way they want (Cardol et al., 2001). According to previous studies, older age, poorer lower extremity function, and perceiving environmental barriers are associated with perceiving poorer autonomy in mobility (Portegijs, Rantakokko, et al., 2014; Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017; Wilkie et al., 2007). In contrast, despite perceiving functional decline, older people who persistently pursue their goals, but are also able to adapt their goals if needed, perceive higher autonomy in mobility (Siltanen et al., 2019).

The concept of unmet physical activity need represents lack of autonomy in physical activity. The introduction of the concept of unmet physical activity need arose from a critical appraisal of the feasibility of physical activity promotion among older people. It became obvious that many older people wanted to increase their physical activity but perceived themselves as having no opportunity to do so. This situation was named as unmet physical activity need (Rantakokko et al., 2010). Previous studies have shown that around 14 % of community-dwelling older people report unmet physical activity need (Eronen, von Bonsdorff, Törmäkangas, et al., 2014; Rantakokko et al., 2010) and that it is more prevalent among older people with walking difficulty, depressive symptoms and musculoskeletal diseases (Rantakokko et al., 2010). In addition, the accumulation of risk factors, including low socioeconomic status, self-reported walking difficulty and lack of social support increase the risk for unmet physical activity need (Eronen et al., 2012).

Unmet physical activity need differs from physical inactivity, although the two concepts are related. Lower neighbourhood mobility and lower levels of physical activity precede the development of unmet physical activity need (Palmberg et al., 2019). It has been suggested that unmet physical activity need is more prevalent among those whose physical activity levels have recently decreased (Rantakokko et al., 2010), indicating that older individuals' desire to be physically active does not disappear. Therefore, those experiencing unmet physical activity need could benefit from physical activity interventions as they already have a willingness to increase their physical activity (Rantakokko et al., 2010). However, owing to multiple factors that hinder their possibilities to increase their physical activity, such as physical limitations, environmental barriers or difficulty in accessing sport facilities, they require extra external support for this purpose (Eronen, von Bonsdorff, Törmäkangas, et al., 2014; Franco et al., 2015).

2.1.4 Physical environment and outdoor mobility

Outdoor mobility requires not only the ability move independently and safely from one place to another but also the ability to cope with challenges presented by the environment, such as, stairs, uphill or uneven surfaces. Thus, environmental factors are critical determinants of mobility in old age (Patla & Shumway-Cook, 1999). Older people accumulate most of their activity close to home, for instance during active travel to desired locations (Cerin et al., 2017; Davis et al., 2011; Tsai, Rantakokko, Viljanen, et al., 2016), and therefore the neighbourhoods environment, especially, has an influence on outdoor mobility among older people (Freedman, 2009; Yun, 2019). Environmental gerontology has explored the relationships between older people and their physical and social environment since the 1970s (Wahl & Weisman, 2003).

Research on the physical environment and outdoor mobility have largely focused on investigating the associations of the neighbourhood environment with total physical activity (Barnett et al., 2017) or simply with walking as active transport or as a recreational activity (Barnett et al., 2017; Cerin et al., 2017; Yun, 2019). In the aforementioned studies, environmental features have been measured as the availability of services, destinations in the nearby environment, the pedestrian infrastructure, traffic safety, walkability, residential density, and street connectivity (Barnett et al., 2017; Cerin et al., 2017; Yun, 2019). Some of these features of the environment can be assessed more directly by means of observational techniques, such as geographic information systems, whereas others can be assessed only from an individual's point of view through self-reported instruments (Orstad et al., 2017; Yun, 2019). Observational techniques aim at gaining knowledge on the actual environment, whereas the information on the perceived environment is affected for instance by individuals' past experiences and by personal capacity and social factors. The agreement between these observational techniques and self-report measures is only low to moderate, demonstrating the considerable difference in the information they give about the environment. For instance, environmental features perceived as supportive, such as parks, green spaces and safety, are more often associated with physical activity than environmental features measured using a geographic information systems (Orstad et al., 2017).

Environmental factors can facilitate or hinder outdoor mobility (Noreau & Boschen, 2010), depending on the individuals' functional capacity and preferences (Sakari et al., 2017). Individuals may differ in their perceptions of the same neighbourhood and living environment. For instance, hills in the nearby environment may serve some people as a training element for walking for fitness but hinder walking for others, such as older people (Eronen, von Bonsdorff, Rantakokko, et al., 2014; Sakari et al., 2017). It has been shown that community-dwelling older people who perceive a higher number of environmental mobility facilitators, such as peaceful walkways or nature in the nearby environment, have a lower risk for developing walking difficulty over time (Eronen, von Bonsdorff, Rantakokko, et al., 2014; Keskinen et al., 2018b; Portegijs et al., 2017). In addition, a safe, walkable and aesthetically pleasant neighbourhood may positively facilitate older people's out-of-home physical activity participation (Barnett et al., 2017). Moreover, physical activity has also been shown to be higher among older people with a favourable local pedestrian infrastructure, including the availability of resting places and more destinations, such as nearby recreational facilities or parks (Barnett et al., 2017; Cerin et al., 2017). In contrast, environmental demands that exceed a person's capacity are risk factors for the development of walking difficulty over time (Keskinen et al., 2018a; Rantakokko et al., 2011). For instance, poor conditions of streets or lack of resting places are associated with increased risk for developing walking difficulty over time (Keskinen et al., 2018a; Rantakokko et al., 2016). Moreover, certain other features of the environment, such as high curbs or poor street conditions may restrict a person's possibilities to participate in outdoor activities (Rantakokko et al., 2015; Rantakokko, Portegijs, Viljanen, Iwarsson, Kauppinen, et al., 2017).

COVID-19 pandemic restrictions as a global natural experimental setting

In spring 2020, restrictions caused by COVID-19 pandemic created a situation in which environmental facilitators for outdoor mobility were rapidly removed. Countries and regions all around the world implemented protective measures to slow down the spread of the SARS-CoV-2 virus causing COVID-19 and to protect high-risk populations from exposure to the virus. Older people over 70 years of age were especially advised to distance themselves socially from other people, including their relatives and friends. While unfortunate, these circumstances offered an opportune natural experimental setting (Thomson, 2020).

A dictionary of epidemiology defines a natural experiment as follows: "Naturally occurring circumstances in which subsets of the population have different levels of exposure to a hypothesized causal factor in a situation resembling an actual experiment" (Porta, 2014). In a natural experiment, exposure to the factor of interest has changed temporally or permanently for reasons outside of researcher's control. Natural experimental conditions usually occur in ordinary life, and can, therefore, lead to changes in individuals' behaviour (Thomson, 2020) as well as to the normally occurring associations.

Such changes in the living environment are generally rare and slow, which makes them difficult to investigate. During the COVID-19 pandemic restrictions, individuals' opportunities to participate in out-of-home activities were severely restricted. This provided an opportunity to study how withdrawing environmental support for outdoor mobility and participation influenced different aspects of mobility among older people. This experiment would otherwise have been unethical and unfeasible to conduct as part of a researcher-initiated project.

2.2 Walking and walking modifications in old age

2.2.1 Age-related changes in walking

Walking enables moving from one place to another without a vehicle, and it is the most common physical activity among older people (Szanton et al., 2015). *Gait* is the medical term for walking and is often used when referring to the manner or style of walking (Beauchet et al., 2017). Walking requires the integrated functioning of multiple organ systems and has two essential prerequisites: the capacity to maintain an upright posture and balance (*equilibrium*), and the ability to start and maintain rhythmic stepping (*locomotion*) (Nutt et al., 1993).

In adults, walking typically consists of repeated gait cycles. Gait cycles include the stance phase, swing phase, double-leg stance, and single-leg stance. In a gait cycle, one leg is always in contact with the ground, and there are two periods of double and single leg support. Spatiotemporal gait parameters include base width, step length, stride length, cadence, and gait speed. Base width is the distance between the two feet, and it normally ranges from 5 to 10 cm. Step length is the distance between the first contact of one foot and the initial contact of the opposite foot. Step length is approximately 72 cm, varying by sex, age, and height. Normally, the right and left step lengths are equal. Stride length is the distance of one gait cycle, i.e., linear distance of the foot-to-foot contact of the same foot. Stride length is normally about 144 cm. Cadence refers to the number of steps taken within a certain period of time and normally varies between 90 to 120 steps per minute. Gait speed is usually measured as meters (m) per second (s), and normal gait speed is approximately 1.4 m/s (Magee, 2008).

The majority of people learn to walk independently during the first two years of life (Malina, 2004). The general motor developmental changes leading to walking during infancy include several stages from controlling the head and upper trunk to standing without support. At first, infants balance walking by, for instance, stretching out their arms and by having a wide base of support (Malina, 2004). During the first months of walking, many gait characteristics, such as stride length and joint motions change rapidly and walking becomes more and more stable (Kermoian et al., 2005). Mature walking is typically achieved at the age of 7 (Kermoian et al., 2005; Magee, 2008), meaning that walking becomes more predictable and the rates of changes in gait parameters decrease (Kermoian et al., 2005). From that time on, and throughout midlife, walking remains rather stable and automated (Butler et al., 2005) and typical phases of walking and normal spatiotemporal gait parameters can be observed (Magee, 2008). However, certain special conditions, such as pregnancy, alcoholism, or musculoskeletal or neural disorders may cause changes in gait parameters also during midlife before age-related changes in walking occur (Butler et al., 2005).

Age-related changes in gait parameters have typically been assessed by visual observation (Nutt et al., 1993) or using standardized clinical tests, such as the Timed Up & Go test (Podsiadlo & Richardson, 1991) in a clinical setting. However, these measures have their limitations. Visual observation is highly dependent on the experience of the individual performing the test (Kressig & Beauchet, 2006), whereas both visual observation and Timed Up & Go fail to capture information about changes in all of the spatiotemporal gait parameters (Beauchet et al., 2017). The use of advanced technology-based gait assessment methods has become more common over the last few decades. These gait analysis systems include pressure sensitive floor sensors, which requires a laboratory setting (e.g., the GAITRite® system), and wearable sensors, such as accelerometers, which can be used in a free-living setting to capture information about gait characteristics (Beauchet et al., 2017).

The first age-related changes in walking and in gait characteristics occur typically around the ages of 60–70 years (Butler et al., 2005; Ferrucci et al., 2016). For instance, poor muscle strength and balance, poor cognition, obesity, and chronic pain may coexist and increase the risk for changes in gait and perceived walking difficulty (Anton et al., 2015; Ferrucci et al., 2016; Siltanen et al., 2018; Simonsick et al., 2008). Older people typically compensate for functional deficits by a wider base width, shorter step length and decreased cadence and gait speed compared to younger people (Butler et al., 2005). A recent study showed that people over 85 years old had a shorter stride length (101 cm vs. 138 cm) and a slower walking speed (0.9 m/s vs. 1.3 m/s) compared to people aged 65 to 75 years (Beauchet et al., 2017). Lower walking speed predicts disability in activities in daily living (Heiland et al., 2016). Studenski et al. (2011) reported in a pooled analysis of nine cohort studies (total 34 485 participants aged 65 or older) that every 0.1 m/s increase in gait speed was associated with higher odds for survival. The smallest meaningful change in gait speed in relation to perceived walking difficulty among older people with mild to moderate mobility deficits has been suggested to be 0.05 m/s (Perera et al., 2006).

2.2.2 Progression of walking limitation

The timing and duration of walking limitation varies widely between individuals. Developing walking difficulty can be a slow process stemming from gradual functional decline, or an acute event resulting from a catastrophic occurrence. The slow development of walking difficulty is typically a consequence of a worsening health conditions, such as arthritis, whereas the sudden onset of walking difficulty can be a result of a traumatic event, such as a fracture or a stroke (Guralnik et al., 2001). The progression of walking limitation can also be seen as a dynamic process that includes periods of decline and recovery (Gill et al., 2006). In light of the volume of individual adversities and of the burden on public health systems associated with walking difficulty, detecting walking difficulty among older people during the early or preclinical stage is important for implementing preventative measures and interventions (Chaves et al., 2000; Rivera et al., 2008).

The progression of walking limitation can be assessed for instance through performance-based measures, such as gait speed, or through self-report measures. Gait speed can be measured in a standardized environment, and thus yields information that is comparable across countries (Rantakokko, Mänty, et al., 2013; Rantanen, 2013). However, measuring gait speed, especially in a laboratory setting, may be too time-consuming in large studies and in a clinical setting. Therefore, epidemiological studies on the mobility of older people have often relied on self-reports of difficulty in walking specific distances, e.g., across a small room, 500 meters, or longer distances, such as 2 km (Chung et al., 2015). Level of difficulty in walking certain distances is an important, reliable, and widely used indicator of walking limitation in large epidemiological aging studies, such as the Invecchiare in Chianti; Aging in the Chianti area (InCHIANTI) study (Ferrucci et al., 2000), Women's Health and Aging Study (WHAS) study (Guralnik, Fried, et al., 1995), and Established Populations for Epidemiologic Studies of the Elderly (EPESE) (Cornoni-Huntley et al., 1993).

Perceived difficulty in walking shorter distances (e.g., 400 or 500 meters) is a critical level that threatens the ability to walk outdoors and run daily errands independently (Hardy et al., 2011). Perceived difficulty in walking longer distances (e.g., 2 km), is an early indicator of functional decline preceding further disability and dependence (Mänty et al., 2007). The validity of perceived walking difficulty is supported by its associations with multiple adverse health events, such as higher risk for repeated falls, dependency, higher mortality rates, institutionalization, and higher health care costs (Hardy et al., 2011; Hirvensalo et al., 2000; Leskinen et al., 2015; Mutikainen et al., 2011; Tinetti et al., 1995; Viljanen et al., 2021). In addition, walking difficulty is associated with more restricted life-space mobility and lower levels of physical activity (Manns et al., 2015; Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017).

Perceiving walking difficulty increases with increasing age (Ferrucci et al., 2016; Satariano et al., 2012; Shumway-Cook et al., 2005; Simonsick et al., 2008). This was clearly shown in the latest FinHealth Study, which has a representative sample of adults residing in Finland. The results revealed that the prevalence of people perceiving difficulty walking 500 m was 10 % among those aged 60–69, 30 % among those aged 70–79, and 50–70 % among those aged 80 and over (Sainio et al., 2018). Perceiving walking difficulty is more common among women than among men (Sainio et al., 2018). In two cohort studies conducted in Finland, the prevalence of persons reporting difficulty in walking 2 km varied from 36 % to 42 % among community-dwelling older people with a mean age of 81 years

(Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017; Siltanen et al., 2018).

The advantages of self-reported measures of walking difficulty are that they are easy to administer, less time-consuming than objective measures and cost effective (Chung et al., 2015). In addition, self-reported measures give valuable information about an older person's everyday life, since it is based on their evaluation of their walking in their own living environment (Rantanen, 2013). However, the reasons for perceiving walking difficulty might vary. For instance, a previous study showed that the most common reasons for reporting walking difficulty in covering a quarter mile were the need to change the frequency of walking or way of walking (Gregory & Fried, 2003). Thus, some people may perceive that they have walking difficulty when they need to change their way of walking, whereas others may perceive walking difficulty only then when they are unable to walk. Similarly, people who report no walking difficulty show great variability (Fried et al., 1996). Some may be highly active while others may already be experiencing the early signs of physical decline, which may manifest as *walking modifications*, such as using an aid, lowered walking speed or resting in the middle of walking without perceiving themselves as having walking difficulty (Fried et al., 2000; Mänty et al., 2007). This finding led to a new line of research that also evaluates the use of walking modifications among older people who do not perceive walking difficulty but nevertheless are at the preclinical stage (Figure 2). Older people using walking modifications are an interesting and important research topic, since they are already in the early phases of mobility decline and would, therefore, potentially benefit the most from preventive interventions (Rantanen, 2013). Recent studies have also suggested that walking modifications may also be used to avoid perceived walking difficulty when experiencing minor functional decline (Higgins et al., 2013). Therefore, in recent years, studies investigating walking modifications from the adaptive or compensatory point of view have also emerged.

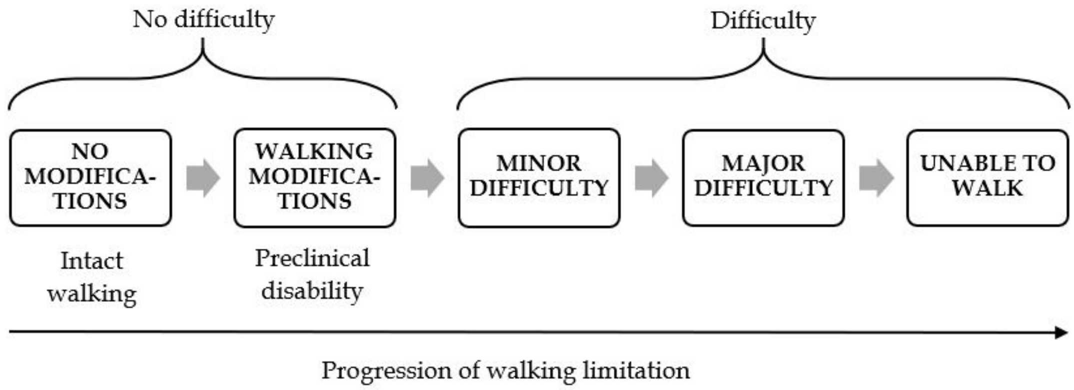

FIGURE 2 Progression of walking limitation in old age. Modified from Mänty et al. (2007). Older people using walking modifications form an intermediate group in physical functioning or disease level between high-functioning older people with intact walking and those perceiving walking difficulty (Fried et al., 2001; Mänty et al., 2007). Consequently, using walking modifications can be considered a preclinical disability marking a stage between intact walking and walking difficulty that predicts walking difficulty over time (Fried et al., 2000, 2001; Nicolson et al., 2021).

2.2.3 Walking modifications

Walking modifications are referred by various terms, such as compensatory strategies, adaptations, or task modifications in theoretical models and empirical studies. Nevertheless, their definitions and changes in behaviour they describe are very similar. Typically, modifications are seen as something not normally done by healthy people when performing certain activities, meaning that the individual has changed their way of doing the activity in question (Weiss et al., 2007). Older people use multiple modifications in their daily lives in order to cope with a physical impairment or other detrimental changes in the environment or in personal factors (Gitlin et al., 2017; Higgins et al., 2013) to maintain preferred activities and to prevent losses (Ebner et al., 2006). Modifications are responses to task demand and can have two opposite meanings: on the one hand they can help with striving for independence (Gitlin et al., 2017) and on the other they indicate risk for poor health outcomes (Weiss et al., 2012). Previous empirical studies among older people have investigated modifications in different activities, such as in changing body position (Manini et al., 2006), walking certain distances, climbing a flight of stairs (Naugle et al., 2012; Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017) or taking care of oneself (Gignac et al., 2000). The present study focuses on the use of walking modifications among community-dwelling older people.

The use of compensatory strategies and modifications has been acknowledged as a positive process (Baltes & Baltes, 1990; Lang et al., 2002). However, the study of walking modifications originally started from the need to determine the preclinical stage of disability prior to designing and implementing effective interventions to prevent walking difficulty among older people (Fried et al., 2000). Thus, the use of walking modifications was studied by asking people who do not yet perceive difficulty in walking whether they have somehow changed their way of walking (Fried et al., 2000; Mänty et al., 2007). The prevalence of using walking modifications ranges from 30 % to 40 % of older people who do not perceive walking difficulty (Fried et al., 1996; Wolinsky et al., 2005). Typically, older people report having reduced their walking speed, needing to rest during walking longer distances or using a walking aid. Of these walking modifications, the most commonly reported is slower walking speed (Rantakokko et al., 2016; Weiss et al., 2012) and the least reported is giving up walking certain distances (Rantakokko et al., 2016).

Higgins et al. (2013) suggested that modifications can be categorized into *intrinsic* and *extrinsic* compensation strategies. Intrinsic compensatory strategies include, for instance, walking at a slower pace and leaning on a handrail while climbing stairs, and require movement modification strategies (internal factors) within a given environment in order to continue participating in an activity (Higgins et al., 2013). Most walking modifications, such as reducing walking speed or the frequency of walking, can be intuitively categorized as intrinsic compensatory strategies. Extrinsic compensatory strategies, in turn, consist of adaptations that require modifying the environment, such as using assistive devices or asking for assistance (external factors) (Higgins et al., 2013).

Although it is recognized that walking modifications comprise a wide variety of strategies (Higgins et al., 2013), the use of walking modifications has often been categorized as simply their presence vs. absence without considering the actual strategies used. A binary categorization does not distinguish between whether specific requirements are attached to the use of different modifications or whether some modifications lead to more or to less activity (Weiss et al., 2007). It is also possible that older people adopt specific modifications in accordance with their functional status, suggesting that compensatory modifications may be adopted in a particular order (Higgins et al., 2013; Weiss et al., 2007). It has been suggested that older people facing the early signs of functional decline prefer to use intrinsic modifications in the first instance, but that once their health condition worsens, they may need to use extrinsic strategies if they wish to continue a desired activity. Assistance from other people is the most extensive type of compensation strategy (Higgins et al., 2013) and can already be perceived as severe difficulty in doing a given task (Gregory & Fried, 2003).

While several studies have investigated the determinants of perceived walking difficulty, fewer data have been published on the determinants of using walking modifications. Lower-extremity muscle weakness has been associated with daily task modifications including walking modifications (Hoenig et al., 2006; Marko et al., 2012). Obesity has also been associated with modifying tasks that involve use of the lower body or the transfer of body weight, such as from kneeling to standing, and ascending or descending stairs (Naugle et al., 2012). Apart from physical capacity, a previous study showed that among high-functioning older women, lower education (less than nine years) was associated with the use of walking modifications independent of chronic conditions and living arrangements (Gregory et al., 2011).

Although it has been suggested that the modifications chosen may reflect, for instance, a person's capabilities, access to resources, preferred approach to performing the activity, and environmental possibilities (Gitlin et al., 2017), the process of selecting walking modifications remains unknown and hence warrants further study. However, it seems reasonable to assume that since the use of walking modifications precedes perceived walking difficulty over time (Weiss et al., 2012), the risk factors prior to perceiving walking difficulty may be the same. Walking modifications occur when older people experience the early phases of functional decline (Lien et al., 2015) whereas walking difficulty is usually perceived by people whose functional decline is more advanced (Fried et al., 2001). It can, therefore, be suggested that the more resources older people have, the better will be their capacity to use adaptive strategies, even if they are experiencing losses.

2.3 Theoretical models explaining mobility and environmental factors

The National Health and Aging Trends Study (NHATS) Disability Conceptual framework was developed to serve researchers studying late-life disability by blending the disablement process model and the language provided by the World Health Organization's International Classification of Functioning, Disability and Health (ICF) (Freedman, 2009; Verbrugge & Jette, 1994; World Health Organization, 2002). According to the disablement process model, pathology (e.g., diseases, injuries) leads to impairments (e.g., system dysfunctions, structural abnormalities), and hence to the development of functional limitations (e.g., restrictions in performing fundamental physical and mental activities). Functional limitations, in turn, lead to disability (Verbrugge & Jette, 1994). Similarly, the ICF offers a language and a framework for the description of health and disability at both the individual and population levels (World Health Organization, 2002). It extends the disablement process model by presenting both positive and negative aspects of functioning and disability in a more neutral language. The ICF comprises three interacting components 1) Body functions and structures; 2) Activities; and 3) Participation. These interrelate with a person's state of health as influenced by both environmental and personal factors. Thus, the ICF illustrates what a person with a specific health condition can do in a standard environment (level of capacity) and what the person actually does in their usual environment (level of performance) (World Health Organization, 2002).

The NHATS framework extends the previous models in a few noteworthy ways. First, the ICF term capacity is highlighted in the model to refer to an individual's capabilities to carry out different activities, such as mobility, learning and communicating. In addition, new domain termed "accommodations", defined as behavioural responses to changes in capacity, has been added to the NHATS framework. Accommodations include the use of different compensatory strategies, such as doing an activity differently, receiving help or using assistive devices. Furthermore, the framework distinguishes the ability to carry out activities from participation. Lastly, the NHATS framework, as in the ecological model of aging (Lawton & Nahemow, 1973), recognizes the role of the environment in the entire disablement process (Freedman, 2009). In the NHATS framework, accommodations capture strategies that are related to individual behaviour or to the environment. Changes in a behaviour include doing the activity less frequently, differently, or more slowly. Changes in the environment include receiving help, using assistive devices, and installing handrails, ramps or other modifications to the home. All the modifications used are responses to changes in a specific physical capacity or in a person's living environment and can help maintain the person's ability to carry out essential activities and participation (Freedman, 2009; Kasper & Freedman, 2020).

Compared to the disablement process model and ICF model, the ecological model of aging, presented by Lawton and Nahemow (1973), has focuses on the person-environment relationship. According to the model, as also in both the disablement process model and the ICF model, human behaviour is dependent on personal capabilities and competencies and on the individual living environment. Individual competence refers to a person's functional capacity, whereas the environmental component includes various aspects of the living environment, such as the physical and personal environment. Based on the model, older people with lower competence are more prone to environmental press, such as obstacles or barriers in the living environment, than those with higher competence. The ecological model of aging recognizes individuals' ability to adapt and change their behaviour by presenting two main behaviours: adaptive behaviour and maladaptive behaviour. In adaptive behaviour, physical competence and environmental demands are balanced, and the individual is able to continue carrying out valued tasks. In contrast, a situation in which environmental demands exceed individual capacity may lead to maladaptive behaviour, manifested as doing things less often or avoiding some tasks (Lawton & Nahemow, 1973).

According to the ecological model of aging, older individuals continuously adapt their behaviour owing to changes in their personal competence and the demands of the physical environment (Lawton & Nahemow, 1973). Selective optimization with compensation (SOC) model, presented by Baltes and Baltes (1990) has similar perspective. Overall, the SOC model offers a framework for understanding developmental change and resilience throughout the lifespan. According to the SOC model, older people respond to physical, social, and psychological functional losses with three types of adaptive behaviours: selection, optimization, and compensation. Selection refers to doing things less often or losing functions; optimization is about learning new ways to achieve goal-related success; and compensation is about maintaining desired functional outcomes in response to losses (Baltes & Baltes, 1990).

Recently, Gore et al (2018) presented a novel framework, the compression of functional decline (CFD) that describes age-related functional decline in the context of behavioural changes that can be used to postpone disability to a later phase. This conceptual approach to coping with functional decline comprises four stages which should be undertaken in a specific order. The first stage, called protection against decline, emphasizes, for instance, the importance of exercise training in coping with loss of muscle mass. In the second stage, re-activation, the focus is on ability, such as walking certain distances. In this stage, exercise should be targeted to improve the ability to walk. In the third stage, compensatory technology, such as walking aids or home modifications, can be used to maintain activity. Finally, personal support might be needed in order to run daily errands. This final stage should be postponed via the previous stages for as long as possible in order to minimize the time spent in it (Gore et al., 2018).

2.4 Study framework

The present study investigated older people's use of walking modifications and how this is related to mobility patterns, the extent of mobility and autonomy in mobility. The complex relationships between the environment and individuals' behaviour, the associations of environmental characteristics with using walking modifications or perceiving walking difficulty were also investigated. Walking modifications were examined from two perspectives: as a sign of preclinical disability (Fried et al., 1991) and as modifications. The study framework was based mainly on the NHATS Disability Conceptual Framework (Freedman, 2009). The ecological model of aging (Lawton & Nahemow, 1973), and the model of selective optimization with compensation (Baltes & Baltes, 1990) were also utilized as central models of the person-environment relationship and use of modifications in old age.

The study framework is presented in Figure 3. The study framework assumes, that despite the decline in personal competencies that accompany aging, the extent of a person's mobility can be maintained by lowering the environmental demands, and/or by reducing the task demands by walking modifications. As physical functioning declines and environmental press increases, individuals may modify their behaviour in order to decrease the task demands of valued activities (*adaptive behaviour*), thereby minimizing their losses in those activities, or they may give up doing a task altogether or reduce its frequency (*maladaptive behaviour*) (Freedman et al., 2016; Lawton & Nahemow, 1973). Drawing on features of all of the previously presented models, a person's selection of particular walking modifications or perception of walking difficulty may reflect, e.g., the person's capabilities, access to resources, preferred approach to performing an activity and environmental opportunities (Baltes & Baltes, 1990;

Freedman, 2009; Lawton & Nahemow, 1973; Verbrugge & Jette, 1994; World Health Organization, 2002).

Walking modifications are typically assessed using self-reports. Self-reported walking modifications have been shown to reflect intermediate levels of walking speed and muscle power (Mänty et al., 2007). Research to date has not investigated how the self-reported use of walking modifications manifest in older people's free-living walking as measured with accelerometers. To explore whether self-reported walking modifications are manifested in free-living walking, the associations between walking modifications and daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity and activity fragmentation were investigated in this dissertation research project. Moreover, while previous empirical studies have focused on the associations between personal factors and the use of walking modifications (Freedman et al., 2016; Hoenig et al., 2006), little attention has been paid to the associations between the perceived neighbourhood environment and the use of walking modifications. Adaptations in everyday tasks require not only capabilities from the individual but also a suitable environment (Lang et al., 2002). For instance, if the environment is demanding, people with no evident physical decline may also need to adopt compensatory strategies in their walking activities (Weiss et al., 2007). Based on the ecological model of aging (Lawton & Nahemow, 1973) and disablement process model (Verbrugge & Jette, 1994), it has been hypothesized that the perceived outdoor environment is related to the use of adaptive and maladaptive walking modifications.

This study highlights the adaptive aspect of walking modifications, whereas previous studies have focused on walking modifications as signs of preclinical disability. It is currently unknown if walking modifications lead to less or more activity (Weiss et al., 2007). To explore whether some walking modifications influence outdoor mobility more favourably than others, self-reported modifications in walking a distance of 2 km were categorized into adaptive (e.g., reduced pace, using an aid, resting in the middle) and maladaptive (reduced frequency or giving up doing the task) walking modifications. The aim of this categorization was to investigate whether people made changes to their walking behaviour that allowed them to continue walking 2 km vs. whether they gave up walking 2 km altogether or reduced their frequency of walking 2 km. This categorization was inspired by the ecological theory of aging (Lawton & Nahemow, 1973) and the SOC model (Baltes & Baltes, 1990). Furthermore, the associations of walking modifications with the extent of mobility and autonomy in mobility were studied during the normal aging process and during COVID-19 pandemic restrictions.

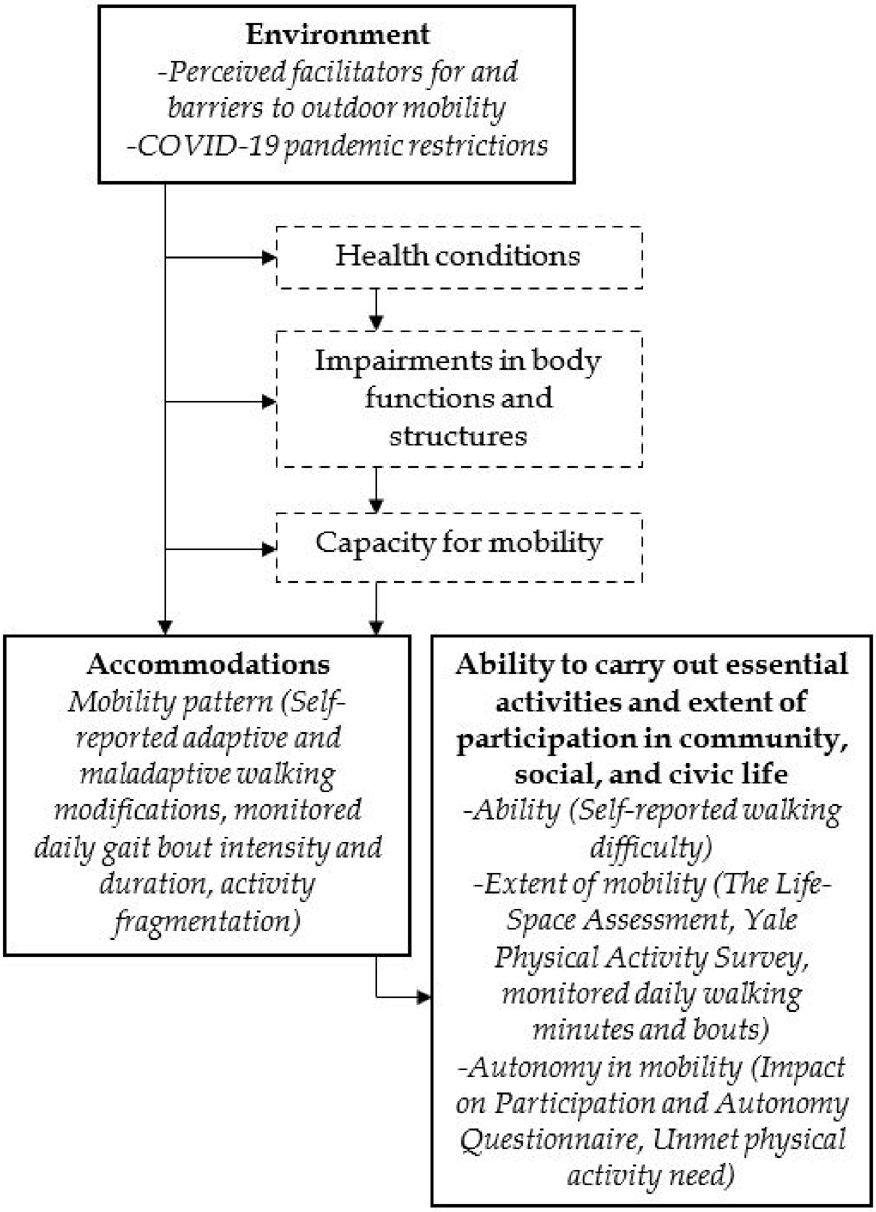

FIGURE 3 Conceptual framework of the study, modified from the NHATS Disability Conceptual Framework (Freedman 2009). This study investigates the associations between the environment, accommodations, the ability to carry out essential activities, and the extent of participation in community, social and civic life (text boxes with solid outline). Health conditions, impairments in body functions and structures and capacity for mobility precede accommodations and changes in mobility, but they were not investigated specifically in this study (text boxes with dashed outline).

3 PURPOSE OF THE STUDY

The purpose of the study was to explore the contribution of walking modifications to the extent of mobility and autonomy in mobility in old age. To explore whether self-reported walking modifications are reflected in free-living walking, the associations of walking modifications with accelerometer-based daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity and activity fragmentation were investigated. The associations between perceived environmental factors and use of walking modifications were investigated to evaluate the role of the environment in the selection of adaptive or maladaptive walking modifications. To gain understanding on the compensatory aspect of walking modifications, walking modifications were categorized into adaptive and maladaptive walking modifications. The associations of walking modifications with the extent of mobility, and autonomy in mobility were investigated during the normal aging process and during the period when environmental facilitators for outdoor mobility were limited due to the COVID-19 pandemic restrictions. The specific research questions were:

1. How are accelerometer-based free-living walking patterns reflected in the self-reported use of walking modifications and perceived walking difficulty? (Study I)

2. Are environmental factors associated with the use of adaptive or maladaptive walking modifications in old age? (Study II)

3. Do adaptive and maladaptive walking modifications have different consequences for life-space mobility, autonomy in participation outdoors and unmet physical activity need over time? (Study III)

4. To what extent did intact walking, walking modifications or walking difficulty predict changes in life-space mobility, autonomy in participation outdoors, and self-reported physical activity during the COVID-19 pandemic restrictions compared to the preceding two years? (Study IV)

4 METHODS

4.1 Datasets and study designs

The data for this dissertation were drawn from two research projects: Life-Space Mobility in Old Age (LISPE) and Active Ageing – Resilience and External Support as Modifiers of the Disablement Outcome (AGNES). The AGNES study includes datasets on the AGNES cohort, AGNES cohort sub-study and AGNES-COVID-19 study. The AGNES cohort sub-study includes participants who agreed to wear accelerometers in addition to participating in the other baseline measurements. In both research projects, the participants were community-dwelling older people. The datasets, study designs, and number of participants are summarized in Table 1.

TABLE 1 Datasets, study designs, and participants in the different studies.

Study	Dataset	Study design	N (data collection years)	Average follow-up
I	AGNES cohort sub-study	Cross-sectional cohort study	n = 496 (2017–2018)	-
II & III	LISPE	Longitudinal prospective cohort study	Baseline n = 848 (2012) Follow-up n = 761 (2014)	2 years
IV	AGNES cohort & AGNES-COVID-19	Longitudinal prospective cohort study	Baseline n = 1021 (2017–2018) Follow-up n = 809 (2020)	2 years

4.1.1 Active Ageing – Resilience and External Support as Modifiers of the Disablement Outcome (AGNES, Studies I & IV)

AGNES cohort

AGNES was a population-based observational cohort study conducted between autumn 2017 and spring 2018 (Rantanen et al., 2018). Power calculations made for the primary outcomes indicated a sufficient sample size of 1 000. A random sample of individuals based on three age cohorts (75, 80 and 85 years) and resident in specific Jyväskylä postal code areas was drawn from the Population Information System administered by the Digital and Population Data Services Agency. The inclusion criteria for the study were living in the study area (Jyväskylä), being community-dwelling, being willing to participate, and being able to communicate and provide an informed consent. After exclusions, 1 021 participants consented to a face-to-face computer-assisted structured interview in their homes (Portegijs et al., 2019).

AGNES cohort sub-study (Study I)

AGNES cohort sub-study includes 496 participants who agreed to wear thigh-worn accelerometers (Portegijs et al., 2019). The data of AGNES cohort and AGNES cohort sub-study was used in Study I to investigate the cross-sectional associations between accelerometer-based free-living walking and self-reported walking. Only participants with adequate accelerometer data (≥ three days) and information on self-reported walking modifications and difficulty were included to the analyses (n = 479).

AGNES-COVID-19 (Study IV)

AGNES-COVID-19 data were collected via postal questionnaires in May and June 2020 during the COVID-19 pandemic restrictions (Rantanen et al., 2021). The questionnaire was sent to the 985 AGNES cohort participants who had not withdrawn their consent and who had responded either to the questionnaire or to the home interview at baseline. In cases where the participant had difficulty in answering the questionnaire or preferred an interview, a telephone interview was conducted. In the end, data were obtained from 809 participants (including seven phone interviews). In Study IV, the AGNES-COVID-19 data were compared to the AGNES baseline data in order to investigate changes in life-space mobility, autonomy in participation outdoors, and physical activity during the COVID-19 pandemic restrictions according to self-reported walking modifications and walking difficulty. Of the participants who responded to the AGNES-COVID-19 questionnaire, 797 had valid baseline data on self-reported walking modifications and difficulty and thus were included in the longitudinal analyses.

4.1.2 Life-Space Mobility in Old Age (LISPE, Studies II & III)

LISPE was a 2-year prospective cohort study conducted between the years 2012–2014 (Rantanen et al., 2012). The purpose of the LISPE study was to investigate the associations of the home and physical environment of older people with their health, physical functioning, disability, quality of life, and life-space mobility. The study targeted community-dwelling people aged 75 to 90 years whose personal data were extracted from the Population Information System (Digital and Population Data Services Agency) based on their age and residence in the municipalities of Jyväskylä and Muurame in Central Finland (age-stratified random sample N = 2 550). Based on power calculations made for the primary outcomes (e.g., life-space mobility), a sufficient sample size was estimated to be 800. Based on a preliminary review of potential participants' addresses, those living in assisted living facilities were excluded. In total, 2 269 persons were contacted to enquire about their willingness to take part in the study. Inclusion criteria were community-dwelling in the study area, willing to participate, and able to communicate and provide a written informed consent. After exclusions, 848 participants were interviewed face-to-face in their homes at baseline and 761 took part in the 2-year follow-up (drop-out rate 10 %). All the baseline interviews were conducted using a structured computer-assisted personal interview. At follow-up, participants were interviewed over the telephone. Participants who were unable to answer questions via the telephone were offered a face-to-face interview.

Cross-sectional and longitudinal data from LISPE were used in Studies II and III. In Study II, the cross-sectional analyses included 764 participants with data on the use of walking modifications and perceived environmental outdoor mobility facilitators and barriers at baseline. In addition, to study the associations between perceived environmental outdoor mobility facilitators and barriers and the incidence of adaptive walking modifications over time, only participants without walking modifications at baseline were included in analyses (n = 218). Similarly, the incidence of maladaptive walking modifications was studied only among those without maladaptive modifications at baseline (n = 610).

In Study III, the associations between the use of adaptive and maladaptive walking modifications and changes in life-space mobility, autonomy in participation outdoors and unmet physical activity need over time were investigated. Participants who died during the follow-up (n = 41) or had been admitted to institutional care (n = 15) were excluded from the analyses. The final model comprised 792 participants in the life-space mobility and autonomy in participation outdoors analyses and 787 participants in the unmet physical activity need analysis.

4.2 Ethics

The study protocols of the LISPE and the AGNES studies have followed the good scientific and clinical practices laid out by the Declaration of Helsinki. All the study participants were older adults, and all were informed about the study orally and provided with a written description of the study before signing an informed consent form. Participation was voluntary.

The ethical statement for the LISPE study was approved by the Ethical Committee of the University of Jyväskylä on 2 November 2011, and for the AGNES study by the Ethical Committee of the Central Finland Health Care District on 23 August 2017 and on 13 May 2020. The principles of the European Union's General Data Protection Regulation (GDPR) were followed in the AGNES study. The GDPR was adopted on 14 April 2016, and it came into force on 25 May 2018.

4.3 Measurements

All the study outcomes and independent variables are presented in Table 2.

TABLE 2 Summary of outcomes and independent variables.

Variable	Study	Methods and reference
Environment		
Barriers to outdoor mobility	II	Self-reported (Rantakokko et al., 2014)
Facilitators for outdoor mobility	II	Self-reported (Rantakokko et al., 2015)
COVID-19 pandemic restrictions	IV	Measures to address the coronavirus outbreak (Finnish Government, 2020)
Mobility pattern		
Walking modifications in 2 km	I, IV	Self-reported (Mänty et al., 2007)
Adaptive and maladaptive walking modifications in 2 km	II, III	Self-reported
Number of daily walking bouts, daily walking bout duration and intensity	I	Monitored, UKK RM 42 tri-axial accelerometers (Portegijs et al., 2019; Skotte et al., 2014)
Activity fragmentation	I	Monitored, Active-to-Sedentary Transition Probability (ASTP), UKK RM 42 tri-axial accelerometers (Palmberg et al., 2020; Schrack et al., 2019)
Ability to move		
Difficulty in walking 2 km	I, IV	Self-reported (Mänty et al., 2007)
Extent of mobility		
Life-space mobility	III, IV	Self-reported, Life-Space Assessment (LSA) composite score (Baker et al., 2003)
Physical activity	IV	Self-reported, Yale Physical Activity Survey (YPAS) (Dipietro et al., 1993)
Daily walking minutes	I	Monitored, UKK RM 42 tri-axial accelerometers (Portegijs et al., 2019; Skotte et al., 2014)
Autonomy in mobility		
Autonomy in participation outdoors	III, IV	Self-reported, Impact on Participation and Autonomy (IPA), outdoors subscale (Cardol et al., 2001)
Unmet physical activity need	III	Self-reported (Rantakokko et al., 2010)

4.3.1 Perceived environmental barriers to and facilitators for outdoor mobility

Environmental factors relating to the use of adaptive and maladaptive walking modifications were investigated in Study II. Perceived environmental barriers to outdoor mobility were studied at baseline with a standardized questionnaire (Rantakokko et al., 2014) comprising 15 environmental barriers to outdoor mobility. Participants were asked to report all the listed features in their living environment that they perceived as hindering their outdoor mobility (present/absent). In the analyses, environmental barriers were used individually and also as clusters recoded into three groups. The subgroups were nature (hills in the nearby environment and snow and ice in winter); infrastructure (poor street conditions, high curbs, lack of sidewalks, long distances to services, lack of benches during summer or winter, and poor lighting); and safety (noisy traffic, busy traffic, dangerous crossroads, vehicles on walkways, cyclists on walkways, and insecurity due to other pedestrians).

Perceived environmental facilitators for outdoor mobility were studied at baseline with a standardized questionnaire comprising 16 items (Rantakokko et al., 2015). Participants were asked to report all the items present in their living environment that they perceived as facilitating their outdoor mobility (present/absent). In the analyses, environmental facilitators were used individually and as categorized into three groups. The groups were nature (park or other green area, walking trail and skiing track, and nature and lakeside); infrastructure (good lighting, services close, even sidewalks, walkways without steep hills, resting places by the walking route, peaceful and good quality pedestrian routes, and safe crossings); and safety (appealing landscape, familiar surroundings, own yard, other people outdoors, no car traffic, and no cyclists on walkways) (Keskinen et al., 2019).

4.3.2 COVID-19 pandemic restrictions

In Study IV, the COVID-19 pandemic restrictions provided a possibility to investigate the associations between self-reported walking modifications and difficulty with the extent of mobility and autonomy in mobility in a situation when environmental facilitators for outdoor mobility were rapidly removed. Multiple restrictions and recommendations due to the spread of the SARS-CoV-2 virus were announced in Finland in March 2020. Social distancing, i.e., limiting close contact with other people, was recommended especially for people aged 70 years and older. Although a curfew was not imposed in Finland, cultural events and other organized activities were cancelled and many public places, including libraries, and indoor sport facilities were closed (Finnish Government, 2020). It was advised to avoid all unnecessary visits outside the home. For instance, older people were offered food delivery by municipality, in order to limit the time spent in public places.

4.3.3 Self-reported walking modifications and walking difficulty

In Studies I and IV, participants were first asked whether they perceived difficulty in walking a distance of 2 km with a standardized question: "*Do you have difficulty walking 2 kilometers*?" The response alternatives were 1) able to manage without difficulty, 2) able to manage with some difficulty, 3) able to manage with a great deal of difficulty, 4) able to manage only with help of another person, and 5) unable to manage even with help. Second, to identify participants using walking modifications, those who reported being able to walk 2 km without difficulty were asked the following additional question about the use of walking modifications: "*Have you changed the way of walking 2 km distances due to your health or physical functioning?"* The modifications listed were walking slower, resting during walking, using an aid, reducing frequency of walking, and having given up walking distances of 2 km. Participants were asked to report all the walking modifications that they used ("yes" or "no"). Then, based on their self-reported walking modifications and walking difficulty in 2 km, they were categorized into three groups as follows: 1) *intact walking* (reporting neither difficulty nor modifications), 2) *walking modifications* (reporting no difficulty and ≥ 1 modifications) and 3) *walking difficulty* (reporting at least some difficulty). As only those who perceived no walking difficulty in the AGNES study were asked about the use of walking modifications, and the number reporting walking modifications was low, the categorization into adaptive and maladaptive walking modifications was not meaningful.

4.3.4 Adaptive and maladaptive walking modifications

In Studies II and III, self-reported modifications in walking a distance of 2 km were assessed with a standardized questionnaire at baseline and at the 2-year follow-up (Rantakokko et al., 2016). All participants irrespective of perceived walking difficulty were asked about their possible walking modifications as follows: "*Have you changed the way of walking 2 km distances due to your health or physical functioning?"*. The modifications listed were walking slower, resting during walking, using an aid, reducing frequency of walking, and having given up walking distances of 2 km, and participants were asked to report all the walking modifications that they used ("yes" or "no"). Those who reported having given up walking 2 km or only reducing their frequency of walking 2 km in the absence of adaptive modifications, were categorized as using maladaptive modifications, as these indicate a reduced striving to continue the activity. Walking slower, resting during walking, and using an aid were considered to indicate a striving to continue walking 2 km distances by reducing task demand and thus were categorized as adaptive modifications. Those who reported adaptive walking modifications in addition to reduced frequency of walking 2 km were also categorized as using adaptive walking modifications. Finally, the use of modifications in walking 2 km were analysed in Studies II and III, using the following categories: *no walking modifications*, *adaptive walking modifications*, and *maladaptive walking modifications*.

4.3.5 Free-living walking

Data on free-living walking (Study I) were collected to capture participants' patterns and amount of daily walking activity in free-living conditions. The associations between free-living walking (what people *actually* do) and self-reported walking modifications and walking difficulty (what people *can* do) were investigated in Study I.

In the AGNES study, free-living walking (daily walking minutes, daily walking bouts, average walking bout duration, and walking bout intensity) were assessed using tri-axial accelerometer recordings (range ±16 g, 13-bit analog-to-digital conversion, UKK RM42, UKK Terveyspalvelut Oy, Tampere, Finland) (Rantanen et al., 2018). AGNES participants willing to participate in the physical assessments in the research center (n = 910) were asked to wear an accelerometer continuously for 7 to 10 days until the laboratory assessments following the home interview. Exclusion criteria for the accelerometer measurements were a known allergy to adhesive, and swimming, bathing, or having a sauna multiple times per week since the accelerometers were directly taped onto the skin and were not fully water-resistant. After exclusions, 496 participants agreed to wear an accelerometer. The accelerometer was attached by a research assistant to the anterior aspect of the mid-thigh of the dominant leg with self-adhesive film (Karavirta et al., 2020). The non-respondent analyses showed that those who did not participate in the accelerometer measurements had lower self-reported physical activity and walking speed than those who were willing to wear the accelerometer (Portegijs et al., 2019).

The accelerometer sampling rate was set at 100 samples per second and acceleration was recorded in units of gravity (g). The mean amplitude deviation (MAD) of each 24-h epoch was calculated from the resultant acceleration magnitude ($resultant = \sqrt{X^2 + Y^2 + Z^2}$) in non-overlapping 5-second epochs (Vähä-Ypyä et al., 2015). Only days with complete 24-hour data without non-wear were included in the analysis, and therefore the raw data were verified visually. After excluding the data of 11 participants due to either loss of the monitor (n = 2), technical error (n = 1) or availability of data for less than three full days (n = 8), acceptable accelerometer data were available for 485 participants.

Walking bouts were extracted from the free-living accelerometer data by modifying a previously presented method (Skotte et al., 2014). Continuous walking bouts of ≥ 20 second in duration were identified based on the orientation angle of the thigh (to be eligible for consideration as walking, an angle for postural estimation (APE) of < pi/4 was required) (Vähä-Ypyä et al., 2018), and on the intensity of the signal (MAD between 0.035 g and 1.2 g, determined from the results of laboratory experimentation). Continuous walking bouts subsequent to standing still for at least 5 seconds were calculated as new walking bouts. Afterwards, daily walking bouts (bouts/d), average walking bout duration (seconds) and average walking bout intensity (g) were calculated. Mean daily walking minutes (min/d) were calculated by multiplying walking bouts by walking bout duration. Daily walking minutes, daily walking bouts, walking bout duration, and walking bout intensity were used as continuous variables in the analyses.

4.3.6 Activity fragmentation

Activity fragmentation (Study I) was assessed by calculating the Active-to-Sedentary Transition Probability (ASTP), which indicates the probability of transitioning from an active to a sedentary state (Schrack et al., 2019). The ASTP was calculated by dividing the number of activity bouts by the mean sum of at least light active daily minutes (a MAD value of at least 16.7 milligravity) (Palmberg et al., 2020). A higher ASTP represents a more fragmented activity pattern. Activity fragmentation was used as a continuous variable in the analyses.

4.3.7 Life-space mobility

Life-space mobility (Studies III and IV) was measured at baseline and at the 2-year follow-up using the Finnish version (Portegijs, Iwarsson, et al., 2014) of the University of Alabama Study of Aging Life-Space Assessment (LSA) (Baker et al., 2003). The LSA captures the individual's actual mobility performance in daily life during the preceding four weeks, considering all forms of mobility from walking to driving and using public transportation. At its smallest, life-space mobility can be restricted to the individual's own bedroom. As it expands, life-space covers other rooms, the yard, the neighbourhood, the town and beyond.

The Life-Space Mobility Assessment comprises six life-space *levels* (0 = bedroom, 1 = other rooms, 2 = outside the home, 3 = neighbourhood, 4 = town, and 5 = beyond town). Participants were asked on how many days per week (frequency: 1 = less than once a week, 2 = 1–3 times a week, 3 = 4–6 times a week or 4 = daily) they reached each life-space level and whether they needed assistance (2 = independent, 1.5 = using equipment, 1 = personal assistance). A life-space composite score was then calculated based on the participant's responses as follows: the scores for level (0–5), frequency (0–4) and assistance (1–2) were multiplied for each life-space level and then summed. The composite score ranges from zero to 120, with higher scores indicating greater life-space mobility (Baker et al., 2003).

A change of more than ten points in the LSA composite score is considered to indicate clinically meaningful change (Baker et al., 2003; Portegijs et al., 2016) and scoring under 60 points indicates restricted life-space mobility (Baker et al., 2003; Shimada et al., 2010). Restricted life-space mobility means that the individual rarely moves outside of their immediate neighbourhood (Portegijs, Iwarsson, et al., 2014). The LSA is a validated measure to capture the individual's actual mobility performance in daily life. The test-retest reliability between the baseline and two-week follow-up measurements was high, with an ICC > 0.86, and the LSA correlates highly with physical performance ($r = .60$, $p < .01$) (Baker et al., 2003).

4.3.8 Physical activity

In Study IV, self-reported physical activity was assessed using the Yale Physical Activity Survey for older adults (Dipietro et al., 1993) at baseline and during the COVID-19 pandemic restrictions. Participants were asked how many times they performed vigorous physical activity and leisure walking for at least 10 minutes during the past month and the usual duration of a session. The responses on *frequency* (0 = not at all, 1 = 1–3 times per month, 2 = 1–2 times per week, 4 = 3–5 times per week, and 6 = 5+ times per week) and *duration* (20 = 10–30 min, 40 = 30–50 min, and 60 = 60+ min) were recoded to estimate total minutes spend in vigorous physical activity and in leisure walking per day. Total minutes spent in vigorous physical activity and in walking per day were calculated using the following formula: (frequency*duration)/7. Finally, mean daily vigorous physical activity and leisure walking minutes were summed (Portegijs et al., 2019) and the result used as a continuous variable. The Yale Physical Activity Survey is a validated measure of physical activity among older people with test-retest reliability in previous studies varying from unacceptable to good (Moore et al., 2008).

4.3.9 Autonomy in participation outdoors

Autonomy in participation outdoors was measured using the relevant domain of the Impact on Participation and Autonomy (IPA) questionnaire (Cardol et al., 2001) in Studies III and IV. The autonomy outdoors domain assesses an individual's level of satisfaction with their opportunities to move and take part in activities in the out-of-home environment and consists of five items: visiting relatives and friends, making trips, traveling, spending leisure time, meeting other people, and living life the way one wants to. Each item is scored from 0 (very good possibilities) to 4 (very poor possibilities). A sum score (range 0–20) of the scores for all five items is then calculated. A higher sum score indicates poorer autonomy in participation outdoors. The IPA is a validated measure for assessing participation and autonomy in older people, and it can be used as a whole questionnaire or as subscales (Cardol et al., 2001; Kersten et al., 2007).

4.3.10 Unmet physical activity need

The presence of unmet physical activity need describes lack of autonomy in physical activity. It was assessed in Study III using two questions: "*Would you like to increase your level of outdoor physical activity*?" and "*Do you feel that you have an opportunity to increase your level of outdoor physical activity if someone recommended you to do so*?". The response alternatives for these two questions were "yes" and "no". Participants were categorized as perceiving unmet physical activity need if they reported wanting to increase their outdoor physical activity but perceiving no opportunity to do so (Rantakokko et al., 2010). Unmet physical activity need was used as a dichotomous variable (yes/no).

4.3.11 Descriptive variables and covariates

Descriptive variables and covariates are summarized in Table 3. In all four Studies, data on participants' age and sex were drawn from the Population Information System administered by the Digital and Population Data Services Agency. Years of education were enquired with the question, "*How many years of education have you had in total?*" and used as an indicator of socio-economic status in all the Studies. In Studies II and III, physician-diagnosed chronic conditions were enquired with a list of 22 specified chronic conditions followed by an open-ended question on any other diseases the participant might have. Based on the responses, the number of chronic conditions was calculated (Portegijs, Rantakokko, et al., 2014). In Studies I and IV, the number of chronic conditions was calculated as the sum of individual chronic conditions selected from a list of 34 specific physician-diagnosed chronic conditions followed by an open-ended question on any other chronic conditions the participant might have (Rantanen et al., 2018).

Depressive symptoms were assessed with the Center for Epidemiologic Studies Depression Scale, CES-D (range 0–60; higher scores indicate more depressive symptoms) (Radloff, 1977) in all four Studies. Cognitive function was measured using the Mini-Mental State Examination (MMSE) in Study III (Folstein et al., 1975). SPPB was assessed to measure lower extremity function in all Studies (Guralnik et al., 1994). The tests comprise standing balance (feet together, semi-tandem, full tandem), walking at normal gait speed (for 2.44 m in Studies II and III, or 3 m in Studies I and IV), and repeated chair rise (five times). Each test was scored from zero to four and a sum score ranging from 0 to 12 calculated, with higher scores indicating better lower extremity function (Portegijs, Rantakokko, et al., 2014). The sum score was calculated only for those who completed at least two of the three tests.

TABLE 3 Descriptive variables and covariates of the present study.

Variable	Study	Methods and reference
Age	I–IV	Digital and Population Data Services Agency (https://dvv.fi/en/)
Sex	I–IV	Digital and Population Data Services Agency (https://dvv.fi/en/)
Years of education	I–IV	Self-reported
Number of chronic conditions	I–IV	Self-reported
Depressive symptoms	I–IV	Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977)
Lower extremity performance	I–IV	Short Physical Performance Battery (SPPB) (Guralnik et al., 1994)
Cognitive function	III	Mini-Mental State Examination (MMSE) (Folstein et al., 1975)

4.4 Statistical analyses

All the main statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) versions 24–26 (SPSS Inc., Chicago, IL). In addition, R version 3.6.1 was used to calculate the false discovery rates in Study II (R Core Team, 2019). The results were regarded as statistically significant if the 95 % confidence intervals did not include 1 or when the p-value was <.05.

4.4.1 Descriptive statistical analyses

Descriptive statistics were reported as frequencies and percentages for categorical variables and means with standard deviations for continuous variables in all four Studies. Differences between participants' self-reported walking modifications and difficulty in frequencies and proportions were tested with chi-square test, and in means with one-way analysis of variance and the Bonferroni post hoc test.

4.4.2 Missing data

Missing data were minimal. Imputation methods were used in Studies III and IV to maximize the number of participants in the analyses.

In Study I, information on self-reported walking modifications and difficulty was missing for six participants, and thus 479 participants with adequate accelerometer data were included in the analysis. A further four participants had missing information on years of education. These participants were not included in the models in which age, sex, and years of education were covariates.

In Study II, eight participants had missing information for years of education, four participants for depressive symptoms and nine participants for lower extremity function. These 21 participants were not, therefore, included in the models in which years of education, depressive symptoms and lower extremity function were used as covariates.

In Study III, six participants had missing information for years of education, four for depressive symptoms and seven for the Short Physical Performance Battery, and thus these 17 participants were not included in the fully adjusted models. Missing follow-up scores were calculated for 35 participants in life-space mobility, 44 in autonomy in participation outdoors and 42 in unmet physical activity need by using multivariate imputation by chained equation. The sensitivity analysis showed that imputation did not change the results.

In Study IV, 12 participants had missing information on self-reported walking modifications and difficulty. Autonomy in participation outdoors scores were imputed for follow-up participants for whom only one item was missing (n = 14) by using the average of the available items. In addition, missing baseline and follow-up scores for life-space mobility (baseline n = 4, follow-up n = 6), autonomy in participation outdoors (baseline n = 13, follow-up n = 27) and self-reported physical activity (baseline n = 14, follow-up n = 16) were calculated by using multivariate imputation by chained equations in the Generalized estimation equations analyses. Additional analyses showed that these imputations did not change the results.

4.4.3 Receiver operating characteristics (ROC) analysis

In Study I, receiver operating characteristics (ROC) analysis (Akobeng, 2007) was performed to estimate optimal accelerometer-based free-living walking (daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity) and activity fragmentation cut points for predicting perceived walking difficulty. Cut points were investigated as preliminary analyses showed that differences in free-living walking mostly occurred between those with intact walking and those with walking difficulty. In the ROC analyses, participants with intact walking and those using walking modifications were merged into the same reference group (n = 341).

The advantage of ROC analysis is that it is free from parametric assumptions (Lasko et al., 2005). The cut points that best balanced the high sensitivity and high specificity of the test were calculated by using the formula $(1 - sensitivity) + (1 - specificity)^2$ to find the minimal value. The suitability of the test was evaluated by estimating the area under the curve (AUC). The AUC value indicates the accuracy of the test, with the following cut points: 0.5–0.7 = low accuracy, 0.7–0.9 = moderate accuracy, > 0.9 = high accuracy (Akobeng 2007).

4.4.4 Logistic regression analysis

In Study II, logistic regression analysis was used to investigate the associations between perceived environmental outdoor mobility facilitators and barriers and the incidence of adaptive or maladaptive walking modifications. The incidence of adaptive walking modifications was studied among those who reported no walking modifications at baseline and who did not develop maladaptive modifications over the two-year follow-up period (n = 218). Participants who reported adaptive walking modifications at the 2-year follow-up were defined having developed adaptive walking modifications.

Similarly, the incidence of maladaptive walking modifications was studied only among those reporting no maladaptive walking modifications at baseline (n = 610). Participants, who reported maladaptive walking modifications over 2-year follow-up were defined as having developed maladaptive walking modifications.

Associations between environmental factors and the incidence of adaptive or maladaptive walking modifications were conducted separately for each environmental subgroup (nature, infrastructure, and safety; reporting 1 or ≥ 2 vs. no) and item-specific environmental facilitators for and barriers to outdoor mobility. All models were first adjusted for age and sex and then for age, sex, years of education, chronic conditions, depressive symptoms, and lower extremity function.

4.4.5 Multinomial logistic regression analysis

Multinomial logistic regression analysis was used in Studies I and II, as the outcome variables were nominal scale variables in both Studies. In Study I, the associations of accelerometer-based free-living walking with reporting intact walking, walking modifications or walking difficulty were assessed by using multinomial logistic regression analysis after calculating the optimal cut points. Those with intact walking were used as a reference group in the analysis. Free-living walking variables (daily walking minutes, daily walking bouts, average walking bout duration, walking bout intensity) and activity fragmentation were studied in separate models. The models were first unadjusted and then adjusted for age, sex, and years of education.

In Study II, the associations of perceived environmental outdoor mobility facilitators and barriers with reporting no, adaptive or maladaptive walking modifications were assessed cross-sectionally by using multinomial logistic regression analysis. When studying the associations between environmental facilitators and categories of walking modifications, those with maladaptive walking modifications were used as a reference group. This was done to clarify whether the environmental facilitators reported by those using adaptive walking modifications differed from those using maladaptive walking modifications. In contrast, in the analyses on environmental mobility barriers, those reporting no walking modifications were used as a reference group. All separate models were first adjusted for age and sex and then, to control for individual differences, for age, sex, years of education, chronic conditions, depressive symptoms, and lower extremity function.

4.4.6 Generalized estimation equations (GEE) models

Generalized estimation equations models (Liang & Zeger, 1986) with an unstructured working correlation matrix were used in Studies III and IV. In the GEE models, the group difference represents the difference between groups in the score or prevalence at baseline. Group-by-time interaction indicates whether the change over time is different between groups.

In Study III, changes in life-space mobility, autonomy in participation outdoors and unmet physical activity need over the 2-year follow-up among the participants reporting no, adaptive, or maladaptive walking modifications at baseline were investigated. Participants without walking modifications were set as the reference groups in the analyses. A GEE linear model was used to study changes in life-space mobility and autonomy in participation outdoors, whereas a GEE binary logistic regression model was used to study changes in the prevalence of unmet physical activity need over time. The models were first adjusted for age and sex. The second models also included years of education, number of chronic conditions, depressive symptoms, cognitive function, and lower extremity function.

In Study IV, GEE linear models were used to compare changes in life-space mobility, autonomy in participation outdoors and self-reported physical activity over the follow-up between participants reporting intact walking, use of walking modifications or perceiving walking difficulty at baseline. The models were adjusted for age and sex and those with intact walking were used as the reference group.

4.4.7 False discovery rate

Study II included multiple analyses, which increased the risk for type 1 error. Therefore, false discovery rates (adjusted p-values) were calculated to correct for multiple testing (Benjamini & Hochberg, 1995).

5 RESULTS

5.1 Participant characteristics

The baseline characteristics of the participants in Study I (AGNES cohort sub-study), Studies II and III (LISPE), and Study IV (AGNES-COVID-19) are presented in Table 4. In Studies II and III, participants were categorized based on their self-reported modifications in walking 2 km at baseline to those with no modifications (n = 285), those using adaptive modifications (n = 325), and those using maladaptive walking modifications (n = 238). Those with no walking modifications were younger, more often men, had more years of education and had fewer chronic conditions and depressive symptoms, and better lower extremity function than those with adaptive or maladaptive walking modifications ($p < 0.001$ for all). Participants using adaptive and maladaptive walking modifications were similar in years of education ($p = 0.170$) and depressive symptoms ($p = 0.056$).

In Studies I and IV, only those without walking difficulty were asked about the use of walking modifications, and hence the following categories were used: intact walking, walking modifications and walking difficulty. In Study I, 55 % (n = 261) of the participants reported intact walking (no difficulty or modifications), 17 % (n = 80) reported using walking modifications and 29 % (n = 138) perceived difficulty in walking a distance of 2 km. Similarly, in Study IV, half of the participants (50 %, n = 396) had intact walking, 17 % (n = 133) used walking modifications and 34 % (n = 268) perceived difficulty in walking a distance of 2 km. In both these Studies, those with walking difficulty were older, less educated, had more chronic conditions, more depressive symptoms, and poorer lower extremity function compared to those with intact walking ($p < 0.008$ for all). In Study I, participants with walking modifications had poorer lower extremity function than those with intact walking ($p = 0.001$). Compared to those with walking difficulty, those with walking modifications had fewer chronic conditions and better lower extremity function ($p < 0.001$ for both). However, in Study IV, those using walking modifications formed a middle group in terms of their lower extremity function and depressive symptoms between those with intact walking and those with walking difficulty ($p < 0.015$ for all) and had fewer chronic conditions than those with walking difficulty ($p < 0.001$).

TABLE 4 Baseline characteristics of study participants in the datasets used in this study.

Characteristics	**LISPE N = 848**	**AGNES cohort N = 1021**	**AGNES cohort sub-study N = 479**	**AGNES-COVID-19 N = 809**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
Age (years)	80.6 ± 4.2	na	na	na
Age groups	na	75 y, 45 % 80 y, 33 % 85 y, 22 %	75 y, 51 % 80 y, 31 % 85 y, 18 %	75 y, 48 % 80 y, 33 % 85 y, 20 %
Education (years)	9.6 ± 4.1	11.5 ± 4.2	11.6 ± 4.3	11.8 ± 4.3
Number of chronic conditions	4.4 ± 2.4	3.4 ± 2.0	3.3 ± 2.0	3.4 ± 2.0
Depressive symptoms (CES-D, score)	9.6 ± 6.8	8.6 ± 7.1	7.8 ± 6.6	8.3 ± 6.9
Lower extremity function (SPPB, score)	9.6 ± 2.5	9.9 ± 2.4	10.3 ± 1.9	10.1 ± 2.2
Cognitive function (MMSE, score)	26.2 ± 2.8	27.1 ± 2.6	27.4 ± 2.4	27.5 ± 2.1
Life-space mobility (score)	63.9 ± 20.6	71.2 ± 18.9	73.3 ± 18.0	72.6 ± 18.6
Autonomy in participation outdoors (score)	6.2 ± 3.8	5.4 ± 3.7	4.8 ± 3.5	5.1 ± 3.7
Self-reported physical activity (min/day)	na	34.7 ± 20.8	37.5 ± 21.0	35.3 ± 20.7
	%	%	%	%
Women	62.0	57.3	59.7	58.5
Self-reported walking 2 km distances				
Intact walking	31.6	47.2	54.5	49.7
Walking modifications	26.4	16.6	16.7	16.7
Walking difficulty	42.0	36.2	28.8	33.6
Unmet physical activity need	13.6	na	na	na

Note. SD = standard deviation; CES-D = Center for Epidemiologic Studies Depression Scale; SPPB = Short Physical Performance Battery; MMSE = Mini-Mental State Examination; na = data not available.

5.2 Use of adaptive and maladaptive walking modifications

In Studies I and IV, the most often reported walking modification was walking slower (77 %) among those perceiving no walking difficulty but reporting walking modifications (Table 5). In both Studies, a minority reported having given up walking 2 km distances. Reducing the frequency of walking was reported by one third of the participants.

In Studies II and III, participants who reported adaptive walking modifications used on average 2.1 walking modifications. The majority (81 %) walked more slowly, 47 % needed to rest during walking, 37 % used walking aids when walking 2 km distances, and 50 % had also reduced their frequency of walking 2 km distances. Among those categorized as using maladaptive walking modifications, the majority (86 %) had given up walking 2 km distances, whereas 14 % had reduced their frequency of walking 2 km distances and reported no adaptive walking modifications.

TABLE 5 Percentages of walking modifications used among those using adaptive or maladaptive walking modifications in Studies II and III and those with using walking modifications in Studies I and IV.

	Study I	**Studies II and III**		**Study IV**
	n = 80	**Adaptive walking modifications (n = 325)**	**Maladaptive walking modifications (n = 238)**	**n = 133**
	%	%	%	%
Walking modifications in walking 2 km distances				
Walking slower	77.2	80.9	-	76.5
Taking rest breaks	14.1	46.9	-	19.8
Using an aid	10.3	36.6	-	13.0
Reducing the frequency of walking 2 km distances	32.5	49.5	13.9	31.6
Having given up walking 2 km distances	3.8	-	86.1	4.6
Perceived difficulty in walking 2 km	-	48.6	81.9	-

5.3 Cross-sectional associations between accelerometer-based free-living walking and the use of walking modifications and perceived walking difficulty (Study I)

Those with intact walking accumulated the highest number of daily walking minutes (115.0 min, SD 37.9) and walking bouts (120.2, SD 38.1) (Figure 4). Their walking bouts were also the longest (58.5 seconds, SD 14.0), showed the highest average intensity (0.13 g, SD 0.05), and their activity were the least fragmented (0.23 ASTP, SD 0.05). Participants with walking modifications accumulated similar amount of daily walking bouts (120.7, SD 45.0) at the same intensity (0.12 g, SD 0.02), and a similar activity fragmentation pattern (0.24 ASTP, SD 0.06) as those with intact walking ($p > 0.05$ for all). However, they had fewer daily walking minutes (102.4 min, SD 42.9, $p = 0.035$) and shorter walking bouts (50.9 seconds, SD 9.7, $p < 0.001$) than those with intact walking. Those with walking difficulty showed the poorest values in all the free-living walking variables compared to those with intact walking or using walking modifications ($p > 0.05$ for all).

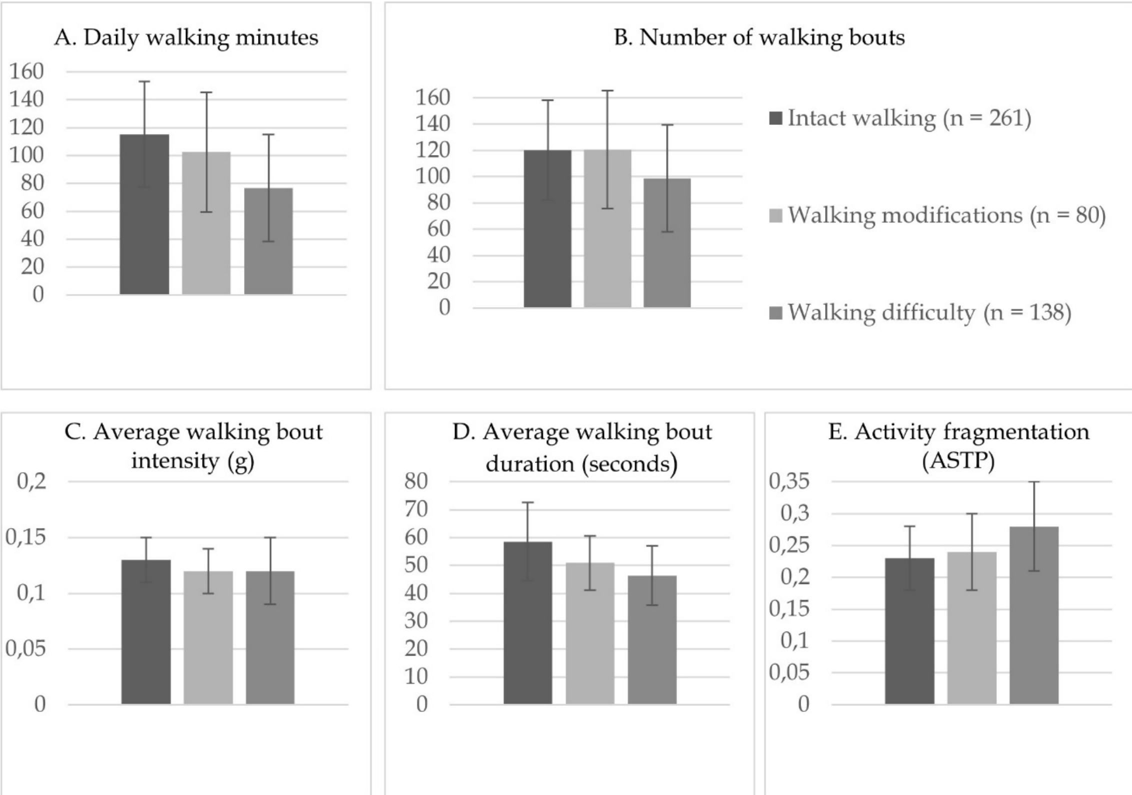

FIGURE 4 Means and standard deviations of daily walking minutes (A), number of walking bouts (B), average walking bout intensity (C), average walking bout duration (D), and activity fragmentation among older people with intact walking, using walking modifications, or reporting walking difficulty.

Accelerometer-measured free-living walking cut points for increased risk for reporting walking difficulty were established (Table 6). The ROC curve analyses showed moderate accuracy in daily walking minutes (cut point 83.1 min, AUC 0.745), walking bout duration (cut point 47.8 seconds, AUC 0.756), and activity fragmentation (cut point 0.257 ASTP, AUC 0.715), whereas the number of daily walking bouts (cut point 99.4 bouts) and walking bout intensity (cut point 0.119 g) showed low accuracy (AUC < 0.7) in discriminating between older people with walking difficulty and those with intact walking. In the analyses adjusted for age, sex, and years of education, walking equal to or less than 83.1 minutes daily and accumulating walking bouts equal to or shorter than 47.8 seconds was more common among those with walking modifications than those with intact walking. Instead, accumulating walking bouts equal to or less than 99.4 per day, having walking bouts equal to or lower than 0.119 g intensity, and having a more fragmented activity pattern were associated with perceiving walking difficulty but not with the use of walking modifications.

TABLE 6 Associations of free-living walking with use of walking modifications or perceiving walking difficulty.

Free-living walking		**Walking modifications (n = 78)**		**Walking difficulty (n = 136)**	
	AUC (95 % CI)	**OR (95 % CI)**	**P-value**	**OR (95 % CI)**	**P-value**
Daily walking minutes ≤ 83.1 min vs. > 83.1 min	0.745 (0.696–0.794)	**2.6 (1.5–4.5)**	**0.001**	**5.5 (3.4–8.8)**	**<0.001**
Number of walking bouts ≤ 99.4 vs. > 99.4	0.646 (0.590–0.702)	1.0 (0.6–1.7)	0.958	**2.3 (1.5–3.6)**	**<0.001**
Walking bout intensity ≤ 0.119 g vs. > 0.119 g	0.641 (0.584–0.697)	1.3 (0.8–2.2)	0.303	**1.9 (1.2–3.0)**	**0.005**
Walking bout duration ≤ 47.8 seconds vs. > 47.8 seconds	0.756 (0.702–0.801)	**2.3 (1.3–3.9)**	**0.003**	**6.7 (4.2–10.9)**	**<0.001**
Activity fragmentation ≥ 0.257 ASTP vs. < 0.257 ASTP	0.715 (0.663–0.766)	1.1 (0.7–2.0)	0.642	**3.3 (2.1–5.1)**	**<0.001**

Note. AUC = area under curve; OR = odds ratio; CI = confidence interval; g = gravity; ASTP = Active-to-Sedentary Transition Probability. Areas under curves were examined by using ROC models and associations by using multinomial logistic regression analyses. Participants with intact walking (n = 261) were used as a reference group in all separate models. Models are adjusted for age, sex, and years of education. Statistically significant values are bolded.

5.4 Cross-sectional and longitudinal associations between perceived environmental factors and the use of adaptive or maladaptive walking modifications (Study II)

Associations of perceived environmental facilitators for and barriers to outdoor mobility with the prevalence and incidence of adaptive and maladaptive modifications in walking 2 km among older people were investigated in Study II. At baseline, 38 % (n = 325) used adaptive and 28 % (n = 238) maladaptive modifications in walking 2 km. Half (n = 112) of the 218 participants without walking modifications at baseline developed adaptive walking modifications during the 2-year follow-up. Of the participants without maladaptive walking modifications at baseline, 22.3 % (n = 136) developed maladaptive walking modifications during the 2-year follow-up.

Associations between perceived environmental facilitators for outdoor mobility and the use of adaptive or maladaptive walking modifications

Reporting at least two nature- or infrastructure-related environmental facilitators (OR 2.9, 95 % 1.5–5.6; 2.5, 1.5–4.2, respectively) were more often associated with using no walking modifications than with using maladaptive walking modifications (Table 7). Similarly, those reporting at least two infrastructure- or safety-related facilitators for outdoor mobility had 2.4- to 2.5-fold greater odds for reporting the use of adaptive walking modifications than the use of maladaptive walking modifications. In the item-specific analyses, reporting a walking trail or a skiing track (OR 1.9, 95 % CI 1.3–2.8), good lighting (OR 1.8, 95 % CI 1.2–2.6), peaceful and good quality walkways (OR 1.8, 95 % CI 1.2–2.6), walkways without steep hills (OR 2.4, 95 % CI 1.4–4.3), nearby services (OR 1.9, 95 % CI 1.3–2.7), safe crossings (OR 1.9, 95 % CI 1.2–3.0) or a familiar environment (OR 1.7, 95 % CI 1.2–2.5) as facilitators for outdoor mobility were more commonly associated with using adaptive than maladaptive walking modifications.

Perceiving a walking trail or skiing track as a facilitator for outdoor mobility protected against the development of maladaptive walking modifications over time (OR 0.5, 95 % CI 0.3–0.7). Otherwise, no associations over time between environmental outdoor mobility facilitators and the incidence of adaptive or maladaptive walking modifications were observed.

Finally, sensitivity analyses were conducted by excluding participants who reported being unable to walk 2 km independently at baseline. The results showed that all of the associations between environmental facilitators and adaptive walking modifications were attenuated and non-significant.

TABLE 7 Associations of the perceived environmental facilitators for outdoor mobility with the prevalence and incidence of adaptive and maladaptive modifications in walking 2 km.

	Prevalence*				Incidence**			
	No walking modifications (n = 281)		Adaptive walking modifications (n = 319)		Adaptive walking modifications [a]		Maladaptive walking modifications [b]	
Facilitators	**OR (95 % CI)**	**Adjusted p-value**	**OR (95 % CI)**	**Adjusted p-value**	**OR (95 % CI)**	**Adjusted p-value**	**OR (95 % CI)**	**Adjusted p-value**
Sum of nature facilitators								
1 vs. 0	1.1 (0.5–2.2)	0.893	1.5 (0.9–2.4)	0.356	0.4 (0.1–1.2)	0.906	0.7 (0.4–1.2)	0.305
≥ 2 vs. 0	**2.9 (1.5–5.6)**	**0.006**	0.7 (0.4–1.2)	0.256	0.7 (0.3–1.8)	0.339	1.0 (0.5–1.8)	0.977
Sum of infrastructure facilitators								
1 vs. 0	1.8 (1.0–3.2)	0.179	1.5 (0.9–2.5)	0.305	0.7 (0.4–1.3)	0.406	0.8 (0.5–1.3)	0.893
≥ 2 vs. 0	**2.5 (1.5–4.2)**	**<0.001**	**2.4 (1.6–3.7)**	**<0.001**	0.6 (0.3–1.3)	0.819	0.9 (0.5–1.6)	0.937
Sum of safety facilitators								
1 vs. 0	0.7 (0.4–1.6)	0.630	2.0 (1.0–3.7)	0.119	1.5 (0.6–3.3)	0.305	0.9 (0.5–1.6)	0.872
≥ 2 vs. 0	1.9 (1.1–3.6)	0.094	**2.5 (1.4–4.3)**	**0.006**	1.2 (0.4–3.6)	0.217	1.7 (0.8–3.4)	0.288

Note. OR = odds ratio; CI = confidence interval. False discovery rates (adjusted p-values) were calculated to correct for multiple testing. *Multinomial logistics regression analyses, participants reporting maladaptive walking modifications (n = 227) were used as the reference category. **Incidence of adaptive and maladaptive walking modifications were analysed in separate models by using binary logistic regression models. [a] Reference category: no walking modifications. [b] Reference category: no and adaptive walking modifications. All separate models were adjusted for age, sex, years of education, depressive symptoms, chronic conditions, and lower extremity function measured at baseline. Statistically significant values are bolded.

Associations between perceived environmental barriers to outdoor mobility and the use of adaptive or maladaptive walking modifications

Reporting at least two infrastructure-related environmental barriers increased the odds for using adaptive (OR 2.5, 95 % CI 1.4–4.2) or maladaptive (OR 2.3, 95 % CI 1.3–4.2) walking modifications compared to reporting no walking modifications (Table 8). In addition, reporting one (OR 1.8, 95 % CI 1.2–2.7) or two (OR 3.5, 95 % CI 2.0–6.2) nature-related environmental barriers increased the odds for using adaptive walking modifications compared reporting no walking modifications. Of the individual mobility barriers, hills in the nearby environment (OR 2.0, 95 % CI 1.2–3.2), snow and ice during winter (OR 2.2, 95 % CI 1.6–3.2), and lack of resting places in winter (OR 2.3, 95 % CI 1.3–4.0) were more commonly reported by people using adaptive walking modifications than by those without walking modifications. Instead, only reporting long distances to services (OR 4.5, 95 % CI 2.1–9.6) was related to the use of maladaptive walking modifications. Safety-related barriers to outdoor mobility were not associated with the use of adaptive or maladaptive walking modifications when the models were adjusted for all the covariates.

In the sensitivity analyses, excluding participants who reported being unable to walk 2 km independently at baseline did not change the observed associations between environmental barriers and the prevalence or incidence of adaptive or maladaptive walking modifications.

TABLE 8 Associations of perceived environmental barriers to outdoor mobility with the prevalence and incidence of adaptive and maladaptive modifications in walking 2 km.

	Prevalence*				Incidence**			
	Adaptive walking modifications (n = 319)		Maladaptive walking modifications (n = 227)		Adaptive walking modifications [a]		Maladaptive walking modifications [b]	
Barriers	**OR (95 % CI)**	**Adjusted p-value**	**OR (95 % CI)**	**Adjusted p-value**	**OR (95 % CI)**	**Adjusted p-value**	**OR (95 % CI)**	**Adjusted p-value**
Sum of nature barriers								
1 vs. 0	**1.8 (1.2–2.7)**	**0.014**	1.2 (0.8–1.9)	0.609	0.3 (0.1–1.3)	0.244	1.9 (1.1–3.2)	0.058
2 vs. 0	**3.5 (2.0–6.2)**	**<0.001**	2.0 (1.0–3.8)	0.128	1.0 (0.5–2.0)	0.937	1.4 (0.9–2.1)	0.244
Sum of infrastructure barriers								
1 vs. 0	1.4 (0.9–2.1)	0.339	1.3 (0.8–2.3)	0.494	1.2 (0.3–4.4)	0.872	1.3 (0.8–2.1)	0.502
≥ 2 vs. 0	**2.5 (1.4–4.2)**	**0.006**	**2.3 (1.3–4.2)**	**0.029**	0.5 (0.2–1.2)	0.244	1.0 (0.6–1.6)	0.971
Sum of safety barriers								
1 vs. 0	1.3 (0.8–2.0)	0.500	0.7 (0.4–1.3)	0.468	0.7 (0.3–1.8)	0.923	0.9 (0.5–1.6)	0.872
≥ 2 vs. 0	1.4 (0.8–2.4)	0.494	0.6 (0.3–1.2)	0.305	0.3 (0.1–0.8)	0.076	1.3 (0.8–2.1)	0.384

Note. OR = odds ratio; CI = confidence interval. False discovery rates (adjusted p-values) were calculated to correct for multiple testing. *Multinomial logistics regression analyses, participants without walking modifications (n = 281) were used as the reference category. **Incidence of adaptive and maladaptive walking modifications were analysed in separate models by using binary logistic regression models. [a] Reference category: no walking modifications. [b] Reference category: no and adaptive walking modifications. All separate models were adjusted for age, sex, years of education, depressive symptoms, chronic conditions, and lower extremity function measured at baseline. Statistically significant values are bolded.

5.5 Use of walking modifications and changes in outdoor mobility over the 2-year follow-up (Studies III & IV)

The cross-sectional and longitudinal associations of the use of adaptive and maladaptive walking modifications in 2 km distances with life-space mobility, autonomy in participation outdoors and unmet physical activity need were investigated in Study III. In Study IV, differences in the levels and changes in life-space mobility, autonomy in participation outdoors, and in self-reported physical activity during COVID-19 pandemic restrictions were compared between those reporting intact walking, walking modifications, and difficulty in walking 2 km distances at baseline.

5.5.1 Associations of the use of adaptive and maladaptive walking modifications with life-space mobility, autonomy in participation outdoors and unmet physical activity need (Study III)

Life-space mobility scores were highest at baseline (mean 77.3, SD 15.6) and almost unchanged at follow-up (mean change -0.9, SE 1.0) among those without walking modifications. However, those with maladaptive walking modifications at baseline had the lowest life-space mobility scores (mean 49.1, SD 18.1), which decreased (mean change -4.6, SE 1.1) more steeply over time than the scores of those with no walking modifications, even when adjusted for age, sex, years of education, number of chronic conditions, depressive symptoms, cognitive function, and lower extremity function (Table 9). Those with adaptive walking modifications had intermediate life-space mobility scores (mean 63.9, SD 17.9) at baseline compared to those with no walking modifications or with maladaptive walking modifications ($p < 0.005$ for both). Over time, their scores declined (mean change -5.6, SE 1.1) more than the scores of those without walking modifications and at a similar rate as the scores of those with maladaptive walking modifications.

At baseline, those with maladaptive walking modifications perceived the poorest autonomy in participation outdoors (mean 8.2, SD 4.3) and the highest prevalence of unmet physical activity need (26.1 %) compared to those with no (mean 4.5, SD 3.0; 4.4 %, respectively) or with adaptive (mean 6.1, SD 3.3; 11.8 %, respectively) walking modifications. Over time, autonomy in participation outdoors worsened among those with adaptive walking modifications (mean change 1.2, SE 0.2) while remaining similar among those with no (mean change 0.4, SE 0.2) or with maladaptive (mean change 0.4, SE 0.3) walking modifications.

TABLE 9 Use of adaptive or maladaptive walking modifications and changes in life-space mobility, autonomy in participation outdoors and unmet physical activity need over the 2-year follow-up.

	Model 1					Model 2				
	Intercept		Slope			Intercept		Slope		
	B	SE	B	SE	P-value	B	SE	B	SE	P-value
Life-space mobility										
No walking modifications	79.5	1.1	-1.0	1.0	0.304	41.9	5.1	-0.9	1.0	0.347
Adaptive walking modifications	**69.6***	**1.2**	**-5.5***	**1.1**	**<0.001**	**36.4***	**5.0**	**-5.6***	**1.1**	**<0.001**
Maladaptive walking modifications	**48.8*†**	**1.2**	**-4.7***	**1.1**	**<0.001**	**20.9*†**	**4.9**	**-4.6***	**1.1**	**<0.001**
Autonomy in participation outdoors										
No walking modifications	4.4	0.2	0.4	0.2	**0.044**	7.7	1.0	0.4	0.2	**0.044**
Adaptive walking modifications	**5.6***	**0.2**	**1.2***	**0.2**	**<0.001**	8.1	1.0	**1.2***	**0.2**	**<0.001**
Maladaptive walking modifications	**8.1*†**	**0.3**	**0.4†**	**0.3**	0.127	**9.5*†**	**1.0**	**0.4†**	**0.3**	0.158
	Group difference		**Group by time difference**			**Group difference**		**Group by time difference**		
Unmet physical activity need	**OR**	**95 % CI**	**OR**	**95 % CI**	**P-value**	**OR**	**95 % CI**	**OR**	**95 % CI**	**P-value**
No walking modifications	1		1			1		1		
Adaptive walking modifications	**2.5***	**1.3–4.9**	1.4	0.7–3.1	0.393	1.9	0.9–3.7	1.4	0.6–3.1	0.398
Maladaptive walking modifications	**5.8*†**	**3.0–11.3**	0.8	0.4–1.7	0.555	**3.5*†**	**1.7–7.1**	0.8	0.4–1.8	0.611

Note. B = unstandardized regression coefficient; SE = standard error. GEE models were run separately for each outcome variable. Intercept indicates adjusted baseline values and slope indicates change over time. *Statistically significantly different from those with no walking modifications. †Statistically significantly different from those with adaptive walking modifications. Model 1: adjusted for age and sex; Model 2: adjusted for age, sex, years of education, number of chronic conditions, depressive symptoms, cognitive function, and lower extremity function. Statistically significant values are bolded.

5.5.2 Use of walking modifications, perceived walking difficulty and changes in life-space mobility, autonomy in participation outdoors, and self-reported physical activity during COVID-19 pandemic restrictions compared to two years before (Study IV)

Overall, life-space mobility declined, autonomy in participation outdoors worsened and physical activity increased during the COVID-19 pandemic social distancing recommendations compared to two years before. The older people with walking difficulty at baseline had a lower life-space mobility score (mean 61.4, SD 19.7) and showed a steeper decline over time (B -14.1, SE 1.3) than those with intact walking (mean 79.8, SD 14.9, B -8.7, SE 1.1, respectively) at baseline (Table 10). Those with walking modifications also had a lower life-space mobility score at baseline (mean 73.5, SD 14.9) and showed steeper decline at follow-up (B -13.6, 1.7) than those with intact walking.

Persons with walking difficulty showed a poorer baseline level (mean 6.6, SD 4.0) but smaller decline (B 6.2, SE 0.3) over time in autonomy in participation outdoors than those with intact walking (mean 4.0, SD 3.2; B 7.2, SE 0.3, respectively). Persons with walking modifications at baseline perceived poorer autonomy in participation outdoors (mean 5.4, SD 3.3) than those with intact walking, although the level of change between these groups remained similar over time.

At baseline, persons reporting walking difficulty (mean 24.1, SD 16.9) or walking modifications (mean 35.0, SD 18.1) accumulated fewer daily vigorous physical activity and walking minutes than those with intact walking (mean 43.3, SD 20.4, respectively). During the COVID-19 pandemic social distancing recommendations, daily vigorous physical activity and number of walking minutes increased from their baseline values among those with intact walking (B 9.1, SE 1.9) but remained unchanged among those with 2 km walking difficulty and those with walking modifications (B 1.3, SE 1,3; B 2.8, SE 2.3, respectively).

TABLE 10 Self-reported walking modifications and difficulty in walking 2 km, and changes in life-space mobility, autonomy in participation outdoors and physical activity during COVID-19 pandemic restrictions compared to two years before.

	Intercept		**Slope**		
	B	**SE**	**B**	**SE**	**P-value**
Life-space mobility					
Intact walking	84.2	1.0	-8.7	1.1	**<0.001**
Walking modifications	**79.1***	**1.4**	**-13.6***	**1.7**	**<0.001**
Walking difficulty	**59.2***	**1.2**	**-14.1*†**	**1.3**	**<0.001**
Autonomy in participation outdoors					
Intact walking	3.3	0.2	7.2	0.3	**<0.001**
Walking modifications	**4.5***	**0.3**	6.3	0.4	**<0.001**
Walking difficulty	**7.0***	**0.3**	**6.2*†**	**0.3**	**<0.001**
Physical activity					
Intact walking	44.1	1.3	9.1	1.9	**<0.001**
Walking modifications	**36.3***	**1.8**	**2.8***	**2.3**	0.221
Walking difficulty	**23.7***	**1.1**	**1.3*†**	**1.3**	0.341

Note. B = unstandardized regression coefficient; SE = standard error. GEE models were run separately for each outcome variable. Intercept indicates adjusted baseline values and slope indicates change over time. *Statistically significantly different from those with no walking modifications. †Statistically significantly different from those with adaptive walking modifications. Models were adjusted for age and sex. Statistically significant values are bolded.

6 DISCUSSION

This study suggests that older people using walking modifications may be able to postpone decline in their extent of mobility and autonomy in mobility and thereby potentially delay further restrictions in participation and independent living. While decreased physical capacity and factors in older people's living environment may hinder their possibilities to participate in out-of-home activities, the use of walking modifications may lower task demand in walking, enabling them to continue walking outdoors. Another main finding of this study was that the use of walking modifications and perceived walking difficulty reflect accelerometer-measured mobility patterns and daily walking minutes. The temporary loss of environmental mobility supports, such as destinations of interest, during spring 2020 was particularly detrimental for the mobility of older people who already had early or more advanced mobility limitations. These findings highlight the importance of environmental mobility facilitators in supporting autonomy and extent of outdoor mobility among older people. Whereas previous studies have mainly focused on studying walking modifications as a preclinical sign of disability, the present study also highlights the compensatory aspect of the use of walking modifications. A shift of focus to older people's walking modifications instead of walking difficulty, i.e., a shift from recovery to prevention, may promote interest in planning successful interventions.

6.1 Cross-sectional associations between accelerometer-measured mobility patterns and use of walking modifications

This study found that differences in the amount of daily walking, especially accumulating 83 or fewer daily walking minutes and walking bouts of 48 seconds or shorter duration, were associated with older people's use of walking modifications and perceived walking difficulty. Accumulating shorter walking bouts and fewer walking minutes during the day were more common among people reporting walking modifications than among people reporting no walking difficulty. These findings were expected, as self-reported walking modifications include such strategies as taking rest breaks during longer walks. This is in line with previous findings showing that older people showing the first signs of functional decline start dividing their walking into shorter bouts to avoid exhaustion or pain (Brawley et al., 2003). Older people who reported walking difficulty accumulated 36 fewer daily walking minutes than those with intact walking, who averaged around almost two hours of walking daily, a result supported by previous studies (Manns et al., 2015; Morie et al., 2010; Schrack et al., 2019). Moreover, the present results suggest that older people perceiving walking difficulty mainly walks indoors, as their walking bouts were shorter and of lower intensity, and their activity was more fragmented when compared to those with intact walking. The longer walking bouts observed among people with intact walking suggest that they may travel to destinations located further away from home on foot (Davis et al., 2011; Tsai, Rantakokko, Viljanen, et al., 2016), or that they may go for walks as exercise (Lim & Taylor, 2005).

Previous findings showed that older people with walking modifications form an intermediate group between older people with and those without walking difficulty in physical performance and in walking speed (Fried et al., 2000; Mänty et al., 2007). Other health and physical functioning factors have also been found to correlate highly with self-reported walking difficulty (Ganesh et al., 2011; Hoenig et al., 2006). Hence, it is possible that poor physical capacity increases the risk for low levels of physical activity, including daily walking (Portegijs, Rantakokko, et al., 2014) and perceived walking difficulty (Ganesh et al., 2011). In turn, low levels of physical activity and a decrease in the amount of daily walking, together with aging-related changes, lead to a decline in physical capacity (Fielding et al., 2017). However, the present study was limited to cross-sectional findings and a longitudinal study design would be required to study this sequence of events. Instead, the results of this study underline the importance of asking older people about their use of walking modifications as these yields valuable information on their current level of mobility and mobility patterns. This finding is important as using self-reports is both more feasible and faster in large epidemiological studies and in clinical practice than monitoring mobility over several days with accelerometers.

6.2 Environmental factors, use of walking modifications, and extent of mobility and autonomy in mobility

The choice of categorizing walking modifications into adaptive and maladaptive walking modifications stemmed from the need to determine whether walking modifications have similar consequences for both the extent of mobility and autonomy in mobility. Intuitively, some walking modifications, e.g., resting in the middle of walking or using an assistive device, appeared to reflect a strategy of optimization and compensation as a means to continue walking despite physical impairments. Other walking modifications, such as giving up walking longer distances, which leads to a lower level of mobility and less activity, were more loss-based choices. Overall, the findings suggest that older people using adaptive walking modifications are able to maintain a higher level of outdoor mobility and autonomy than those using maladaptive walking modifications. This is important, since higher life-space mobility is associated, for instance, with better quality of life in older people (Rantakokko, Portegijs, et al., 2013).

The smallest life-space, poorest level of autonomy in participation outdoors and highest prevalence of unmet physical activity need were observed among those using maladaptive walking modifications. Those with intact walking had the largest life-space, best level of autonomy outdoors and lowest prevalence of unmet physical activity need. Those with adaptive walking modifications formed an intermediate group between these two. Some of the statistically significant differences were attenuated when the models were adjusted for years of education, number of chronic conditions, depressive symptoms, cognitive function, and lower extremity function. This finding indicates that individual differences in health and physical functioning also underlie the levels of and changes in outdoor mobility.

In the early stage of functional decline, some older people lower the task demand of walking by using adaptive walking modifications to be able to maintain their outdoor mobility. This finding supports the SOC model, which posits that older people use different modifications in order to maintain participation in meaningful activities and life situations (Baltes & Baltes, 1990). However, as the decline in physical functioning progresses, the task demand in walking may exceed the individual's capacity to compensate by using adaptive modifications and instead adopt maladaptive walking modifications. While these findings are in line with those of previous studies showing that walking modifications may facilitate continued participation in meaningful activities and postpone the aging-related reduction in life-space mobility (Freedman et al., 2016; Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017), they also expand them by distinguishing between adaptive and maladaptive walking modifications and using multiple measures of mobility.

Another finding was that perceiving environmental facilitators for outdoor mobility was more common among those using either no walking modifications or adaptive walking modifications than among those using maladaptive walking modifications. This finding also accords with previous research showing an association between perceiving environmental facilitators and higher physical activity levels (Barnett et al., 2017; Cerin et al., 2017; Keskinen et al., 2019). Awareness of the presence of environmental outdoor mobility facilitators may enable or motivate individuals to use adaptive walking modifications that allow them to continue going to certain places. For instance, installing resting places in parks may encourage older people to visit them, whereas lack of such environmental support or not knowing about it may contribute to giving up walking longer distances.

In contrast to environmental facilitators, which were more common among people using adaptive walking modifications, perceiving environmental barriers was common among the older people reporting the use of any kind of walking modifications when the models were adjusted for age and sex. Perceiving nature- and infrastructure-related environmental outdoor mobility barriers was especially associated with using adaptive or maladaptive walking modifications. However, the associations across the different environmental outdoor mobility barriers were not similar and most of the observed associations were attenuated when health and physical capacity were added into the models.

The present study showed that environmental facilitators and barriers coincided with rather than preceded the use of walking modifications. In the prospective analyses, the sole exception was that perceiving a walking or skiing trail as a facilitator for outdoor mobility protected against developing maladaptive walking modifications over the 2-year follow-up. Similarly, when the models were adjusted for health and physical capacity, none of the perceived barriers to outdoor mobility was associated with higher odds for adopting new maladaptive walking modifications.

According to the ecological model of aging and the SOC model (Baltes & Baltes, 1990; Lawton & Nahemow, 1973), older people modify their behaviour in line with their personal competence and environmental barriers. In the present study, adjusting the models for physical functioning, such as lower extremity function and other health related covariates, attenuated most of the associations between the environmental barriers to outdoor mobility and use of walking modifications. These findings underline the importance of individual characteristics in person-environment fit models. Previous empirical studies have also shown that multiple personal factors, such as age, family context and functional capacity, are associated with the use of modifications (Gitlin et al., 2017; Hoenig et al., 2006; Lang et al., 2002). Similarly, it has been suggested in previous studies that older people tend to use modifications in a certain order depending on their level of physical functioning (Higgins et al., 2013; Weiss et al., 2007). The proposed order based on the findings of this study is that when their physical functioning first starts to decline and environmental press increases, older people first seek to reduce the task demand of walking. In that first stage of functional decline, they may use adaptive walking modifications, such as using an aid or lowering their walking speed, in order to continue walking. However, as physical functioning further declines and it becomes more difficult to compensate for functional loss via adaptive walking modifications, environmental press also increases, possibly leading to the increasing use of maladaptive walking modifications, such as giving up walking longer distances altogether. Resorting to loss-based selection (Baltes & Baltes, 1990) is logical in that final stage, since the use of modifications demands some resources from the individual (Gitlin et al., 2017). It can, therefore, be suggested that individuals' physical functioning affects their perceptions of their living environment, and that both these factors are important determinants of their selection of walking modifications. Thus, in line with ecological model of aging (Lawton & Nahemow, 1973), the use of adaptive and maladaptive walking modifications seems to stem from seeking to effect a balance in person-environment interaction.

The findings of the Study IV indicated that older people perceiving walking difficulty had the poorest life-space mobility and autonomy in participation outdoors and the lowest number of physical activity minutes 2 years before COVID-19 pandemic, and that they experienced the steepest decline in life-space mobility over time. Older people with intact walking reported the most extensive life-space mobility and also perceived the fewest restrictions in autonomy in participation outdoors over time. They also increased their physical activity the most during the COVID-19 pandemic restrictions. In contrast, older people using walking modifications remained in an intermediate position in all three outcome variables, i.e., life-space mobility, autonomy in participation outdoors, and self-reported physical activity, at both measurement points. However, their life-space mobility also declined over time. This finding indicates that the compensatory effect of using walking modifications decreased during the COVID-19 pandemic restrictions, as life-space mobility also declined over time among those using walking modifications. In spring 2020, many features that facilitate outdoor mobility disappeared, and thus older people had fewer opportunities to move further away from home.

Overall, the decline in life-space mobility was notably steeper during the COVID-19 pandemic emergency recommendations compared to the pre-COVID era, as found in Study III among a comparable cohort and follow-up period. Autonomy in participation outdoors declined during the COVID-19 pandemic restrictions, whereas it remained almost stable in pre-COVID Study III. These findings are reasonable, since in addition to the closure of restaurants, clubs, sport venues and parish activities and cancellations of events, older people were recommended to avoid crowded places and close contact with people outside their immediate family. Hence, it is likely that the changes observed in the participants' life-space mobility and autonomy in participation outdoors reflect the impact of the COVID-19 pandemic restrictions rather than individuals' personal capacity. This is supported by the finding that older people with intact walking perceived a larger decline in their autonomy in participation outdoors compared to those reporting walking difficulty. Whether or not the observed changes in outdoor mobility were mainly caused by the COVID-19 pandemic restrictions, these changes had a meaningful negative effect on older people's lives. For instance, restricted life-space mobility is associated with multiple adverse health outcomes, such as increased risk for further decline in physical functioning (Shimada et al., 2010) and mortality (Boyle et al., 2010). Older people perceiving walking difficulty and with the greatest decline in life-space mobility may especially be at risk for becoming homebound if the restrictions are prolonged. Being homebound is further associated with, for instance, dependence in self-care (Musich et al., 2015; Ornstein et al., 2015).

In contrast to changes in life-space mobility and autonomy in participation outdoors, older people's physical activity increased during the COVID-19 pandemic restrictions in the present study population. The increase in physical activity was highest among those with intact walking who were, at least partially, able to compensate for suspended activities by exercising at home or walking for leisure (Portegijs et al., 2021). Among those using walking modifications or perceiving walking difficulty, physical activity remained at approximately the same level from before to during the COVID-19 pandemic restrictions.

6.3 Methodological considerations

The Studies comprising this dissertation research form part of the larger LISPE and AGNES studies, both of which are prospective observational cohort studies. Both LISPE and AGNES targeted large population-based samples of community-dwelling older people. Using samples of this kind instead of convenience samples or non-probability samples reduces the risk of bias and hence increases the generalizability of the findings (Delgado-Rodriguez & Llorca, 2004; Infante-Rivard & Cusson, 2018). For example, drawing participants from the Population Information System administered by the Digital and Population Data Services Agency reduced or even eliminated self-selection bias (Hernán et al., 2004).

The LISPE and AGNES research projects both followed good scientific and clinical practices as laid down by the Declaration of Helsinki. The studies did not cause the participants physiological or psychological harm beyond what might be expected in normal everyday life. In addition, participants were informed about their opportunity to request information about the study and withdraw their consent at any time during the study. All the digital data gathered in both research projects were stored in secure computers on the University's network, protected by passwords, and only accessible to members of the research group. The data, which were also pseudonymized for the analyses, have been stored in a way that ensures the identities of the participants remain confidential.

Extensive home interviews with functional tests were included in both the LISPE and AGNES studies, while the AGNES study also included laboratory measurements. Thus, the study protocols of the LISPE and AGNES study were rather demanding and time-consuming for the participants. Therefore, despite the aim of recruiting participants with a wide range of physical functioning in both projects, the participants, as indicated by their SPPB scores (mean score > 9 in both studies), were relatively well-functioning older people. Older people with SPPB scores of 7 to 9 are 1.6–1.8 times more likely to have disability in activities of daily living or mobility-related disability than those with the highest scores (10–12), while for those with poorer scores (4 to 6) the risk is even higher (4.2 to 4.9) (Guralnik, Ferrucci, et al., 1995). Therefore, the present study is not totally free of the healthy volunteer effect, since the participants seem to be healthier than age peers in the general population (Delgado-Rodriguez & Llorca, 2004). This especially concerns Study I, which included only those participants who were willing to wear accelerometers. These participants reported higher levels of physical activity than those participating only in the home interview (Portegijs et al. 2019). In Studies II and III, this may have led to underestimation of the use of maladaptive walking modifications in the community-dwelling older population. Therefore, the findings of this study may not be applicable to vulnerable community-dwelling older people with poorer health and physical functioning.

Both cross-sectional and longitudinal study designs were used in this dissertation research. At the time of Study I, a cross-sectional design was the only possibility, and therefore further longitudinal studies are needed to investigate whether accelerometer-based free-living walking cut points can be used to detect the development of walking difficulty over time. Notable strength of this study was the possibility to investigate changes in extent of mobility and autonomy in mobility in relation to older people's self-reported walking modifications and walking difficulty (Studies III and IV) within a longitudinal study design with a 2-year follow-up. The longitudinal design enabled study not only of baseline differences in outdoor mobility levels, but also whether the change over time differed among older people using adaptive or maladaptive walking modifications or with different levels of self-reported walking modifications and difficulty. In Study IV, baseline data collected prior to the COVID-19 pandemic restrictions enabled comparison of outdoor mobility levels during the COVID-19 restrictions with the pre-COVID situation.

The present research includes secondary analyses conducted within the LISPE and AGNES study projects. Therefore, although the aims of the LISPE and AGNES studies were closely related to the aims of this dissertation project, the data, including the sample sizes and assessment methods, were not optimized for present purposes. The LISPE study was optimized to investigate outdoor mobility among older people by using multiple measures. Many of those measures were introduced and tested for the first time in Finland in the LISPE study. These measures were further developed and used in the AGNES study. However, the availability of an extensive dataset with multiple measures of physical functioning, perceived outdoor environment, self-reported walking modifications, walking difficulty, extent of mobility, and autonomy in mobility enabled the research questions to be addressed at the level set for this dissertation research. Missing data were few in the original studies, as the self-report data had mainly been gathered during face-to-face structured computer-assisted personal interviews. The follow-up data used in Study IV was the only dataset collected using postal questionnaires, a necessity owing to the COVID-19 pandemic restrictions. The use of postal questionnaires alone may be problematic as it cannot be certain who has responded to the questionnaire or whether some participants have misunderstood some of the items. Moreover, postal questionnaires without personal contact and the possibility to fill in blanks afterwards usually have a high amount of missing data. In the present study, however, the response rate was surprisingly high and missing values were few and could be imputed using purposeful imputation methods.

Self-reported walking modifications and perceived walking difficulty over a 2 km distance were investigated with a validated measure (Mänty et al., 2007). However, when asking someone about their ability to walk 2 km with or without difficulty obliges that person to make a decision about their ability to perform a task that they may have not attempted recently (Guralnik et al., 2012). A further limitation of the present study is that the categorization of walking modifications into adaptive and maladaptive types was not possible in Studies I and IV, as the information on the use of walking modifications was collected slightly differently in LISPE and AGNES studies. In the LISPE study, all the participants, irrespective of their perceived walking difficulty, were asked about their possible use of walking modifications, whereas, in the AGNES study, the walking modifications data were only collected from those who were able to walk 2 km without difficulty. Therefore, in Studies I and IV, the use of walking modifications was only an indicator of preclinical disability, whereas in Studies II and III it was possible to investigate walking modifications as accommodations. Furthermore, as task limitations initially occur in the most demanding tasks, such as walking longer distances (Weiss et al., 2007), a walking distance of 2 km was an appropriate measure for investigating walking modifications in this well-functioning study sample.

A strength of this study was that, in the LISPE study, people perceiving walking difficulty were also asked about their use of walking modifications. This enabled investigation of whether certain modifications could help maintain the extent of mobility and autonomy in mobility of people who may already perceive walking difficulty but who are still able to continue walking. Typically, the use of walking modifications has been assessed as a disability preceding functional decline, i.e., as preclinical, and thus people who do not report difficulty are not asked about this issue. However, a previous study suggested that some older people perceive the use of walking modifications as indicative of difficulty in walking (Ramos-Pichardo et al., 2014), despite the fact that the use of walking modifications may have a positive impact on their lives. For instance, an individual needing to rest when walking longer distances may report difficulty in walking, even if optimizing their performance by resting in the middle of it helps to maintain their ability to walk longer distances. It is also possible that a person who has recently experienced a sudden decline in their physical functioning and a person whose decline in physical functioning has occurred over a long period of time (Guralnik et al., 2001) will report walking difficulty differently. Therefore, the distinction between walking modifications and walking difficulty may be artificial when studying the effects, especially the compensatory effects, of walking modifications. However, in research aimed at investigating walking modifications as a preclinical stage before walking difficulty is actually perceived, the use of walking modifications should only be investigated among from those reporting no walking difficulty.

Environmental factors were investigated as perceived facilitators for and barriers to outdoor mobility. All the reported facilitators and barriers reported by the participants represent their subjective impressions of their living environment and whether they perceive certain factors as facilitating or hindering their opportunities for outdoor mobility. Therefore, it is possible that perceptions may be dependent on participants' cultural and environmental contexts. For instance, in Study II, the participants were mainly living in urban or suburban areas and hence the findings might not be applicable to older adults living in rural areas. Also relocating or experiencing changes in the living environment may change the factors that participants' report as outdoor mobility facilitators and barriers. In the present study, only 31 participants relocated during the follow-up, and thus the effect of this on the longitudinal findings is likely to be small. It can similarly be expected that improvements in the built environment over the 2-year follow-up were minor and not likely to have a major impact on the longitudinal findings. The COVID-19 pandemic restrictions created a natural experimental setting, which enabled investigation of person-environment interaction from an additional perspective. This unique situation offered the possibility to investigate how the environmental restrictions imposed affected the associations of the use of walking modifications and perceived walking difficulty with the extent of mobility and autonomy in mobility.

A further strength is that mobility was measured from four perspectives: as mobility patterns, the ability to move, extent of mobility, and autonomy in mobility. The use of different mobility variables, which differ conceptually from self-reported walking modifications and walking difficulty yielded information about the complex path from individual ability to participation. This knowledge will be of value in preventing or delaying restrictions in participation in old age.

We were able in this study to distinguish walking bouts from accelerometer recordings and calculate accelerometer-based free-living walking cut points for predicting increased risk of perceiving walking difficulty. However, although we used a previously defined method for distinguishing walking bouts from accelerometer recordings (Skotte et al., 2014), some limitations should be noted when interpreting these findings. In this study, in an attempt to differentiate light moving or standing still from actual walking, only walking bouts of ≥ 20 s duration were identified and used in the analyses. Using this cut point may, however, under-estimate the number of daily walking bouts, especially among those perceiving walking difficulty, as they mainly accumulate shorter gait bouts during the day. In sum, despite these limitations, the present study investigated the associations between older people's free-living daily walking activity with their perceived walking modifications, whereas previous studies have investigated the associations of accelerometer-based walking with perceived walking difficulty only, thereby ignoring those using walking modifications (Manns et al., 2015; Morie et al., 2010).

Despite its limitations, this study targeted a previously less studied topic on the use of walking modifications in old age and thus lays a foundation for further research. The present study also highlights the compensatory side of the use of walking modifications and contributes further knowledge on the determinants of using walking modifications. Therefore, the findings of this study contribute to the literature on the complex factors underlying the progression of walking difficulty restricting mobility and participation later on in old age.

6.4 Implications and future directions

The present findings on the determinants of the use of specific types of walking modifications and perceived walking difficulty support previous findings on the hierarchy of the adoption of walking modifications and perceived walking difficulty. Mobility declines in old age sooner or later and may be manifested as perceived walking difficulty or the end point even as walking limitation. This further impairs individuals' possibilities to participate in out-of-home activities, which is crucial in enabling independent living. However, as observed in this and previous studies (Gore et al., 2018), older people use multiple strategies in seeking to postponing these negative changes.

Walking modifications have two important functions in the complex pathway from diseases or impairments to disability (Verbrugge & Jette, 1994). First, walking modifications, especially when walking longer distances, can help individuals to identify their first signs of functional decline. Using questionnaires on the use of walking modifications in clinical practice may help older people to recognize that their way of walking has changed. Recognizing the early phase of functional decline opens the door to interventions and prevention. After recognizing the first signs of functional decline, further decline in outdoor mobility may be postponed or even prevented by lowering the environmental demands, or by using walking modifications (Lawton & Nahemow, 1973; Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017). Thus, the second important purpose of using walking modifications is that they may enable older people with declining physical functioning to continue walking outdoors, and hence maintain their outdoor mobility, by modifying their walking, such as by resting during longer walks or walking slower.

The findings of this study indicate that older people should aim to continue walking, including with walking modifications, as it can improve the ability to walk and maintain the extent of mobility and autonomy in mobility. Although the ability to move can also be maintained, for instance by improving lower extremity function, using walking modifications is a minimal strategy and readily available to older people when they are encountering a decline in their physical functioning. Similarly, Gore et al. (2018) suggest that in the first stages of functional decline, older people should seek to minimize losses in their physical functioning and in the ability to walk. However, as their health condition worsens and environmental press increases, maintaining the extent of mobility through adaptive walking modifications may become too challenging. At that stage, older people may also need changes in their living environment, which, depending on personal preferences and capacity, can mean anything from installing handrails or ramps at the front door to moving into an age-friendly environment. In the final stage, the extent of mobility may become restricted and external support from other people may be needed to perform daily errands. This final stage represents the end point of functional decline and should be postponed for as long as possible in old age (Gore et al., 2018). The present study suggest that it can be done partly with the help of walking modifications.

The results of this study support the previous finding that enquiring about the use of walking modifications rather than exclusively about walking difficulty may be a sensitive way to detect early functional limitations (Pine et al., 2002). Therefore, focusing on older people's walking modifications instead of just walking difficulty may, by shifting attention away from recovery to prevention, increase efforts to plan successful interventions (Wolinsky et al., 2005). The present study has a few suggestions for future studies on the use of walking modifications in old age. First, also older people perceiving walking difficulty should also be asked about their use of walking modifications. This would allow walking modifications to be studied not only as signs of preclinical disability but also as accommodations that assist walking. These perspectives differ conceptually. This claim is also supported by the previous finding that some older people perceive the use of walking modifications purely as a sign of difficulty in walking (Ramos-Pichardo et al., 2014) despite the positive impacts it may have on their lives. Second, the differences between using different kind of walking modifications should be highlighted in future research. The present findings suggests that adaptive walking modifications can help in maintaining activity, whereas maladaptive walking modifications lead to a less activity.

Although this study yielded novel information on the use of walking modifications, it also prompts new questions. For instance, further studies are required to investigate the order in which different walking modifications are used. Based on this study, it can be speculated that adaptive walking modifications are used first by older people who experience only a minor decline in their physical functioning and suitability of their environment. Instead, those experiencing a major decline in physical functioning and higher environmental press are more prone to use maladaptive walking modifications. For example, whether individuals typically first start to slower their pace of walking before using an aid is currently unknown. In addition, it remains unclear whether other factors than physical functioning and features of the environment are related to the use of walking modifications. For instance, the personal reasons behind using certain modifications remain in need of clarification. Do older people who use walking modifications have personal goals that motivate them to continue walking? Or are walking modifications used only because older people have no other options than to continue walking to accomplish daily errands? All in all, using walking modifications seems to be the result of a complex relationship between personal preferences, capabilities, and the living environment.

7 MAIN FINDINGS AND CONCLUSIONS

The main findings of this study are:

1. Self-reported walking modification and difficulty measure and accelerometer-based free-living walking give parallel information about older people's mobility pattern. This finding is important as using self-report is feasible and fast to use in a clinical practice when investigating older people's mobility.

2. Some of the environmental factors perceived as facilitators may motivate individuals to continue walking in an adaptive way despite functional decline. The present finding of an association between perceived environmental barriers to outdoor mobility and the use of maladaptive walking modifications highlights the importance of a safe and walkable environment for increasing outdoor mobility among older people. It would, therefore, be beneficial to reduce environmental barriers, especially for those with poorer physical capacity.

3. Some older people may postpone the age-related decline in extent of mobility and autonomy in mobility by adopting adaptive walking modifications. Encouraging the use of adaptive walking modifications when needed and designing age-friendly environments, for example, by providing opportunities to rest when walking outdoors, may help older people to maintain their life-space mobility and autonomy to participate in outdoor activities, and protect them from unmet physical activity need.

4. The decline in life-space mobility and autonomy in participation outdoors during the first wave of COVID-19 pandemic compared to the levels reported two years ago exceeded the decline that would naturally have occurred due to the aging process over the same period. The compensatory effect of using walking modifications decreased during the COVID-19 pandemic restrictions.

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ORIGINAL PAPERS

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ASSOCIATIONS BETWEEN ACCELEROMETER-BASED FREE-LIVING WALKING AND SELF-REPORTED WALKING CAPABILITY AMONG COMMUNITY-DWELLING OLDER PEOPLE

by

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Associations between Accelerometer-Based Free-Living Walking and Self-Reported Walking Capability among Community-Dwelling Older People

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ABSTRACT

Introduction: We examined whether accelerometer-based free-living walking differs between those reporting walking modifications or perceiving walking difficulty vs. those with no difficulty.

Methods: Community-dwelling 75-, 80- or 85-year-old people (N=479) wore accelerometers continuously for 3–7 days, and reported whether they perceived no difficulties, used walking modifications, or perceived difficulties walking 2km. Daily walking minutes, walking bouts, walking bout intensity and duration, and activity fragmentation were calculated from accelerometer recordings, and cut-points for increased risk for perceiving walking difficulties were calculated using ROC analysis.

Results: Our analyses showed that accumulating ≤83.1 daily walking minutes and walking bouts duration ≤47.8 seconds increased the likelihood of reporting walking modifications and difficulties. Accumulating walking bouts ≤99.4 per day, having walking bouts ≤0.119 g intensity, and ≥0.257 ASTP fragmented activity pattern were associated only with perceiving walking difficulties.

Conclusions: The findings suggest that older people's accelerometer-based free-living walking reflects their self-reported walking capability.

Keywords: aging, compensation, walking accumulation, mobility

INTRODUCTION

In the context of aging-related decline in individuals' competencies, walking can be maintained by increasing walking capacity (e.g., improving lower extremity function), lowering environmental demands (e.g., improving the accessibility of the environment), or modifying walking (e.g., using an aid or resting during walking) (Nahemow & Lawton, 1973; Skantz, Rantanen, Palmberg et al., 2020a; Skantz, Rantanen, Rantalainen et al., 2020b). Older people's outdoor walking consists mostly on running daily errands, such as going shopping (Davis et al., 2011; Tsai et al., 2016), and thus the maintenance of walking ability is essential in enabling independent living (Rantanen, 2013). In addition, walking is a commonly reported form of physical activity among older people (Lim & Taylor, 2005). Among the strategies for maintaining walking activity, those aimed at reducing task demands with walking modifications, such as lowering walking speed, using an aid, resting during walking, and reducing the frequency of walking longer distances (Mänty et al., 2007), are the most readily available to people facing functional decline. Based on the self-report measures, older people using walking modifications are able to continue walking longer distances (Skantz et al., 2020a) and postpone decline in life-space mobility compared to those with walking difficulties (Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2017; Skantz et al., 2020).

Walking modifications are typically used by older people who exhibit the first signs of functional decline but do not perceive themselves as having walking difficulties. Thus they form an intermediate group in their health and functional status between those with and those without walking difficulties (Fried, Bandeen-Roche, Chaves, & Johnson, 2000; Mänty et al., 2007). In addition to current functional status (Gitlin, Winter, & Stanley, 2017; Hoenig et al., 2006; Lang, Rieckmann, & Baltes, 2002; Skantz et al., 2020), the use of walking modifications is also related to features of an individual's living environment (Skantz et al., 2020). Older people with the first signs of functional decline who report barriers in their environment may be able to overcome them by modifying their walking activity and thus maintain their participation in outdoor activities (Skantz et al., 2020). As physical capacity further declines, environmental demands may exceed a person's capacity to negotiate the environment. This leads to considering such environmental features as mobility barriers and hindering the use of walking modifications (Skantz et al., 2020). This is the point when older people may start to experience walking difficulties and reduce their walking activity (Nahemow & Lawton, 1973; Weiss, Fried, & Bandeen-Roche, 2007).

While self-report measures of walking capability yield important knowledge about individuals' ability to walk in their own environment (what they **can** do) (Mänty et al., 2007), wearable accelerometers capture bouts of movement and non-movement in free-living conditions (what they **do** do). Thus, accelerometers can be used to gain information about free-living walking; the amount of walking (e.g. daily walking minutes, daily walking bouts, walking bout duration, and walking bout intensity) and about the patterns of daily walking activity (e.g. walking bout duration and activity fragmentation) (Palmberg et al., 2020; Schrack et al., 2018; Skotte, Korshøj, Kristiansen, Hanisch, & Holtermann, 2014). However, to the best of the present authors' knowledge, studies aimed at extracting walking bouts from free-living accelerometer data among older people are limited and the critical cut-points for increased risk for perceiving walking difficulties are undefined. In addition, studies on the associations of accelerometer-based free-living walking with self-reported walking modifications are lacking. Studying the associations between accelerometer-based free-living walking and self-reported walking capability will benefit researchers in interpretation of the future results, especially if it is not possible to gather information about walking by using both measures.

Based on previous findings, persons accumulating lower intensity in accelerometer-based physical activity and longer sedentary bouts more often report walking difficulties (Manns, Ezeugwu, Armijo-Olivo, Vallance, & Healy, 2015; Morie et al., 2010). Thus, it can be hypothesized that, accelerometer-based walking is associated with the use of walking modifications, as well as with walking difficulties. In addition, based on previous self-report data (Rantakokko et al., 2017; Skantz et al., 2020), it can be hypothesized that older people using walking modifications are able to maintain their free-living walking at close to the same level as those without walking difficulties. It has also been shown that as functional capacity declines, it becomes harder to maintain longer bouts of physically demanding activities, such as walking longer distances, and hence the activity patterns of daily life often become more fragmented (Palmberg et al., 2020; Schrack et al., 2018). We expect that persons who show a more fragmented activity pattern are either using walking modifications or perceive difficulties in walking 2-km distances, as higher activity fragmentation may indicate declining health (Schrack et al., 2018). However, the newest global physical activity guidelines suggests that physical activity at any intensity and duration, and reducing sedentary time throughout the day provides health benefits (Bull et al., 2020). Thus, breaking up sedentary time with short activity bouts throughout the day can be advantageous (Fanning et al., 2020).

The aim of this study was to determine optimal accelerometer-based free-living walking cut-points for an increased likelihood of self-reported walking difficulties. In addition, the aim was to investigate associations between the accelerometer-based free-living walking cut-points and self-reported walking capability, including walking difficulties and walking modifications.

METHODS

Study Design and Participants

This study is a part of the ‘Active Ageing – resilience and external support as modifiers of the disablement outcome’ (AGNES) observational cross-sectional cohort study. The study protocol (Rantanen et al., 2018) and non-respondent analyses (Portegijs, Karavirta, Saajanaho, Rantalainen, & Rantanen, 2019) have been reported previously. Briefly, AGNES is an observational study of three age cohorts (75, 80 and 85 years) living in the Jyväskylä area in Central Finland. A random sample of individuals based on age and residence in specific Jyväskylä postal code areas was drawn from Population Information System administered by the Finnish Population Register Centre (http://vrk.fi/en). The inclusion criteria for the study were living in the study area (Jyväskylä), being community-dwelling, willing to participate, and being able to communicate and provide an informed consent. After exclusions, a total of 1021 participants took part and were administered a face-to-face computer-assisted structured interview in their homes. Those willing to participate in the physical assessments in the research center (n = 910) were asked to wear an accelerometer for seven to ten days. An additional exclusion criterion for the accelerometer measurements was a known allergy to adhesive, since the accelerometer was directly taped onto the skin. In addition, participants who swam, bathed or took a sauna bath several times per week were excluded, as the accelerometers were not fully water-resistant. Finally, 496 participants agreed to wear the accelerometer. Based on the non-respondent analyses, those who did not participate in the accelerometer measurements had lower self-reported physical activity and lower walking speed than those wearing the accelerometers (Portegijs et al., 2019). The AGNES study was approved by ethical committee of the Central Finland Health Care District and the study protocol followed the principles of the Declaration of Helsinki.

Accelerometer Data

Free-living walking (daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity, activity fragmentation) was assessed with a tri-axial accelerometer (range ±16 g, 13-bit analog-to-digital conversion, UKK RM42, UKK Terveyspalvelut Oy, Tampere, Finland) (Rantanen et al., 2018). The accelerometer was attached by a research assistant to the anterior aspect of the mid-thigh of the dominant leg with self-adhesive film during the home interview and participants were instructed to wear the accelerometer continuously for 7 to 10 days until the laboratory assessments. The dominant leg was defined primarily as the take-off leg, secondarily as the kicking leg, and thirdly as the leg on the side of the dominant hand (Karavirta et al., 2020). Although the self-adhesive film was waterproof, longer water-related activities such as swimming or taking a bath or sauna were not allowed while wearing the monitor. The data were verified visually to ensure that only days with complete 24-hour data without non-wear were included in the analysis. After excluding the data of 11 participants owing to either loss of monitor (n = 2), technical error (n = 1) or data availability for less than three full days (n = 8), acceptable accelerometer data were obtained for 485 participants. The accelerometer sampling rate was set at 100 samples per second and acceleration recorded in units of gravity (g). The mean amplitude deviation (MAD) of each 24-h epoch was calculated from the resultant acceleration ($resultant = \sqrt{X^2 + Y^2 + Z^2}$) in non-overlapping 5-second epochs (Vähä-Ypyä, Henri, Vasankari, Husu, Suni, & Sievänen, 2015; Vähä-Ypyä et al., 2015).

The previously defined method was modified and used to identify walking bouts from the free-living accelerometer data (Skotte et al., 2014). Continuous walking bouts of ≥ 20 sec in duration were identified based on the orientation angle of the thigh (an angle for postural estimation (APE) of < pi/4 to be eligible to be consideration as walking) (Vähä-Ypyä, H., Husu, Suni, Vasankari, & Sievänen, 2018), and the signal intensity (MAD of between 0.035 g and 1.2 g, results of the laboratory experimentation). Thereafter, *daily walking bouts* (bouts/d), *walking bout duration* (sec) and *walking bout intensity* (g) were calculated. *Mean daily walking minutes* (min/d) were calculated by multiplying walking bouts by walking bout duration. *Activity fragmentation* was assessed as the Active-to-Sedentary Transition Probability (ASTP), i.e., the probability of transitioning from an active to a sedentary state (Schrack et al., 2018). The ASTP was calculated by dividing the number of activity bouts by the mean sum of active daily minutes (at least light activity, with a MAD value of at least 16.7 mg) (Palmberg et al., 2020). A higher ASTP represents a more fragmented activity pattern. Daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity, and activity fragmentation were used as continuous variables in the analyses.

Questionnaire Data

Self-reported walking capability was evaluated based on self-reported walking difficulties and walking modifications. First, participants were asked if they perceived difficulties in walking 2 kilometers (km) with a standardized question: "*Do you have difficulty walking 2 kilometers?"* (Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2016). The response alternatives were 1) able to manage without difficulty, 2) able to manage with some difficulty, 3) able to manage with a great deal of difficulty, 4) able to manage only with help of another person, and 5) unable to manage even with help. Second, to identify participants using walking modifications, those who reported being able to walk 2 km without difficulties were asked an additional question: "*Have you noticed any of the following changes when walking 2 km due to your health or physical functioning*?". The walking modifications were: walking slower, resting during walking, using an aid, reduced frequency of walking, and having given up walking distances of 2 km. Participants were asked to report all the walking modifications that they used ("yes" or "no"). For the analyses, participants were categorized into groups of *self-reported walking capability* as follows: 1) *no difficulties* (reporting neither difficulty nor modifications), 2) *walking modifications* (reporting no difficulties and ≥ 1 modification) and 3) *walking difficulties* (reporting at least some difficulty).

Age and sex were drawn from national population register. Years of education, number of chronic conditions, depressive symptoms and lower extremity function were assessed during the at-home interview and examination. *Years of education,* used as an indicator of socioeconomic status, was self-reported. *Number of chronic conditions* was calculated as the sum of individual chronic conditions selected from a list of specific physician-diagnosed chronic conditions followed by an open-ended question on any other chronic conditions the participant might have (Rantanen et al., 2018). *Depressive symptoms* were assessed with the Center for Epidemiologic Studies Depression Scale, CES-D (range 0–60, with higher scores indicating more depressive symptoms) (Radloff, 1977). *Lower extremity function* was assessed with the Short Physical Performance Battery (SPPB, range 0-12, with higher scores indicating better lower extremity function) and included balance, walking speed and chair stands (Guralnik et al., 1994; Rantanen et al., 2018).

Statistical Analyses

Descriptive statistics by self-reported walking capability were reported in percentages for categorical variables and means with standard deviations (SD) for continuous variables, and differences between groups were tested with chi-square tests (χ^2) or one-way analysis of variance (ANOVA). As preliminary analyses mostly showed differences in free-living walking between participants with no difficulties and participants with walking difficulties, Receiver Operating Characteristics (ROC) analysis (Akobeng, 2007) was performed to estimate optimal accelerometer-based free-living walking (daily walking minutes, daily walking bouts, walking bout duration, walking bout intensity, activity fragmentation) cut-points for predicting perceived walking difficulties. The advantage of Receiver Operating Characteristics (ROC) analysis is that it is free from parametric assumptions (Lasko, Bhagwat, Zou, & Ohno-Machado, 2005). In these analyses, participants with no difficulties and those with walking modifications were merged into the same reference group (n = 341). The cut-points that best balanced the high sensitivity and high specificity of the test were calculated by finding the minimal value by using formula $(1 – \text{sensitivity})^2 + (1 – \text{specificity})^2$. The suitability of the test was evaluated by estimating the area under the curve (AUC). This value serves as a single measure that indicates the accuracy of the test: 0.5–0.7 = low accuracy, 0.7–0.9 = moderate accuracy, > 0.9 = high accuracy (Akobeng, 2007).

After calculating the optimal cut-points, the associations of free-living walking with self-reported walking capability were assessed by using multinomial logistic regression analysis. Multinomial logistic regression analysis was used because the outcome variable was a nominal scale variable. Those with no difficulties were used as a reference group in the analyses. The models were first unadjusted and then adjusted for age, sex and years of education. Age and sex were available for all participants with adequate accelerometer data; however, for six participants information on self-reported walking capability was missing, and thus 479 participants with adequate accelerometer data were included into this study. A further four participants had missing information for years of education and thus these participants were not included in the fully adjusted models. IBM SPSS version 24 for Windows (IBM Corp., Armonk, NY) was used for statistical analyses. The results were regarded as statistically significant if the 95 % confidence intervals did not include 1 or when the p-value was < 0.05.

RESULTS

Participant characteristics by self-reported walking capability are presented in Table 1. Comparison by self-reported walking capability revealed that those with walking difficulties ($n = 138$) had the poorest CES-D and SPPB scores, while those with no difficulties ($n = 261$) reported the least depressive symptoms and best lower extremity function (Table 1). Based on the post hoc comparisons, the older people with walking modifications ($n = 80$) did not differ from those without walking difficulties in age ($p = 0.347$), years of education ($p = 0.319$), depressive symptoms ($p = 0.166$) or number of chronic conditions ($p = 0.455$). Instead, participants with walking modifications formed a middle group in lower extremity function between those with no difficulties and those with walking difficulties ($p < 0.001$ for both) and had less chronic conditions than those with walking difficulties ($p < 0.001$).

Across all participants, the mean number of daily walking minutes was 101.9 (SD 42.2) and the mean number of daily walking bouts 114.1 (SD 41.2). Mean walking bout intensity was 0.12 (SD 0.02) g, mean bout duration 53.7 (SD 13.5) seconds, and mean activity fragmentation 0.24 ASTP (SD 0.06). Those without walking difficulties accumulated the highest number of daily walking minutes (115.0 min, SD 37.9) and walking bouts (120.2, SD 38.1). Their walking bouts were also the longest (58.5 sec, SD 14.0), and showed the highest average intensity (0.23 g, SD 0.05) (Table 1). In addition, their activity was the least fragmented (0.23 ASTP, SD 0.05). Participants reporting walking modifications had a similar mean number (120.7, SD 45.0, $p = 1.000$) and intensity (0.12 g, SD 0.02, $p = 0.751$) of daily walking bouts and a similar activity fragmentation pattern (0.24 ASTP, SD 0.06, $p = 0.594$) as those without walking difficulties. However, participants reporting walking modifications accumulated fewer daily walking minutes (102.4 min, SD 42.9, $p = 0.035$) and had shorter walking bouts (50.9 sec, SD 9.7, $p < 0.001$) than those without walking difficulties. Participants with walking difficulties showed the poorest values in all the free-living walking variables.

The associations between free-living walking cut-points and self-reported walking capability

The free-living walking cut-points for increased risk for reporting walking difficulties were established by using ROC curve analyses (Table 2). Daily walking minutes (cut-point 83.1 min, AUC 0.745), walking bout duration (cut-point 47.8 sec, AUC 0.756), and activity fragmentation (cut-point 0.257 ASTP, AUC 0.715) showed moderate accuracy, while the number of daily walking bouts (cut-point 99.4 bouts) and walking bout intensity (cut-point 0.119 g) showed low accuracy (AUC < 0.7) in discriminating between older people with walking difficulties and those without difficulties. Multinomial logistic regression analyses revealed that, adjusting the models for age, sex and years of education did no change the associations between free-living walking and self-reported walking capability, and thus we present only adjusted models (Table 3). In the analyses, participants walking less than 83.1 minutes daily had over two-fold greater odds for using walking modifications and 5.5-fold odds for perceiving walking difficulties than perceiving no difficulties. Similarly, participants accumulating walking bouts shorter than 47.8 seconds had over two-fold greater odds for using walking modifications and over 6-fold greater odds for perceiving walking difficulties than perceiving no difficulties. Accumulating walking bouts equal to or less than 99.4 per day, having walking bouts equal to or lower than 0.119 g intensity, and having a more fragmented activity pattern were associated with perceiving walking difficulties but not with the use of walking modifications.

DISCUSSION

To the authors' best knowledge, this is the first study to establish accelerometer-based free-living walking cut-points for predicting increased risk of perceiving walking difficulties and to investigate the associations of these cut-points with self-reported walking capability. The present findings showed that differences in daily walking activity and walking patterns were, as expected, related to self-reported walking capability. We observed that accumulating 83 or fewer daily walking minutes and walking bouts of 48 seconds or shorter duration were associated with the use of walking modifications or perceiving walking difficulties.

In this study, we observed that people with shorter walking bouts were more likely to report walking modifications than no walking difficulties. This finding is reasonable, since walking modifications include taking rest breaks during longer walks perceived as tiring, meaning that older people with the first signs of functional decline start dividing their walking into shorter bouts to avoid exhaustion or to avoid pain (Brawley, Rejeski, & King, 2003). Moreover, as shown in previous studies, this strategy enables them to maintain their self-reported outdoor mobility on the same level as before (Rantakokko et al., 2017; Skantz et al., 2020). We also observed slightly fewer daily walking minutes among those using walking modifications than those without walking difficulties. This finding was expected, since older people using walking modifications are already experiencing the first signs of declining physical capacity (Fried et al., 2000; Mänty et al., 2007). This finding is also consistent with the results of our previous study in which we observed a slightly lower life-space mobility score among older people using walking modifications than those with no difficulties (Skantz et al., 2020). However, the life-space mobility measurement includes other ways of moving besides walking, such as using a car or public transport (Baker, Bodner, & Allman, 2003), and thus older people with poorer physical capacity may be able to achieve higher life-space mobility scores if they are able to use car or public transport.

In line with previous studies (Manns et al., 2015; Morie et al., 2010; Schrack et al., 2018), we noticed that the present sample of older people with walking difficulties accumulated 36 fewer daily walking minutes than those without walking difficulties, who averaged around almost two hours walking daily. Moreover, the daily walking activity of older people with walking difficulties may consist mainly of indoor walking, as their walking bouts were of shorter duration and lower intensity and their activity was more fragmented compared to those without walking difficulties. In addition, the longer walking bouts among people without walking difficulties suggest that they may run errands located also further away from home on foot (Davis et al., 2011; Tsai et al., 2016), or they may go for walks to exercise (Lim & Taylor, 2005). However, walking outdoors, with the help of others or with a walking aid, would be beneficial for older people perceiving walking difficulties, as previous research has shown that older people are more physically active on days when they go outdoors from their homes (Portegijs, Tsai, Rantanen, & Rantakokko, 2015). In addition, older people with walking difficulties would gain health benefits by breaking up sedentary time even with short activity bouts throughout the day (Bull et al., 2020; Fanning et al., 2020). Differences in daily walking activity and activity patterns were also observed between older people with walking modifications and those with walking difficulties. This finding supports previous suggestions that older people using walking modifications form an intermediate group between older people with and those without walking difficulties (Fried et al., 2000; Mänty et al., 2007). Thus, it is important to include the questions of the use of walking modifications in studies investigating older people's self-reported walking capability.

In previous studies, physical capacity and health are shown to be associated with self-reported walking capability (Ganesh, Fried, Taylor, Pieper, & Hoenig, 2011; Hoenig et al., 2006). However, including lower extremity function and other health characteristics into our models, would have potentially led to over-adjustment, as they may be factors on the pathway rather than confounders. It is possible that, poor physical capacity increases the risk for low levels of physical activity (Portegijs, Rantakokko, Mikkola, Viljanen, & Rantanen, 2014) and perceiving walking difficulties (Ganesh et al., 2011). In turn, low levels of physical activity, together with aging-related changes, declines physical capacity (Fielding et al., 2017). The use of walking modifications may, by slowing or even halting this chain of events, help older people to continue walking despite poor physical capacity (Skantz et al., 2020). However, studying this chain of events requires longitudinal data.

The strengths of this study include the accelerometer-based assessment of the free-living walking of a relatively large population-based sample of community-dwelling older people. Using accelerometer data enabled us to study the associations of older people's free-living daily walking activity with perceived walking modifications, whereas previous studies have been limited to self-reported data or have investigated the associations of accelerometer-based walking with perceived walking difficulties without considering the use of walking modifications (Manns et al., 2015; Morie et al., 2010; Skantz et al., 2020). The present self-reported data were gathered during face-to-face structured interviews, and therefore missing values were few. Moreover, we used a self-reported walking modifications measure that has been shown to be a validated and reliable indicator of preclinical disability (Mänty et al., 2007).

The study also has its limitations. First, this study reported cross-sectional findings and thus causality cannot be inferred. Therefore, longitudinal studies are needed to ascertain whether accelerometer-based free-living walking cut-points predicts self-reported walking capability over time. Second, our study population comprised relatively well-functioning older people, as those who wore accelerometers, and thus participated in this study, reported higher levels of physical activity than those who did not wear accelerometers (Portegijs et al., 2019). Thus, the study should be repeated with the more vulnerable older people to determine whether they exhibit similar associations. Third, the participants using walking modifications can be expected to be heterogeneous in their level of physical functioning. However, since data on walking modifications were only collected from those who were able to walk 2 km without difficulties, we were unable to categorize walking modifications into adaptive and maladaptive types (Skantz et al., 2020). Despite this limitation, studying walking modifications among those without walking difficulties was informative on how walking activity can be sustained among those who are at increased risk for future walking difficulties. Finally, only $\geq$ 20 seconds long walking bouts were identified and used in our analyses because we wanted to make sure that we will capture only actual walking bouts excluding light moving or standing still. However, using this cut-point may under-estimate the amount of daily walking minutes especially among those with walking difficulties. In addition, the original method for identifying types of physical activity (Skotte et al., 2014) was modified, as we have found from visual inspection that distinguishing stair walking from walking on the flat lead to misclassification. Thus, our analyses include stair walking. Skotte et al. (2014) also reported challenges in identifying stair walking. However, in future studies, it would be interesting to differentiate stair walking from walking on the flat, as stair walking presents a major challenge for muscle strength in older people (Tikkanen et al., 2016).

CONCLUSIONS

This study showed that older people's self-reported walking capability is partly determined by their daily walking pattern, especially by the accumulation of daily walking minutes and duration of walking bouts. These findings, together with previous findings, suggest that older people evaluate walking capability based on their free-living walking, physical capacity, and current living environment. In addition, we observed that self-reported walking capability gives a realistic picture of older peoples' walking activity in their everyday life.

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CONFLICT OF INTEREST

MR serves on the Journal of Aging and Physical Activity editorial board. Otherwise, the authors declare no conflicts of interest.

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Table 1. Baseline Characteristics by Self-Reported Walking Capability (N = 479).

Characteristics	No difficulties (n = 261) Mean (SD)	Modifications (n = 80) Mean (SD)	Difficulties (n = 138) Mean (SD)	P-value
Age (y)	77.7 (3.1)	78.4 (3.3)	79.6 (3.7)	**<.001** [a]
Education (y)	12.2 (4.2)	11.3 (4.6)	10.8 (4.1)	**0.006** [a]
No. of chronic conditions	2.7 (1.7)	3.0 (2.0)	4.6 (2.1)	**<.001** [a]
CES-D	6.5 (6.1)	8.1 (6.8)	10.3 (7.0)	**<.001** [a]
SPPB	11.0 (1.3)	10.2 (1.6)	9.0 (2.4)	**<.001** [a]
Female, %	54.8	56.3	71.0	**0.003** [b]
Daily walking minutes	115.0 (37.9)	102.4 (42.9)	76.7 (38.2)	**<.001** [a]
Number of walking bouts	120.2 (38.1)	120.70 (45.0)	98.56 (40.7)	**<.001** [a]
Average walking bout intensity, g	0.13 (0.02)	0.12 (0.02)	0.12 (0.03)	**<.001** [a]
Average walking bout duration, sec	58.5 (14.0)	50.9 (9.7)	46.3 (10.7)	**<.001** [a]
Activity fragmentation	0.23 (0.05)	0.24 (0.06)	0.28 (0.07)	**<.001** [a]

Note: CES–D = Center for Epidemiologic Studies Depression Scale, SPPB = Short Physical Performance Battery. [a]: tested with one–way analysis of variance, [b]: tested with chi square test. Statistically significant p-values are bolded.

Table 2. Sensitivity and Specificity of Accelerometer-Based Daily Walking Minutes, Daily Walking Bouts, Walking Bout Intensity, Walking Bout Duration, and Activity Fragmentation in Identifying Walking Difficulties.

	Cut-point	Sensitivity, %	Specificity, %	Area under curve (95 % CI)
Daily walking minutes	83.1	63	74	0.745 (0.696–0.794)
Daily walking bouts	99.4	56	66	0.646 (0.590–0.702)
Walking bout intensity, g	0.119	62	60	0.641 (0.584–0.697)
Walking bout duration, sec	47.8	67	73	0.756 (0.702–0.801)
Fragmentation*	0.257	58	73	0.715 (0.663–0.766)

Note: Values equal to or below the cut-point are related to perceived walking difficulties. Walking difficulties were defined as reporting at least minor difficulties in walking 2-km distances and compared to reporting no walking difficulties (including use of walking modifications).

*Values equal or over the cut-point are related to perceived walking difficulties.

Table 3. Associations of Free-Living Walking with Self-Reported Walking Capability in Community-Dwelling Older People. Odds are Reported for Those with Walking Modifications and Walking Difficulties vs. Those with No Walking Difficulties (Reference).

Free-living walking	Crude				Model 1			
	Walking modifications (n = 80)		Walking difficulties (n = 138)		Walking modifications (n = 78)		Walking difficulties (n = 136)	
	OR (95 % CI)	P-value	OR (95 % CI)	P-value	OR (95 % CI)	P-value	OR (95 % CI)	P-value
Daily walking minutes ≤ 83.1 min vs. > 83.1 min	**2.6 (1.5–4.5)**	**<0.001**	**6.4 (4.1–10.1)**	**<0.001**	**2.6 (1.5–4.5)**	**0.001**	**5.5 (3.4–8.8)**	**<0.001**
Number of walking bouts ≤ 99.4 vs. > 99.4	1.0 (0.6–1.8)	0.894	**2.7 (1.7–4.0)**	**<0.001**	1.0 (0.6–1.7)	0.958	**2.3 (1.5–3.6)**	**<0.001**
Walking bout intensity ≤ 0.119 g vs. > 0.119 g	1.4 (0.8–2.3)	0.185	**2.4 (1.6–3.7)**	**<0.001**	1.3 (0.8–2.2)	0.303	**1.9 (1.2–3.0)**	**0.005**
Walking bout duration ≤ 47.8 sec vs. > 47.8 sec	**2.3 (1.4–3.9)**	**0.002**	**6.8 (4.3–10.7)**	**<0.001**	**2.3 (1.3–3.9)**	**0.003**	**6.7 (4.2–10.9)**	**<0.001**
Activity fragmentation ≥ 0.257 vs. < 0.257	1.2 (0.7–2.0)	0.532	**3.8 (2.5–5.9)**	**<0.001**	1.1 (0.7–2.0)	0.642	**3.3 (2.1–5.1)**	**<0.001**

Note: Multinomial logistic regression analyses. Reference category: no difficulties, n=261. Model 1: Adjusted for age, sex and years of educations.

OR = Odds Ratio; CI = Confidence Interval. Statistically significant values are bolded.

II

ASSOCIATIONS BETWEEN PERCEIVED OUTDOOR ENVIRONMENT AND WALKING MODIFICATIONS IN COMMUNITY-DWELLING OLDER PEOPLE: A TWO-YEAR FOLLOW-UP STUDY

by

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Associations between Perceived Outdoor Environment and Walking Modifications in Community-Dwelling Older People: A Two-Year Follow-Up Study

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Abstract

Objectives: To examine associations of perceived outdoor environment with the prevalence and development of adaptive (e.g., slower pace) and maladaptive (e.g., avoiding walking) modifications in walking 2 km among older people. **Methods:** Community-dwelling 75–90 -year-old persons (N = 848) reported environmental outdoor mobility facilitators and barriers at baseline. Modifications in walking 2 km (adaptive, maladaptive, or no) were assessed at baseline and one and two years later. **Results:** Outdoor mobility facilitators were more often reported by those not using modifications or using adaptive versus maladaptive walking modifications. Differences in health and physical capacity explained most of the associations between outdoor mobility barriers and walking modifications. Perceived outdoor environment did not systematically predict future adaptive or maladaptive walking modifications. **Discussion:** Facilitators may compensate the declined physical capacity and alleviate the strain of walking longer distances by enabling the use of adaptive walking modifications, while lack of such facilitators fuels avoidance of walking longer distances.

Keywords

aging, environment, compensation, mobility

In old age, declining functional ability increases vulnerability to environmental demands (Nahemow & Lawton, 1973). As environmental press increases, individuals may, decrease task demands and minimize losses in valued activities, modify their behavior or give up or reduce the frequency of doing a task (Freedman et al., 2016; Nahemow & Lawton, 1973; Skantz et al., 2019). The first modifications are often seen in the most demanding physical tasks, such as walking longer distances (Mänty et al., 2007; Weiss et al., 2007).

Walking modifications are typical indicators of functional decline or preclinical disability (Fried et al., 2000). At the same time, some modifications may be adaptive and help individuals continue walking by reducing task demands, whereas other modifications may be maladaptive and lead to task avoidance (Skantz et al., 2019). We categorized self-reported modifications in walking 2 km distance into adaptive (e.g., reduced pace, using an aid, and resting in the middle) and maladaptive (reduced frequency or giving up doing the task). Adaptive walking modifications help to identify persons who strive to continue walking, whereas maladaptive walking modifications indicate avoidance, that is, having reduced or given up walking longer distances. In our previous study, the use of walking modifications that we termed adaptive postponed decline in life-space mobility and helped individuals maintain greater autonomy in outdoor participation, while the use of maladaptive walking modifications was associated with restrictions in outdoor mobility at baseline and over time (Skantz et al., 2019). Selecting particular adaptation strategies may be conscious or subconscious (Lien et al., 2015) and may reflect, for example, a person's capabilities, access to resources, preferred approach to perform an activity, and environmental opportunities (Baltes & Baltes,

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1990; Gitlin et al., 2017; Tomey & Sowers, 2009). While previous studies have shown that person-related factors, such as older age and poorer functional ability, are associated with walking modifications (Freedman et al., 2016; Hoenig et al., 2006; Skantz et al., 2019), little attention has been paid to the associations between the outdoor environment and walking modifications. More specifically, it is not known how perceived facilitators for and barriers to environmental outdoor mobility relate to the use of adaptive and maladaptive walking modifications.

Based on the ecological model of aging (Nahemow & Lawton, 1973) and the disablement process model (Verbrugge & Jette, 1994), it can be hypothesized that perceptions of the outdoor environment are related to the use of adaptive and maladaptive walking modifications. These models indicate that as personal competencies decline with aging, walking performance can be maintained in three ways: reducing task demands, increasing the person's capacity, or lowering environmental demands. In reality, assuming that their living environment affords opportunities for doing so, reducing task demands via adaptive walking modifications is most readily available strategy for people facing functional decline.

Specific environmental features can either support or hinder older people's mobility. For example, depending on individuals' functional capacity, hills in the nearby environment can facilitate walking for fitness for some and hinder walking for others (Eronen et al., 2014a; Sakari et al., 2017). Previous studies have shown that older people who perceive a higher number of environmental mobility facilitators, such as nature in the nearby environment or peaceful walkways, have higher physical activity levels and a lower risk for developing walking difficulty over time (Eronen et al., 2014a; Keskinen et al., 2018b; Portegijs et al., 2017a). Thus, we expect that for individuals facing functional decline, perceiving facilitators for outdoor mobility may increase their likelihood of using adaptive walking modifications and decrease their likelihood of using maladaptive walking modifications. In contrast, environmental demands that exceed a person's capacity are risk factors for physical inactivity and the development of functional limitations over time (Keskinen et al., 2018a; Portegijs et al., 2017b; Rantakokko et al., 2011). Previous studies have shown that environmental barriers to outdoor mobility, such as poor street conditions or lack of resting places, are associated with restricted outdoor mobility (Rantakokko et al., 2015; Tsai et al., 2013) and increased the risk for developing walking difficulty over time (Keskinen et al., 2018a; Rantakokko et al., 2016). Thus, we expect that perceiving environmental barriers to outdoor mobility may especially be associated with the use of maladaptive walking modifications and increased risk for adopting maladaptive walking modifications over the follow-up among those not reporting such modifications at the baseline.

The aim of this study was to investigate whether perceived environmental outdoor mobility facilitators and barriers are associated with the use of adaptive and maladaptive walking modifications among community-dwelling older people. In addition, we investigated whether perceived environmental outdoor mobility facilitators and barriers predict the development of adaptive or maladaptive walking modifications over a 2-year follow-up.

Methods

Design and Study Participants

This study includes cross-sectional and longitudinal data drawn from the "Life-Space Mobility in Old Age" (LISPE) project, a 2-year prospective cohort study conducted between the years 2012 and 2014. The purpose of the LISPE study was to investigate the associations of the home and physical environment of older people with their health, functioning, disability, quality of life, and life-space mobility. A more detailed description of the LISPE study, including recruitment and nonrespondent analyses, has been reported previously (Rantanen et al., 2012). Briefly, the study targeted community-dwelling people aged 75–90 years, randomly selected from the Finnish population register based on their age and residence in two municipalities: the city of Jyväskylä and the small town of Muurame (located in Central Finland). The study area is characterized by low hills, several lakes, rather quiet streets with predominantly residential traffic, and some busier streets with several intersections. The area contains several small parks with seating areas. Most of the shops and other services are concentrated in the municipal centers or subcenters. The residential areas comprise detached houses, row houses, and apartment buildings. Due to integrative planning and local housing policy, there is no clear socioeconomic differentiation between residential areas. Inclusion criteria were community-dwelling in the study area, willing to participate, and able to communicate and provide written informed consent. A total of 848 participants met the inclusion criteria and were interviewed face-to-face in their homes at baseline and followed up by telephone one ($n = 816$) and two ($n = 761$) years later. All interviews were conducted using structured computer-assisted personal interviewing. At the follow-ups, participants unable to answer questions via telephone were offered a face-to-face interview. The dropout rate over the 2-year follow-up period was 10%. The Ethical Committee of the University of Jyväskylä approved the LISPE study.

Measurements

Self-reported modifications in walking 2 km were assessed with a standardized questionnaire at baseline and at the 1- and 2-year follow-ups (Rantakokko et al., 2016). Walking modifications were investigated by asking participants whether they had modified their way of walking 2 km due to their health or physical functioning. Modifications were walking slower, resting during walking, using an aid, reducing frequency of walking, and having given up walking distances of 2 km. For each modification, participants were asked to state whether they used it (“yes” or “no”). In line with our previous categorization (Skantz et al., 2019), walking slower, resting during walking, and using an aid were categorized as adaptive modifications, as they indicate a striving to continue walking 2-km distances by reducing task demand. Those who reported adaptive walking modifications and reduced frequency of walking 2 km were also categorized as using adaptive walking modifications. Those who reported having given up walking 2 km or reducing their frequency of walking 2 km were, in the absence of adaptive modifications, categorized as using maladaptive modifications, as they indicate a reduced striving to continue the activity. Thus, we analyzed self-reported modifications in walking 2 km using the categories no modifications, adaptive modifications, and maladaptive modifications.

Perceived environmental facilitators for outdoor mobility were studied at baseline with a standardized questionnaire comprising 16 items selected based on our previous research (Rantakokko et al., 2015). Participants were asked to report all the items present in their living environment that they perceived as facilitating their outdoor mobility (present/absent). Environmental facilitators were categorized into three domains: *nature* (park or other green area, walking trail and skiing track, and nature and lakeside); *infrastructure* (good lighting, services close, even sidewalks, walkways without steep hills, resting places by the walking route, peaceful and good quality pedestrian routes, and safe crossings); and *safety* (appealing landscape, familiar surroundings, own yard, other people outdoors, no car traffic, and no cyclists on walkways) (Keskinen et al., 2019).

Perceived environmental barriers to outdoor mobility were also studied at baseline with a standardized questionnaire (Rantakokko et al., 2014) comprising 15 environmental barriers to outdoor mobility. Participants were asked to report all the features in their living environment that they perceived as hindering their outdoor mobility (present/absent). Environmental barriers were recoded into three domains: *nature* (hills in nearby environment and snow and ice in winter), *infrastructure* (poor street conditions, high curbs, lack of sidewalks, long distances to services, lack of benches during summer or winter, and poor lighting), and *safety* (noisy traffic, busy traffic, dangerous crossroads, vehicles on walkways, cyclists on walkways, and insecurity due to other pedestrians).

For the sensitivity analyses, participants were categorized based on their self-reported ability to independently walk 2 km (Mänty et al., 2007). Participants were considered unable to walk 2 km independently if they reported needing help or being unable to manage even with help.

Covariates. As covariates, we included variables that are associated with the use of walking modifications based on previous studies. Age and sex were obtained from national registers. Years of education, number of chronic conditions, depressive symptoms, lower extremity function, and ability to walk 2 km were assessed during the home interview. *Years of education,* as an indicator of socioeconomic status, was self-reported. The *Number of chronic conditions was* calculated from a list of 22 specified physician-diagnosed chronic conditions followed by an open-ended question on any other chronic diseases the participant might have (Portegijs et al., 2014). *Depressive symptoms* were assessed with the Center for Epidemiologic Studies Depression Scale (range 0–60; higher scores indicate more depressive symptoms) (Radloff, 1977). *Lower extremity function* was assessed with the short physical performance battery (SPPB) (Guralnik et al., 1994). For the sensitivity analyses, participants were categorized based on self-reported difficulties in walking 2 km (Mänty et al., 2007).

Statistical Analyses

Baseline characteristics were described using means and standard deviations or percentages. Differences in the prevalence of perceived environmental outdoor mobility facilitators and barriers and in baseline characteristics between participants categorized according to their baseline walking modifications were tested with chi-square tests (χ^2) and one-way analysis of variance. A Bonferroni test was used to compare means between participants using adaptive or maladaptive walking modifications. The sum of the environmental facilitators and barriers reported was calculated for each facilitator and barrier domain (nature, infrastructure, and safety) separately and then divided into those reporting 0, 1, and 2 or more facilitators or barriers. Analyses were run separately for each environmental facilitator and barrier domain (reporting 1 or ≥ 2 vs. 0) and for item-specific environmental facilitators for and barriers to outdoor mobility. The associations of perceived environmental outdoor mobility facilitators and barriers with walking modifications were assessed cross sectionally by using multinomial logistic regression analysis. The outcome variable was a nominal scale variable. Those with maladaptive walking modifications were used as a reference group when studying associations between environmental facilitators and categories of walking modifications. This was done to clarify whether the environmental facilitators reported by those using adaptive walking modifications differed from those using maladaptive walking modifications. In the analyses on environmental mobility barriers, those without walking modifications were used as a reference group. The cross-sectional models were first adjusted for age and sex and then, to control for individual differences, for age, sex, years of education, chronic conditions, depressive symptoms, and lower extremity function. Eight participants had missing information for years of education, four participants for depressive symptoms and nine participants for SPPB; these 21 participants were not included in the fully adjusted models.

In the longitudinal setting, logistic regression analyses were used to investigate the associations between perceived environmental outdoor mobility facilitators and barriers and the development of adaptive or maladaptive walking modifications. The development of adaptive walking modifications was studied among those who reported no walking modifications at baseline and who did not develop maladaptive modifications over the two-year follow-up period (n = 218). Participants who reported adaptive walking modifications at one or both follow-ups were defined having developed adaptive walking modifications. Similarly, the development of maladaptive walking modifications was studied only among those without maladaptive modifications at baseline (n = 610). Participants, who reported maladaptive walking modifications at one or both follow-ups, were defined as having developed maladaptive walking modifications. Analyses were conducted separately for each environmental subgroup (reporting 1 or ≥ 2 vs. no) and item-specific environmental facilitators for and barriers to outdoor mobility. All models were first adjusted for age and sex and then for age, sex, years of education, chronic conditions, depressive symptoms, and lower extremity function.

Finally, to test the robustness of our findings, we conducted further sensitivity analyses by excluding all participants unable to walk 2 km independently at baseline. This eliminated 112 participants from the maladaptive walking modifications category, four participants from the adaptive walking modifications category and one participant from the no walking modifications category. The sensitivity analyses were not performed for the development of adaptive walking modifications since all participants included in the model constructed from the whole sample were able to walk 2 km independently at baseline. False discovery rates (adjusted p-values) were calculated to correct for multiple testing to avoid type 1 error (Benjamini & Hochberg, 1995).

The results were regarded as statistically significant, if the 95% confidence intervals did not include one or the p-value was <.05. IBM SPSS version 24 for Windows (IBM Corp, Armonk, NY) and R version 3.6.1 (R Core Team, 2019) were used for statistical analyses.

Results

Participant Characteristics

The mean age of the study participants was 80.6 years (N = 848, age range 74.2–89.3, 62% women). At baseline, 38% (n = 325) used adaptive and 28% (n = 238) maladaptive modifications in walking 2 km. Those with no walking modifications (34%, n = 285) were younger, more often men, had more years of education and had fewer chronic conditions and depressive symptoms than those with adaptive or maladaptive walking modifications ($p \leq .011$ for all variables; Table 1). Participants using adaptive walking modifications had intermediate scores in the health and physical capacity measurements compared to those with no walking modifications or with maladaptive walking modifications. Based on post hoc comparisons, statistically significant differences were observed between participants using adaptive and maladaptive walking modifications in all characteristics except for years of education (p = .170) and depressive symptoms (p = .056). For all participants, the most often reported facilitators for and barriers to outdoor mobility were nature related (Table 1). Of the individual items, nature in the nearby environment was the most reported facilitator for outdoor mobility (73%), whereas snow and ice in winter were the most often reported barriers to outdoor mobility (53%, Table 2). In general, those with maladaptive walking modifications reported fewer facilitators and more infrastructure barriers to outdoor mobility compared to those without walking modifications or with adaptive walking modifications. Participants with adaptive walking modifications reported more nature- or safety-related barriers to outdoor mobility than those using maladaptive walking modifications (Tables 1 and 2).

Cross-Sectional Associations of Environmental Outdoor Mobility Facilitators with Walking Modifications

Older people reporting at least two nature- or infrastructure-related environmental facilitators had two to threefold higher odds for using no walking modifications compared to those using maladaptive walking modifications (adjusted for age, sex, years of education, chronic conditions, depressive symptoms, and lower extremity function; Table 3). Similarly, at least two infrastructure (OR 2.4, 95% CI 1.6–3.7) or safety-related (OR 2.5, 95% CI 1.4–4.3) facilitators for outdoor mobility were more likely to be reported by those using adaptive walking modifications than those using maladaptive walking modifications. In the item-specific analyses, participants who perceived a walking trail or a skiing track as a facilitator for outdoor mobility had almost fourfold higher odds for reporting no walking modifications than those reporting maladaptive walking modifications. Most of the infrastructure-related facilitators, such as good lighting or walkways without steep hills, were more commonly associated with those using adaptive than maladaptive walking modifications even when adjusted for all the covariates. Perceiving a walking trail or a skiing track (nature-related facilitators) and a familiar environment (safety-related facilitator) as facilitators was also associated with those using adaptive rather than maladaptive walking modifications.

Cross-Sectional Associations of Environmental Outdoor Mobility Barriers with Walking Modifications

Participants reporting at least two infrastructure-related environmental barriers had increased odds for using adaptive (OR 2.5, 95% CI 1.4–4.2) or maladaptive (OR 2.3, 95% CI

Table 1. Participant Characteristics and Proportion of Participants Reporting Outdoor Mobility Facilitators and Barriers in Subgroups by Modifications in Walking 2 km at Baseline (*N* = 848).

	No walking modifications (*n* = 285)	Adaptive walking modifications (*n* = 325)	Maladaptive walking modifications (*n* = 238)	*p*-value	Adjusted *p*-value
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)		
Age, years	78.9 (3.7)	80.9 (4.2)	82.3 (4.2)	**<.001**[a]	**<.001**
Age, range	74.2–89.1	74.2–89.3	74.4–89.2		
Education, years	10.3 (4.5)	9.5 (4.0)	8.8 (3.8)	**<.001**[a]	**<.001**
Chronic conditions, number	3.3 (2.0)	4.6 (2.4)	5.3 (2.5)	**<.001**[a]	**<.001**
SPPB, score	10.8 (1.4)	9.7 (2.0)	8.1 (3.3)	**<.001**[a]	**<.001**
CES-D, score	7.4 (5.8)	10.2 (6.3)	11.6 (7.9)	**<.001**[a]	**<.001**
	% (*n*)	% (*n*)	% (*n*)		
Women	54.0 (154)	64.3 (209)	68.5 (163)	**.002**[b]	**.011**
Unable to walk 2 km independently	.4 (1)	1.2 (4)	47.0 (112)	**<.001**[b]	**<.001**
Sum of nature facilitators				**<.001**[b]	**<.001**
0	8.1 (23)	16.9 (55)	22.3 (53)		
1	21.1 (60)	24.3 (79)	36.6 (87)		
≥2	70.9 (202)	58.8 (191)	41.2 (98)		
Sum of infrastructure facilitators				**.001**[b]	**.006**
0	21.8 (62)	21.2 (69)	33.3 (79)		
1	21.4 (61)	18.8 (61)	24.1 (57)		
≥2	56.8 (162)	60.0 (195)	42.6 (101)		
Sum of safety facilitators				**<.001**[b]	**<.001**
0	12.6 (36)	9.5 (31)	17.6 (42)		
1	10.9 (31)	20.3 (66)	20.6 (49)		
≥2	76.5 (218)	70.2 (228)	61.8 (147)		
Sum of nature barriers				**<.001**[b]	**<.001**
0	58.9 (168)	32.0 (104)	34.0 (81)		
1	33.3 (95)	44.0 (143)	42.9 (102)		
2	7.7 (22)	24.0 (78)	23.1 (55)		
Sum of infrastructure barriers				**<.001**[b]	**<.001**
0	74.4 (212)	52.6 (171)	45.0 (107)		
1	17.2 (49)	21.2 (69)	22.3 (53)		
≥2	8.4 (24)	26.2 (85)	32.8 (78)		
Sum of safety barriers				**.006**[b]	**.026**
0	75.8 (216)	64.3 (209)	75.6 (180)		
1	15.8 (45)	20.0 (65)	13.9 (33)		
≥2	8.4 (24)	15.7 (51)	10.5 (25)		

Note. SPPB = short physical performance battery; CES-D = Center for Epidemiologic Studies Depression Scale; *SD* = standard deviation. False discovery rates (adjusted *p*-values) were calculated to correct for multiple testing. Statistically significant values are bolded.
[a]Tested with one-way analysis of variance.
[b]Tested with chi-square test.

1.3–4.2) walking modifications compared to those reporting no walking modifications (Table 4). Reporting one or two nature-related environmental barriers increased the odds for using adaptive but not maladaptive walking modifications when compared to those using no walking modifications. Of the individual mobility barriers, reporting hills in the nearby environment (OR 2.0, 95% CI 1.2–3.2), snow and ice during winter (OR 2.2, 95% CI 1.6–3.2) or lack of resting places in winter (OR 2.3, 95% CI 1.3–4.0) were more common among people using adaptive walking modifications than among those using no walking modifications. In contrast, reporting long distances to services (OR 4.5, 95% CI 2.1–9.6) was related to the use of maladaptive walking modifications. Safety-related barriers to outdoor mobility were not associated with the use of adaptive or maladaptive walking modifications when the models were adjusted for all the covariates.

Table 2. Prevalence of Perceived Environmental Facilitators for and Barriers to Outdoor Mobility by Modifications in Walking 2 km at Baseline (*N* = 848).

	No walking modifications (*n* = 285)	Adaptive walking modifications (*n* = 325)	Maladaptive walking modifications (*n* = 238)	*p*-value	Adjusted *p*-value
Facilitators	% (*n*)	% (*n*)	% (*n*)		
Nature					
Park or other green area	43.2 (123)	42.5 (138)	34.9 (83)	.107	.244
Walking trail and skiing track	75.1 (214)	56.6 (184)	37.0 (88)	**<.001**	**<.001**
Nature and lakeside	80.7 (230)	71.7 (233)	64.3 (153)	**<.001**	**<.001**
Infrastructure					
Good lighting	43.9 (125)	40.6 (132)	25.6 (61)	**<.001**	**<.001**
Peaceful and good quality walkways	55.8 (159)	52.3 (170)	41.2 (98)	**.003**	**.014**
Even sidewalks	26.0 (74)	34.8 (113)	27.3 (65)	.038	.118
Resting places by the walking route	15.8 (45)	24.9 (81)	19.3 (46)	.018	.064
Walkways without steep hills	11.6 (33)	16.3 (53)	10.1 (24)	.065	.173
Services close	48.4 (138)	48.3 (157)	31.9 (76)	**<.001**	**<.001**
Safe crossings: traffic lights, zebra crossing, or traffic island between lanes	25.6 (73)	28.3 (92)	16.0 (38)	**.003**	**.014**
Safety					
Familiar environment	70.2 (200)	64.6 (210)	54.2 (129)	**.001**	**.006**
Appealing scenery	74.0 (211)	68.9 (224)	58.4 (139)	**.001**	**.006**
Own yard	55.8 (159)	58.2 (189)	58.0 (138)	.815	.893
Other people outdoors motivate	24.2 (69)	22.2 (72)	16.0 (38)	.060	.163
No car traffic	15.8 (45)	14.2 (46)	8.8 (21)	.052	.148
No cyclists on walkways	4.9 (14)	4.9 (16)	4.2 (10)	.907	.937
Barriers					
Nature					
Hills in the nearby environment	11.9 (34)	28.0 (91)	31.9 (76)	**<.001**	**<.001**
Snow and ice in winter	36.8 (105)	64.0 (208)	57.1 (136)	**<.001**	**<.001**
Infrastructure					
Poor street condition	15.1 (43)	21.5 (70)	19.3 (46)	.121	.257
High curbs	2.5 (7)	8.3 (27)	12.6 (30)	**<.001**	**<.001**
Lack of pedestrian zones	1.8 (5)	1.4 (12)	1.2 (10)	.227	.388
Long distances to services	4.2 (12)	9.2 (30)	24.4 (58)	**<.001**	**<.001**
Lack of resting places, summer	6.0 (17)	18.5 (60)	23.5 (56)	**<.001**	**<.001**
Lack of resting places, winter	7.4 (21)	24.0 (78)	25.2 (60)	**<.001**	**<.001**
Poor lighting	2.5 (7)	5.2 (17)	1.7 (4)	.041	.124
Safety					
Noisy traffic	1.8 (5)	5.5 (18)	3.8 (9)	.050	.145
Busy traffic	4.6 (13)	10.8 (35)	9.7 (23)	.015	.058
Dangerous crossroads	6.7 (19)	12.0 (39)	8.4 (20)	.066	.173
Vehicles on walkways	1.4 (4)	1.5 (5)	2.1 (5)	.807	.893
Cyclists in the walkways	16.8 (48)	23.7 (77)	14.7 (35)	.015	.058
Insecurity due to other pedestrians	4.6 (13)	7.1 (23)	4.2 (10)	.242	.406

Note. Tested with chi-square test. False discovery rates (adjusted *p*-values) were calculated to correct for multiple testing. Statistically significant values are bolded.

Finally, to test the robustness of our findings, we conducted sensitivity analyses by excluding participants who reported being unable to walk 2 km independently at baseline. The results showed that while most of the associations between environmental facilitators and walking modifications disappeared (Supplementary Table 1), no changes were observed in the associations between environmental barriers and walking modifications (Supplementary Table 2).

Longitudinal Associations of Environmental Outdoor Mobility Facilitators and Barriers with Walking Modifications

Of the 218 participants without walking modifications at baseline, 51.4% (*n* = 112) developed adaptive walking modifications during the 2-year follow-up period. No associations between environmental outdoor mobility facilitators

Table 3. Cross-Sectional Associations of Perceived Environmental Facilitators for Outdoor Mobility with Walking Modifications in Community-Dwelling Older People. Odds are Reported for those with No Modifications (n = 281) and Adaptive Modifications (n = 319) versus Maladaptive Modifications (n = 227, reference).

	Model 1				Model 2			
	No walking modifications (n = 281)		Adaptive walking modifications (n = 319)		No walking modifications (n = 281)		Adaptive walking modifications (n = 319)	
Facilitator	OR (95% CI)	Adjusted p-value	OR (95% CI)	Adjusted p-value	OR (95% CI)	Adjusted p-value	OR (95% CI)	Adjusted p-value
Sum of nature facilitators								
1 versus 0	1.4 (.8–2.6)	.434	.8 (.5–1.4)	.636	1.1 (.5–2.2)	.893	1.5 (.9–2.4)	.356
≥2 versus 0	**3.8 (2.1–6.7)**	**<.001**	1.7 (1.1–2.7)	.056	**2.9 (1.5–5.6)**	**.006**	.7 (.4–1.2)	.256
Sum of infrastructure facilitators								
1 versus 0	1.5 (.9–2.6)	.221	1.3 (.8–2.1)	.479	1.8 (1.0–3.2)	.179	1.5 (.9–2.5)	.305
≥2 versus 0	**2.3 (1.5–3.5)**	**<.001**	**2.3 (1.5–3.5)**	**<.001**	**2.5 (1.5–4.2)**	**<.001**	**2.4 (1.6–3.7)**	**<.001**
Sum of safety facilitators								
1 versus 0	.7 (.4–1.4)	.466	1.8 (1.0–3.3)	.113	.7 (.4–1.6)	.630	2.0 (1.0–3.7)	.119
≥2 versus 0	1.8 (1.1–3.0)	.078	**2.1 (1.3–3.6)**	**.014**	1.9 (1.1–3.6)	.094	**2.5 (1.4–4.3)**	**.006**
Item specific								
Nature								
Park or other green area	1.4 (1.0–2.1)	.131	1.4 (1.0–2.0)	.141	1.4 (.9–2.1)	.285	1.4 (.9–2.0)	.244
Walking trail and skiing track	**4.5 (3.0–6.6)**	**<.001**	**2.1 (1.5–3.0)**	**<.001**	**3.7 (2.4–5.8)**	**<.001**	**1.9 (1.3–2.8)**	**.006**
Nature and lakeside	**1.9 (1.3–2.9)**	**.011**	1.3 (.9–1.9)	.264	1.6 (.9–2.6)	.162	1.2 (.8–1.7)	.581
Infrastructure								
Good lighting	**2.1 (1.4–3.0)**	**<.001**	**1.9 (1.3–2.7)**	**.004**	**1.9 (1.2–2.8)**	**.041**	**1.8 (1.2–2.6)**	**.018**
Peaceful and good quality walkways	**1.9 (1.3–2.7)**	**.004**	**1.6 (1.1–2.2)**	**.023**	**2.0 (1.3–3.0)**	**.011**	**1.8 (1.2–2.6)**	**.011**
Even sidewalks	.9 (.6–1.4)	.896	1.4 (1.0–2.1)	.136	1.2 (.7–1.8)	.718	1.6 (1.1–2.4)	.063
Resting places by the walking route	1.0 (.6–1.5)	.922	1.5 (1.0–2.3)	.132	1.3 (.7–2.2)	.582	1.6 (1.1–2.6)	.096
Walkways without steep hills	1.4 (.8–2.4)	.447	1.9 (1.1–3.1)	.055	2.1 (1.0–4.2)	.118	**2.4 (1.4–4.3)**	**.011**
Services close	**2.2 (1.5–3.2)**	**<.001**	**2.0 (1.4–2.9)**	**<.001**	**2.0 (1.3–3.1)**	**.011**	**1.9 (1.3–2.7)**	**.006**
Safe crossings: traffic lights, zebra crossing, or traffic island between lanes	1.7 (1.1–2.7)	.058	**2.0 (1.3–3.1)**	**.004**	1.5 (.9–2.6)	.244	**1.9 (1.2–3.0)**	**.022**
Safety								
Familiar environment	**2.3 (1.5–3.3)**	**<.001**	**1.6 (1.1–2.3)**	**.020**	2.3 (1.5–3.6)	.162	**1.7 (1.2–2.5)**	**.018**
Appealing scenery	**2.0 (1.3–2.9)**	**.004**	1.6 (1.1–2.2)	.045	**2.0 (1.3–3.2)**	**.014**	1.6 (1.1–2.3)	.067
Own yard	.9 (.6–1.3)	.722	1.0 (.7–1.4)	.992	.8 (.5–1.2)	.461	1.1 (.7–1.5)	.872
Other people outdoors motivate	1.6 (1.0–2.5)	.112	1.5 (.9–2.3)	.174	1.9 (1.1–3.3)	.060	1.6 (1.0–2.6)	.138
No car traffic	1.7 (.9–3.1)	.134	1.6 (.9–2.8)	.178	1.8 (.9–3.4)	.192	1.7 (.9–3.0)	.184
No cyclists on walkways	1.1 (.4–2.6)	.926	1.2 (.5–2.6)	.853	1.1 (.4–2.9)	.937	1.2 (.5–2.7)	.872

Note. Multinomial logistic regression analyses. Reference category: maladaptive walking modifications, n = 227. Model 1: Adjusted for age and sex. Model 2: Adjusted for age, sex, years of education, depressive symptoms, chronic conditions, and lower extremity function. OR = odds ratio; CI = confidence interval. False discovery rates (adjusted p-values) were calculated to correct for multiple testing. Statistically significant values are bolded.

Table 4. Cross-Sectional Associations of Perceived Environmental Barriers to Outdoor Mobility with Walking Modifications in Community-Dwelling Older People. Odds are Reported for those with Adaptive Modifications (n = 319) and Maladaptive Modifications (n = 227) versus those with No Modifications (n = 281, reference).

	Model 1				Model 2			
	Adaptive walking modifications (n = 319)		Maladaptive walking modifications (n = 227)		Adaptive walking modifications (n = 319)		Maladaptive walking modifications (n = 227)	
Barrier	OR (95% CI)	Adjusted p-value	OR (95% CI)	Adjusted p-value	OR (95% CI)	Adjusted p-value	OR (95% CI)	Adjusted p-value
Sum of nature barriers								
1 versus 0	**2.3 (1.6–3.3)**	**<.001**	**2.1 (1.4–3.1)**	**<.001**	**1.8 (1.2–2.7)**	**.014**	1.2 (.8–1.9)	.609
2 versus 0	**5.0 (1.6–3.3)**	**<.001**	**4.2 (2.3–7.5)**	**<.001**	**3.5 (2.0–6.2)**	**<.001**	2.0 (1.0–3.8)	.128
Sum of infrastructure barriers								
1 versus 0	1.6 (1.1–2.5)	.065	**1.9 (1.2–3.1)**	**.023**	1.4 (.9–2.1)	.339	1.3 (.8–2.3)	.494
≥2 versus 0	**3.8 (2.3–6.3)**	**<.001**	**5.1 (3.0–8.6)**	**<.001**	**2.5 (1.4–4.2)**	**.006**	**2.3 (1.3–4.2)**	**.029**
Sum of safety barriers								
1 versus 0	1.5 (1.0–2.3)	.155	.9 (.5–1.5)	.775	1.3 (.8–2.0)	.500	.7 (.4–1.3)	.468
≥2 versus 0	**2.1 (1.3–3.7)**	**.018**	1.2 (.6–2.2)	.730	1.4 (.8–2.4)	.494	.6 (.3–1.2)	.305
Item specific								
Nature								
Hills in the nearby environment	**2.6 (1.7–4.0)**	**<.001**	**3.0 (1.8–4.7)**	**<.001**	**2.0 (1.2–3.2)**	**.018**	1.9 (1.1–3.3)	.060
Snow and ice in winter	**2.8 (2.0–4.0)**	**<.001**	**2.0 (1.4–3.0)**	**<.001**	**2.2 (1.6–3.2)**	**<.001**	1.2 (.8–1.8)	.644
Infrastructure								
Poor street condition	1.4 (.9–2.2)	.194	1.2 (.7–1.9)	.626	1.1 (.7–1.7)	.911	.7 (.4–1.2)	.291
High curbs	**3.1 (1.3–7.4)**	**.028**	**4.6 (1.9–11.0)**	**.004**	1.7 (.6–4.4)	.472	1.2 (.4–3.3)	.872
Lack of pedestrian zones	2.2 (.8–6.6)	.242	2.7 (.9–8.5)	.159	2.9 (.9–9.5)	.210	3.6 (1.0–13.3)	.162
Long distances to services	2.0 (1.0–4.1)	.111	**6.1 (3.1–11.9)**	**<.001**	1.8 (.8–3.8)	.275	**4.5 (2.1–9.6)**	**<.001**
Lack of resting places, summer	**3.1 (1.7–5.5)**	**<.001**	**3.9 (2.2–7.1)**	**<.001**	2.0 (1.1–3.7)	.085	2.1 (1.1–4.0)	.094
Lack of resting places, winter	**3.4 (2.0–5.7)**	**<.001**	**3.2 (1.8–5.6)**	**<.001**	**2.3 (1.3–4.0)**	**.018**	1.8 (1.0–3.3)	.178
Poor lighting	2.3 (.9–5.8)	.151	.7 (.2–2.6)	.755	1.7 (.6–4.7)	.447	.4 (.1–1.7)	.380
Safety								
Noisy traffic	3.2 (1.2–8.9)	.065	2.2 (.7–6.9)	.282	2.1 (.7–6.3)	.348	1.5 (.4–5.3)	.730
Busy traffic	**2.5 (1.3–4.8)**	**.028**	**2.2 (1.1–4.6)**	.094	1.8 (.9–3.8)	.229	1.5 (.7–3.4)	.502
Dangerous crossroads	1.8 (1.0–3.3)	.106	1.2 (.6–2.4)	.722	1.4 (.8–2.6)	.473	.9 (.4–1.8)	.840
Vehicles on walkways	1.1 (.3–4.4)	.922	1.5 (.4–6.3)	.726	.8 (.2–3.4)	.872	.7 (.1–3.9)	.864
Cyclists in the walkways	1.4 (.9–2.2)	.182	.8 (.5–1.3)	.428	1.1 (.7–1.8)	.809	.5 (.3–.9)	.064
Insecurity due to other pedestrians	1.6 (.8–3.3)	.288	1.0 (.4–2.4)	.992	1.0 (.5–2.2)	.981	.4 (.2–1.2)	.257

Note. Multinomial logistic regression analyses. Reference category: no walking modifications. Model 1: Adjusted for age and sex. Model 2: Adjusted for age, sex, years of education, depressive symptoms, chronic conditions, and lower extremity function. OR = odds ratio; CI = confidence interval. False discovery rates (adjusted p-values) were calculated to correct for multiple testing. Statistically significant values are bolded.

and the development of adaptive walking modifications over time were observed (Table 5). Perceiving more than two infrastructure-related barriers and perceiving lack of resting places as a barrier to outdoor mobility increased the odds for using adaptive walking modifications over the follow-up in the age- and sex-adjusted model but not in the fully adjusted model (Table 6).

Of the 610 participants who did not report maladaptive walking modifications at baseline, 22.3% ($n = 136$) developed maladaptive walking modifications during the 2-year follow-up period. Perceiving a walking trail or skiing track as a facilitator for outdoor mobility protected against the adoption of maladaptive walking modifications even when adjusted for age, sex, years of education, chronic conditions, depressive symptoms, and lower extremity function (OR .5, 95% CI .3–.7, Table 5). Otherwise, no associations were observed between perceived environmental facilitators and the development of maladaptive walking modifications. Reporting snow and ice in winter (OR 1.8, 95% CI 1.3–2.6) as barriers to outdoor mobility at baseline increased the odds for developing maladaptive walking modifications over time in the age- and sex-adjusted model (Table 6). However, the associations disappeared when all the covariates were added in the models. In the prospective sensitivity analyses, the exclusion of participants unable to walk 2 km independently at baseline did not change the longitudinal results (Supplementary Tables 3 and 4).

Discussion

The present findings suggest that perceived environmental features coincide with, rather than consistently preceding, walking modifications. Perceiving environmental facilitators for outdoor mobility was associated with the use of no walking modifications or adaptive walking modifications rather than with the use of maladaptive walking modifications, whereas perceiving environmental barriers to outdoor mobility increased the odds for using both adaptive and maladaptive walking modifications in the age- and sex-adjusted models. There are several plausible reasons for the different associations found between perceived environmental outdoor mobility facilitators and adaptive and maladaptive walking modifications. Perceiving environmental outdoor mobility facilitators may serve as a motivation or enabler for individuals to adopt strategies that allow them to continue rather than reduce or give up walking longer distances, even when experiencing functional decline (Portegijs et al., 2017a). For example, infrastructural mobility facilitators may compensate for the decline in physical capacity and alleviate the strain of walking longer distances by enabling the use of adaptive walking modifications, while the lack of such facilitators may fuel lower frequency of or giving up walking longer distances, that is, maladaptive walking modifications stemming from the absence of perceived opportunities to reduce the task demands of walking longer distances. The use of maladaptive walking modifications may indicate that the task demands exceed personal capacity, potentially leading to reduced striving to continue the activity (Nahemow & Lawton, 1973). Thus, long distances to services can be considered an excessively demanding task demand for older people with poor physical capacity.

The current findings accord with those of previous studies showing that perceiving environmental facilitators is associated with higher physical activity levels (Barnett et al., 2017; Cerin et al., 2017; Keskinen et al., 2019). Further support for environmental mobility facilitators as motivators of outdoor mobility was provided by the present multinomial logistic regression analysis. In the model, those who reported environmental facilitators for outdoor mobility had higher odds for using no or adaptive walking modifications than those using maladaptive walking modifications. The use of adaptive walking modifications helps in maintaining life-space mobility and autonomy in participation in outdoor activities (Skantz et al., 2019). This is essential since higher life-space mobility is associated with better quality of life among older people (Rantakokko et al., 2013).

In the present study, perceiving nature- and infrastructure-related environmental outdoor mobility barriers was associated with a higher likelihood for both adaptive and maladaptive walking modifications in the age- and sex-adjusted models. However, the associations across the individual environmental outdoor mobility barriers were not identical and most were attenuated when health and physical capacity were added into the models. For instance, reporting snow and ice in the winter as a barrier increased the odds for using adaptive, but not maladaptive, walking modifications. Unlike those who have given up or reduced their frequency of walking longer distances, older people with adaptive walking modifications are likely to walk outdoors during wintertime, and thus perceive snow and ice as barriers that can be overcome (Eronen et al., 2014b).

In our prospective analyses, perceived environmental outdoor mobility facilitators did not predict the use of adaptive or maladaptive walking modifications. The sole exception was that reporting a walking trail or skiing track as a facilitator for outdoor mobility protected the individual from developing maladaptive walking modifications over time. Moreover, when health and physical capacity were included in the models, none of the perceived environmental outdoor mobility barriers increased the risk for using maladaptive walking modifications over time. These weak and unsystematic prospective associations indicate that perceptions of environmental characteristics do not necessarily precede the onset of walking modifications. However, this finding seems to be reasonable. Perceiving outdoor mobility facilitators decreases the risk for functional decline over time, while at the same time, perceiving facilitators encourages the use of adaptive rather than maladaptive walking modifications, thereby weakening longitudinal associations.

In the present study, adjusting the models for physical capacity and other health characteristics attenuated most of the

Table 5. Perceived Environmental Facilitators for Outdoor Mobility as Predictors of Use of Adaptive or Maladaptive Walking Modifications over 2-Year Follow-Up in Community-Dwelling Older People.

	Adaptive walking modifications (N = 218)[a]				Maladaptive walking modifications (N = 610)[b]			
	Model 1		Model 2		Model 1		Model 2	
Facilitator	OR (95% CI)	Adjusted *p*-value	OR (95% CI)	Adjusted *p*-value	OR (95% CI)	Adjusted *p*-value	OR (95% CI)	Adjusted *p*-value
Sum of nature facilitators								
1 versus 0	.8 (.3–2.5)	.810	.4 (.1–1.2)	.906	.7 (.4–1.2)	.282	.7 (.4–1.2)	.305
≥2 versus 0	.4 (.1–1.4)	.248	.7 (.3–1.8)	.339	1.0 (.5–1.7)	.926	1.0 (.5–1.8)	.977
Sum of infrastructure facilitators								
1 versus 0	.9 (.4–1.8)	.810	.7 (.4–1.3)	.406	.9 (.6–1.4)	.863	.8 (.5–1.3)	.893
≥2 versus 0	1.0 (.4–2.3)	.977	.6 (.3–1.3)	.819	.9 (.5–1.5)	.791	.9 (.5–1.6)	.937
Sum of safety facilitators								
1 versus 0	2.0 (.8–5.5)	.264	1.5 (.6–3.3)	.305	1.0 (.6–1.8)	.992	.9 (.5–1.6)	.872
≥2 versus 0	2.8 (.8–10.0)	.198	1.2 (.4–3.6)	.217	1.9 (1.0–3.8)	.128	1.7 (.8–3.4)	.288
Item specific								
Nature								
Park or other green area	1.2 (.7–2.2)	.650	1.0 (.5–2.0)	.977	.8 (.6–1.1)	.268	.8 (.5–1.1)	.872
Walking trail and skiing track	.8 (.4–1.7)	.735	.9 (.4–1.8)	.840	**.5 (.4–.7)**	**<.001**	**.5 (.3–.7)**	**<.001**
Nature and lakeside	1.8 (.8–3.8)	.264	2.0 (.8–4.8)	.256	1.3 (.8–1.9)	.428	1.3 (.8–2.0)	.406
Infrastructure								
Good lighting	.9 (.5–1.5)	.730	.8 (.4–1.5)	.582	.9 (.6–1.3)	.730	.9 (.6–1.3)	.671
Peaceful and good quality walkways	.9 (.5–1.7)	.911	.9 (.5–1.7)	.818	.9 (.6–1.2)	.620	.8 (.6–1.2)	.502
Even sidewalks	.9 (.5–1.8)	.896	.7 (.3–1.5)	.553	1.3 (.9–1.8)	.354	1.2 (.8–1.7)	.579
Resting places by the walking route	2.1 (.9–4.5)	.152	1.1 (.5–2.7)	.893	1.5 (1.0–2.3)	.136	1.3 (.9–2.0)	.386
Walkways without steep hills	1.9 (.8–4.8)	.270	1.9 (.7–5.4)	.380	1.2 (.7–1.9)	.650	1.1 (.7–1.9)	.809
Services close	1.0 (.6–1.8)	.992	.9 (.5–1.7)	.809	1.2 (.8–1.7)	.525	1.2 (.8–1.7)	.502
Safe crossings: traffic lights, zebra crossing, or traffic island between lanes	.9 (.5–1.8)	.903	.6 (.3–1.2)	.288	.9 (.6–1.3)	.623	.8 (.5–1.2)	.502
Safety								
Familiar environment	1.4 (.7–2.6)	.472	1.3 (.7–2.6)	.643	1.0 (.7–1.4)	.992	1.0 (.7–1.5)	.977
Appealing scenery	1.4 (.7–2.8)	.539	1.5 (.7–3.4)	.502	.8 (.5–1.1)	.245	.8 (.5–1.1)	.305
Own yard	1.1 (.6–2.0)	.883	1.2 (.6–2.3)	.809	1.1 (.8–1.6)	.737	1.1 (.8–1.6)	.796
Other people outdoors motivate	1.4 (.7–2.7)	.479	.8 (.4–1.8)	.809	1.0 (.6–1.4)	.910	.8 (.5–1.3)	.555
No car traffic	1.3 (.6–2.8)	.695	1.0 (.4–2.4)	.977	1.0 (.6–1.6)	.730	.9 (.5–1.4)	.787
No cyclists on walkways	2.7 (.7–9.7)	.237	2.3 (.6–9.4)	.409	1.2 (.5–2.6)	.815	1.1 (.5–2.4)	.937

Note. Development of adaptive and maladaptive walking modifications was analyzed in separate models by using binary logistic regression models. Model 1: Adjusted for age and sex. Model 2: Adjusted for age, sex, years of education, depressive symptoms, chronic conditions, and lower extremity function. OR = odds ratio; CI = confidence interval. False discovery rates (adjusted *p*-values) were calculated to correct for multiple testing. Statistically significant values are bolded.
[a]Reference category: no walking modifications.
[b]Reference category: no and adaptive walking modifications.

Table 6. Perceived Environmental Barriers to Outdoor Mobility as Predictors of Use of Adaptive or Maladaptive Walking Modifications over 2-Year Follow-Up in Community-Dwelling Older People.

	Adaptive walking modifications (*N* = 218)[a]				Maladaptive walking modifications (*N* = 610)[b]			
	Model 1		Model 2		Model 1		Model 2	
Barrier	OR (95% CI)	Adjusted *p*-value	OR (95% CI)	Adjusted *p*-value	OR (95% CI)	Adjusted *p*-value	OR (95% CI)	Adjusted *p*-value
Sum of nature barriers								
1 versus 0	1.0 (.3–3.2)	.992	.3 (.1–1.3)	.244	**2.4 (1.4–3.9)**	**.004**	1.9 (1.1–3.2)	.058
2 versus 0	1.2 (.7–2.3)	.726	1.0 (.5–2.0)	.937	**1.7 (1.2–2.5)**	**.023**	1.4 (.9–2.1)	.244
Sum of infrastructure barriers								
1 versus 0	**3.1 (1.0–9.7)**	.114	1.2 (.3–4.4)	.872	1.6 (1.0–2.5)	.116	1.3 (.8–2.1)	.502
≥2 versus 0	.8 (.4–1.8)	.770	.5 (.2–1.2)	.244	1.2 (.7–1.8)	.722	1.0 (.6–1.6)	.971
Sum of safety barriers								
1 versus 0	1.9 (.7–5.1)	.298	.7 (.3–1.8)	.923	1.2 (.7–2.0)	.728	.9 (.5–1.6)	.872
≥2 versus 0	.6 (.3–1.4)	.372	.3 (.1–.8)	.076	1.4 (.9–2.3)	.198	1.3 (.8–2.1)	.384
Item specific								
Nature								
Hills in the nearby environment	1.6 (.7–4.1)	.446	.9 (.3–2.4)	.872	1.7 (1.1–2.5)	.056	1.5 (1.0–2.3)	.185
Snow and ice in winter	1.0 (.5–1.7)	.926	.6 (.3–1.3)	.339	**1.8 (1.3–2.6)**	**.004**	1.5 (1.1–2.2)	.093
Infrastructure								
Poor street condition	.9 (.4–2.0)	.883	.5 (.2–1.4)	.333	1.5 (1.0–2.3)	.136	1.3 (.8–2.0)	.406
High curbs	6.0 (.6–63.5)	.240	6.3 (.4–98.6)	.340	1.7 (.9–3.5)	.237	1.2 (.6–2.6)	.809
Lack of pedestrian zones	1.8 (.3–11.6)	.713	1.2 (.1–12.1)	.923	1.0 (.3–3.1)	.992	1.3 (.4–4.2)	.809
Long distances to services	1.1 (.3–4.0)	.977	.3 (.1–1.5)	.305	1.0 (.5–1.9)	.992	1.0 (.5–1.9)	.946
Lack of resting places, summer	**7.3 (1.5–35.3)**	**.040**	3.7 (.7–19.1)	.261	1.4 (.8–2.3)	.354	1.1 (.6–1.9)	.872
Lack of resting places, winter	2.6 (.7–9.2)	.248	1.2 (.3–4.7)	.893	1.5 (1.0–2.4)	.160	1.2 (.7–2.0)	.607
Poor lighting	1.3 (.2–8.0)	.896	.7 (.1–6.7)	.872	1.2 (.5–2.9)	.755	.9 (.4–2.2)	.872
Safety								
Noisy traffic	1.4 (.2–10.5)	.854	.6 (.1–5.6)	.809	1.0 (.4–2.5)	.992	.7 (.3–1.9)	.667
Busy traffic	1.0 (.2–4.0)	.992	.8 (.2–3.8)	.872	2.0 (1.1–3.6)	.082	1.7 (.9–3.2)	.256
Dangerous crossroads	3.7 (1.0–12.7)	.107	2.7 (.7–10.8)	.321	1.3 (.7–2.2)	.610	1.1 (.6–1.9)	.893
Vehicles on walkways	.5 (.1–5.8)	.727	.2 (.0–3.5)	.450	.9 (.2–3.5)	.910	.8 (.2–3.4)	.872
Cyclists in the walkways	.8 (.4–1.7)	.730	.4 (.2–1.1)	.173	1.3 (.8–1.9)	.446	1.2 (.7–1.8)	.704
Insecurity due to other pedestrians	2.5 (.8–8.0)	.237	.9 (.2–3.3)	.893	1.0 (.5–2.1)	.992	.8 (.4–1.7)	.809

Note. Development of adaptive and maladaptive walking modifications was analyzed in separate models by using binary logistic regression models. Model 1: adjusted for age and sex. Model 2: adjusted for age, sex, years of education, depressive symptoms, chronic conditions, and lower extremity function. OR = odds ratio; CI = confidence interval. False discovery rates (adjusted *p*-values) were calculated to correct for multiple testing. Statistically significant values are bolded.

[a]Reference category: no walking modifications.

[b]Reference category: no and adaptive walking modifications.

associations between the environmental barriers to outdoor mobility and walking modifications. This finding underlines the importance of individual characteristics in person–environment fit models. This was also supported by our sensitivity analyses, which showed that the exclusion of participants who were unable to walk 2 km independently attenuated most of the associations between the environmental facilitators for outdoor mobility and walking modifications. Thus, in line with ecological model of aging (Nahemow & Lawton, 1973), the use of adaptive and maladaptive walking modifications seems to be the result of person–environment interaction. When older people with intermediate physical capacity start to perceive environmental barriers, they are able to overcome them by modifying their walking in an adaptive way and thus continue walking. However, as their physical capacity further declines, environmental press increases and compensation for functional loss via adaptive walking modifications is more difficult. In such a situation, because compensation requires at least some resources (Saajanaho et al., 2016), older people may turn to loss-based selection (Baltes & Baltes, 1990) and use maladaptive walking modifications. Previous studies have shown that multiple factors, such as age, family context, and functional capacity, are associated with the use of compensatory strategies (Gitlin et al., 2017; Hoenig et al., 2006; Lang et al., 2002). Our analyses complement these factors with that of the outdoor environment, which, depending on the individual's level of physical or psychological functioning, seems to have specific impacts on the use of walking modifications.

The strengths of this study are the large population-based sample, with a 2-year follow-up, and the LISPE study design, which was optimized for the purpose of investigating the associations between environmental factors and outdoor mobility. However, the study has some limitations. First, perceptions of environmental facilitators for and barriers to outdoor mobility are individuals' subjective feelings about their living environment and are expressed differently in different contexts. For example, our findings concern community-dwelling older adults mainly living in urban or suburban areas and hence might not be applicable to older adults living in rural areas. Second, participants relocating or experiencing changes in their living environment during the follow-up period might have had a minor effect on our longitudinal findings. It seems reasonable to expect that older people who relocate are likely to move from a more to a less challenging environment. If so, this might attenuate the longitudinal results. However, only 31 participants relocated during the follow-up and thus, any such effect is likely to be small. Similarly, it is possible that during the follow-up changes in the built environment, such as changes related to the availability of benches or to improvements or deterioration in sidewalks, or changes in the natural environment may have influenced the adoption of walking modifications. However, such changes in the study area were minor and not likely to have exerted a major impact on the longitudinal findings. Third, based on their SPPB scores, our participants were relatively well-functioning older people. This may have led to underestimation of the use of maladaptive walking modifications in the community-dwelling older population. However, the main purpose was to study the associations between features of the outdoor environment and walking modifications rather than the prevalence of walking modifications. Moreover, task limitations initially affect the most demanding tasks, such as walking longer distances (Weiss et al., 2007), and therefore using a measure of walking modifications in walking a distance of 2 km was appropriate in this group. Finally, our results may have been influenced by the fact that older people with severe mobility limitations rarely report environmental outdoor mobility barriers (Eronen et al., 2014a) owing to their lack of exposure to such barriers and hence unawareness of them.

Conclusion

Whereas previous research findings have mainly concerned individual determinants of adaptive strategies, the present study, in line with the ecological model of aging, shows that the use of adaptive and maladaptive walking modifications seems to be the result of the person–environment interaction. Older people with adaptive walking modifications reported more environmental facilitators to outdoor mobility than people using maladaptive walking modifications. This indicates that perceived environmental facilitators, such as the availability of good quality walkways and good lighting, motivate individuals to continue walking in an adaptive way despite functional decline. The present finding of an association between perceived environmental barriers to outdoor mobility and the use of maladaptive walking modifications highlights the importance of a safe and walkable environment for increasing outdoor mobility among older people. It would, therefore, be prudent to reduce environmental barriers, especially for those with poorer physical capacity. For example, ensuring snow removal during wintertime (in localities with persistent snowy conditions) and providing resting places in streets and parks would benefit this group of people.

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Supplemental Material

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III

OUTDOOR MOBILITY AND USE OF ADAPTIVE OR MALADAPTIVE WALKING MODIFICATIONS AMONG OLDER PEOPLE

by

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Research Article

Outdoor Mobility and Use of Adaptive or Maladaptive Walking Modifications Among Older People

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Abstract

Background: In old age, decline in functioning may cause changes in walking ability. Our aim was to study whether older people who report adaptive, maladaptive, or no walking modifications differ in outdoor mobility.

Methods: Community-dwelling people aged 75–90 years (N = 848) were interviewed at baseline, of whom 761 participated in the 2-year follow-up. Walking modifications were assessed by asking the participants whether they had modified their way of walking 2 km due to their health. Based on the responses, three categories were formed: no walking modifications (reference), adaptive (eg, walking more slowly, using an aid), and maladaptive walking modifications (reduced frequency of walking, or having given up walking 2 km). Differences between these categories in life-space mobility, autonomy in participation outdoors, and unmet physical activity need were analyzed using generalized estimation equation models.

Results: Participants with maladaptive walking modifications (n = 238) reported the most restricted life-space mobility ($\beta = -9.6$, $SE = 2.5$, $p < .001$) and autonomy in participation outdoors ($\beta = 1.7$, $SE = 0.6$, $p = .004$) and the highest prevalence of unmet physical activity need (odds ratio = 4.3, 95% confidence interval = 1.1–16.5) at baseline and showed a decline in these variables over time. Those with no walking modifications (n = 285) at baseline exhibited the best values in all outdoor mobility variables and no change over time. Although at baseline those with adaptive walking modifications (n = 325) resembled those with no modifications, their outdoor mobility declined over time.

Conclusion: Adopting adaptive modifications may postpone decline in outdoor mobility, whereas the use of maladaptive modifications has unfavorable consequences for outdoor mobility.

Keywords: Physical activity, Functional performance, Physical function, Aging

Mobility can broadly be determined as a person's ability to move independently from one place to another, either on foot or by using other forms of transportation (1). Mobility is an important element and prerequisite of participation in valued activities and community life in old age (2). Although aging and age-related diseases and physical impairments affect mobility (3–5), their impacts on individuals vary depending on their psychological (6,7) resources and environmental demands (8,9). Walking modifications are conscious or subconscious changes in walking which occur when older people start to experience functional decline. Typical self-reported walking modifications include reduced walking speed, resting during walking, using an aid, reducing walking frequency, or giving up walking longer distances (10). Earlier studies have reported that people who do not report walking difficulty but have modified their walking form an intermediate group between those with and without walking difficulties in terms of lower extremity performance and muscle strength (10,11). In line with this, it has been shown that walking modifications may be viewed as preclinical signs of walking difficulties that identify people who are at increased risk for future walking difficulties (11).

According to Lawton and Nahemow's ecological theory of aging (12), in the adaptive stage, a person has matched his/her individual capacity to the task or environmental demand. Some studies have indicated that walking modifications may also be advantageous as they help older people to reduce environmental press and hence continue participating in out-of-home activities despite functional decline (13,14). To explore whether some walking modifications influence outdoor mobility more favorably than others, we divided self-reported walking modifications into adaptive and maladaptive modifications on a discretionary basis, drawing on the ecological theory of aging (12). Adaptive walking modifications, such as using an aid or lowering walking speed, can be viewed as facilitators or enablers of walking when facing physiological impairments. In contrast, we assumed that maladaptive walking modifications, such as giving up or reducing the frequency of walking longer distances, could have harmful consequences for outdoor mobility.

The aim of this study was to compare changes in outdoor mobility over 2 years according to self-reported adaptive, maladaptive, or no walking modifications at baseline. We studied outdoor mobility with respect to three outdoor mobility indicators: life-space mobility (15), autonomy in out-of-home participation (16), and unmet physical activity need (17). These measures correlate with each other although they express different aspects of mobility. Life-space mobility refers to actual mobility behavior in daily life (15), whereas autonomy in out-of-home participation indicates an individual's level of satisfaction with their opportunities to move where and when they want (16). Unmet physical activity need refers to a situation where people would like to increase their outdoor physical activity but perceive no opportunities to do so (17).

Methods

Design and Study Participants

The data for this observational study were drawn from data collected for the "Life-Space Mobility in Old Age" (LISPE) project, a 2-year prospective cohort study conducted between the years 2012 and 2014. A more detailed description of the LISPE study and nonrespondent analysis have been reported previously (18). Briefly, the study targeted community-dwelling people aged 75–90 years whose personal data were extracted from the Finnish population register based on their age and residence in the municipalities of Jyväskylä and Muurame (age-stratified random sample N = 2,550). Based on a preliminary review of potential participants' street addresses, those living in assisted living facilities were excluded. In total, 2,269 persons were contacted to enquire about their willingness to take part in the study. The inclusion criteria were being community dwelling, resident in the study area, willing to participate, and able to communicate and provide an informed consent. After exclusions, 848 participants were interviewed in their homes at baseline and 761 took part in the 2-year follow-up (drop-out rate 10%). The Ethical Committee of the University of Jyväskylä approved the LISPE study project.

Measurements

Self-reported modifications in walking 2 km were studied at baseline with a validated assessment tool for capturing early signs of mobility decline (10). Participants were asked: "Have you noticed any of the following changes when walking 2 kilometers due to your health or physical functioning?" Changes were listed as follows: walking slower, resting during walking, using an aid, reduced frequency of walking, and given up walking distances of 2 km. The response options were "yes" or "no" and participants were asked to report all walking modifications. Walking slower, resting during walking, and using an aid were considered to reduce the task demands and indicate a striving to continue doing the task and thus were categorized as adaptive modifications. Those who reported adaptive walking modifications and also reduced frequency of walking were also categorized as using adaptive walking modifications. Given up walking 2 km and reduced frequency of walking 2 km distances, in the absence of adaptive modifications, were considered to represent maladaptive modifications indicating reduced striving to continue the activity potentially stemming from task demands exceeding personal capacity.

Life-space mobility was measured at baseline and at the 2-year follow-up using the Finnish version of the University of Alabama (UAB) Study of Aging Life-Space Assessment (15,19). The Life-space Mobility Assessment captures the individual's actual mobility performance in daily life during the preceding 4 weeks, taking into account all forms of mobility from walking to driving and using public transportation. Participants were asked on how many days per week (less than once a week, one to three times a week, four to six times a week or daily) they reached each life-space level (bedroom, other rooms, outside home, neighborhood, town, and beyond town), and if they needed help from others or assistive devices. A life-space composite score (range 0–120) comprising level, frequency, and assistance needed was then calculated based on the participant's responses (15). Higher scores indicate greater life-space mobility. A change of more than 10 points in the life-space mobility score is considered to indicate clinically meaningful change (19).

Autonomy in participation outdoors was measured using the relevant domain of the Impact on Participation and Autonomy questionnaire. The Impact on Participation and Autonomy questionnaire has been shown to be a reliable and valid instrument for assessing autonomy and participation in older populations (16). The autonomy outdoors domain consists of five items: visiting relatives and friends, making trips and traveling, spending leisure time, meeting other people, and living life the way one wants to. Each item is scored from 0 (very good possibilities) to 4 (very poor possibilities), with a higher sum score indicating more autonomy restrictions in participation (range 0–20).

Unmet physical activity need was measured using two questions: "Would you like to increase your level of outdoor physical activity?" and "Do you feel that you would have the opportunity to increase your level of outdoor physical activity if someone recommended you to do so?" The response options for each of these questions were "yes" and "no." People wanting to increase their outdoor physical activity while perceiving no opportunity to do so were defined as experiencing unmet physical activity need (17).

Covariates were measured at baseline and selected based on existing knowledge on variables that correlate with mobility. Data on age and gender were gathered from the population register extract used as the basis for recruitment. During the home interview, the participants reported their years of education. Physician-diagnosed chronic conditions were elicited with a list of 22 specified chronic conditions followed by an open-ended question on other any other diseases the participant might have. Based on the responses, we calculated the number of chronic conditions (20). Depressive symptoms were assessed with the Center for Epidemiologic Studies Depression Scale, CES-D (range 0–60; higher scores indicate more depressive symptoms) (21), and cognitive function was measured using the Mini-Mental State Examination (22). Lower extremity function was assessed using the Short Physical Performance Battery (23). The tests comprise standing balance (feet together, semi-tandem, full tandem), walking at normal gait speed for 2.44 m, and repeated chair rise (five times). Each test was scored from 0 to 4 and a sum score ranging from 0 to 12 calculated, with higher scores indicating better lower extremity function (20). The sum score was calculated only for those who completed at least two of the three tests. Participants were categorized based on self-reported difficulties in walking 2 km at baseline (10) for the sensitivity analysis. Participants were asked whether they had difficulties in walking 2 m with the following response options: (i) able to manage without difficulty; (ii) able to manage with some difficulty; (iii) able to manage with great deal of difficulty; (iv) able to manage only with help from another person; and (v) unable to manage even with help. Those who reported needing help to manage or being unable to walk 2 km even with help were categorized as being unable to walk 2 km independently.

Statistical Analysis

Participants who reported no walking modifications were selected as the reference category. Participant characteristics and mobility according to the three walking modification categories (adaptive, maladaptive, or no modifications) were described using means and *SD* for continuous variables and percentages for categorical variables. Differences between categories were tested with chi-square test or one-way analysis of variance.

Generalized estimation equation (GEE) models (24) with unstructured working correlation matrix were used to compare changes between the walking modification categories in life-space mobility and autonomy in participation outdoors over the 2-year follow-up. GEE binary logistic regression was used to study changes in the prevalence of unmet physical activity need over time. In the GEE models, the group difference is the difference between groups in the level of the score or prevalence at the baseline and at the 2-year follow-up. Group × time interaction represents the differences between groups in change over time. The first models were adjusted for age and gender, whereas the second models also included years of education, number of chronic conditions, depressive symptoms, and cognitive function. The final models, in addition to all the previous covariates, included extremity function.

Those who died during the follow-up (n = 41) or were admitted to institutional care (n = 15) were excluded from the longitudinal GEE analyses. Thus, the final model comprised 792 participants in the life-space mobility and autonomy in participation outdoors analyses and 787 participants in the unmet physical activity need analysis. Six participants had missing information for years of education, four for depressive symptoms and seven for Short Physical Performance Battery; these 17 participants were not included in the fully adjusted models. Multivariate imputation by chained equation was used to calculate missing scores for follow-up life-space mobility (n = 35), autonomy in participation outdoors (n = 44), and unmet physical activity need (n = 42). The sensitivity analyses showed that imputation did not change the results. Post hoc analyses were conducted using GEE modeling with maladaptive walking modifications set as the reference. Finally, to test the robustness of our findings, we conducted further sensitivity analyses by excluding from the prospective analyses all the participants who were unable to walk 2 km independently.

All the analyses were carried out with IBM SPSS version 24 (SPSS Inc., Chicago, IL). The results were regarded as statistically significant if the 95% confidence intervals did not include 1 or when p value was <.05.

Results

The mean age of the participants was 80.6 (*SD* = 4.3) years and 62% of the participants were women. At baseline, 285 (34%) were categorized as having no modifications in walking 2 km, 325 (38%) as having adaptive, and 238 (28%) as having maladaptive walking modifications. Those with maladaptive walking modifications were older, more often women, less educated, and had more chronic conditions, depressive symptoms, poorer cognitive function, and poorer lower extremity performance than those without walking modifications ($p < .002$ for all; Table 1). People with adaptive walking modifications formed an intermediate group between those with maladaptive walking modifications and those without walking modifications in age, education, lower extremity function, depressive symptoms, and number of chronic conditions. Participants categorized as using adaptive walking modifications used on average 2.1 walking modifications. The majority of them (80.3%) walked more slowly, 45.6% needed to rest during walking, 37.2% used walking aids when walking 2-km distances, and 50.2% had also reduced their frequency of walking 2-km distances. In the maladaptive walking modifications category, the majority (85.5%) had given up walking 2-km distances, whereas 14.5% had reduced their frequency of walking 2-km distances and reported no adaptive walking modifications.

Life-space mobility scores were highest at baseline and remained almost unchanged during the follow-up among those without walking modifications. Those who used maladaptive walking modifications at baseline had the lowest life-space mobility scores and at follow-up their scores had decreased more than the scores of those with no walking modifications (group difference β = −9.6, *SE* = 2.5,

Table 1. Participant Characteristics by 2-km Walking Modifications at Baseline (N = 848)

Characteristics	No Walking Modifications (n = 285) Mean (*SD*)	Adaptive Walking Modifications (n = 325) Mean (*SD*)	Maladaptive Walking Modifications (n = 238) Mean (*SD*)	p Value
Age, y	78.9 (3.7)	80.9 (4.2)	82.3 (4.2)	<.001[a]
Education, y	10.3 (4.5)	9.5 (4.0)	8.8 (3.8)	<.001[a]
Number of chronic conditions	3.3 (2.0)	4.6 (2.4)	5.3 (2.5)	<.001[a]
CES-D, score	7.4 (5.8)	10.2 (6.3)	11.6 (7.9)	<.001[a]
MMSE, score	26.6 (2.5)	26.1 (2.9)	25.7 (3.0)	<.001[a]
SPPB, score	10.8 (1.4)	9.7 (2.00)	8.1 (3.3)	<.001[a]
Women, % (n)	54 (154)	64 (209)	69 (163)	.002[b]

Notes: CES-D = Center for Epidemiologic Studies Depression Scale; MMSE = Mini-Mental State Examination; SPPB = Short Physical Performance Battery.
[a]Tested with one-way analysis of variance. [b]Tested with chi-square test.

$p < .001$, group × time $p = .010$; Table 2). In the age- and gender-adjusted model, the life-space mobility scores were slightly lower in the adaptive walking modifications group than reference group (group difference β = −5.2, *SE* = 2.4, $p = .026$), although this difference was attenuated after further adjustments. However, over the follow-up, their values declined more than those of the reference category (group × time $p = .001$).

Further post hoc analyses (not shown) indicated that the life-space scores of those with adaptive walking modifications and those without walking modifications were higher than among those with maladaptive walking modifications. The difference was statistically significant ($p < .001$ for those with no walking adaptations; $p < .001$ for those with adaptive walking modifications) and on average clinically significant (β = 9.6, *SE* = 2.5; β = 8.9, *SE* = 2.5, respectively).

The participants with maladaptive walking modifications at baseline showed significantly lower scores for autonomy in participation outdoors (group difference β = 1.7, *SE* = 0.6, $p = .004$; Table 3) and a significantly higher prevalence of unmet physical activity need (group difference odds ratio 4.3, 95% CI = 1.1–16.5, $p = .033$; Table 4) than those without walking modifications. Over the follow-up, they remained on the same lower level, with the same slope of change as that of the reference category (group × time $p = .971$; group × time $p = .611$). In turn, although the baseline scores of those with adaptive walking modifications resembled those without walking modifications, their scores for autonomy in participation outdoors had increased at the 2-year follow-up compared with those of the reference category (group × time $p = .003$).

Finally, to test the robustness of our findings, we conducted sensitivity analyses by excluding from the prospective analyses all those who at baseline had reported being unable to independently walk 2 km. This decreased the number of participants in the maladaptive walking modifications category from 207 to 114 and in the adaptive walking category from 309 to 305. These analyses did not change the results for life-space mobility (Supplementary Table 1). The results for autonomy in participation in outdoor activities remained similar for the most part (Supplementary Table 2). However, the difference in the autonomy in participation outdoor scores over time between those using maladaptive and those reporting no walking modifications was no longer statistically significant in the model adjusted also for lower extremity function (group difference β = 0.9, *SE* = 0.6, $p = .145$). The difference in the prevalence of unmet physical activity need between those with maladaptive walking modifications and those without walking modifications was also no longer statistically significant (Supplementary Table 3).

Table 2. Changes in Life-Space Mobility Scores Over 2-Year Period by Walking Modification Category Among Community-Dwelling People Aged 75–90 Years at Baseline

	Baseline	2-y Follow-up	Model 1			Model 2			Model 3		
	n = 792	*n* = 757									
Category	Mean (*SD*)	Mean (*SD*)	β (*SE*)	Group Difference, *p*	Group × Time, *p*	β (*SE*)	Group Difference, *p*	Group × Time, *p*	β (*SE*)	Group Difference, *p*	Group × Time, *p*
No walking modifications	77.3 (15.6)	76.4 (17.2)	Ref.			Ref.			Ref.		
Adaptive walking modifications	63.9 (17.9)	58.4 (18.8)	−5.2 (2.4)	**.026**	**.001**	−2.7 (2.4)	.223	**.001**	−0.8 (2.4)	.739	**.001**
Maladaptive walking modifications	49.1 (18.1)	44.3 (18.6)	−18.2 (2.5)	**<.001**	**.009**	−14.8 (2.5)	**<.001**	**.010**	−9.6 (2.5)	**<.001**	**.010**

Notes: Reference category: no walking modifications. Model 1: adjusted for age and gender; Model 2: adjusted for age, gender, years of education, number of chronic conditions, depressive symptoms, and cognitive function; and Model 3: adjusted for age, gender, years of education, number of chronic conditions, depressive symptoms, cognitive function, and lower extremity function. Statistically significant values are bolded.

Table 3. Changes in Autonomy in Participation Outdoors Scores Over 2-Year Period by Walking Modification Category Among Community-Dwelling People Aged 75–90 Years at Baseline

	Baseline	2-y Follow-up	Model 1			Model 2			Model 3		
	n = 792	*n* = 748									
Category	Mean (*SD*)	Mean (*SD*)	β (*SE*)	Group Difference, *p*	Group × Time, *p*	β (*SE*)	Group Difference, *p*	Group x Time, *p*	β (*SE*)	Group Difference, *p*	Group × Time, *p*
No walking modifications	4.5 (3.00)	4.8 (3.4)	Ref.			Ref.			Ref.		
Adaptive walking modifications	6.1 (3.3)	7.2 (3.6)	0.4 (0.5)	.338	**.003**	−0.3 (0.4)	.577	**.003**	−0.5 (0.4)	.271	**.003**
Maladaptive walking modifications	8.2 (4.3)	8.7 (4.0)	3.2 (0.6)	**<.001**	.957	2.3 (0.6)	**<.001**	.962	1.7 (0.6)	**.004**	.971

Notes: Reference category: no walking modifications. Model 1: adjusted for age and gender; Model 2: adjusted for age, gender, years of education, number of chronic conditions, depressive symptoms, and cognitive function; and Model 3: adjusted for age, gender, years of education, number of chronic conditions, depressive symptoms, cognitive function, and lower extremity function. Statistically significant values are bolded.

Table 4. Changes in Prevalence of Unmet Physical Activity Need Over 2-Year Period by Walking Modification Category Among Community-Dwelling People Aged 75–90 Years at Baseline

	Baseline	2-y Follow-up	Model 1			Model 2			Model 3		
	n = 787	*n* = 750									
Category	% (*n*)	% (*n*)	OR (95% CI)	Group Difference, *p*	Group × Time, *p*	OR (95% CI)	Group Difference, *p*	Group × Time, *p*	OR (95% CI)	Group Difference, *p*	Group × Time, *p*
No walking modifications	4.4 (12)	5.5 (15)	Ref.			Ref.			Ref.		
Adaptive walking modifications	11.8 (36)	19.0 (56)	1.7 (0.5–6.6)	.427	.410	1.4 (0.4–5.5)	.610	.402	1.3 (0.3–5.2)	.687	.398
Maladaptive walking modifications	26.1 (54)	26.6 (49)	6.6 (1.8–24.6)	**.005**	.640	5.2 (1.4–19.7)	**.016**	.603	4.3 (1.1–16.5)	**.033**	.611

Notes: CI = confidence interval; OR = odds ratio. Reference category: no walking modifications. Model 1: adjusted for age and gender; Model 2: adjusted for age, gender, years of education, number of chronic conditions, depressive symptoms, and cognitive function; and Model 3: adjusted for age, gender, years of education, number of chronic conditions, depressive symptoms, cognitive function, and lower extremity function. Statistically significant values are bolded.

Discussion

The levels and changes in outdoor mobility differed between those using adaptive or maladaptive walking modifications and those with no walking modifications. Older people who used maladaptive modifications had the lowest life-space mobility, the poorest perceived autonomy in participation outdoors, and the highest prevalence of unmet physical activity need at both baseline and at the 2-year follow-up. The outdoor mobility of those who used adaptive walking modifications resembled those with no modifications at baseline but declined over time. To the best of our knowledge, this is the first study to divide walking modifications into adaptive and maladaptive categories and examine their potentially different influences on outdoor mobility. Although our results are in line with those of previous studies indicating that walking modifications may facilitate continued participation in meaningful activities (9,14) and postpone reduction in life-space mobility (13), they expand them by distinguishing between adaptive and maladaptive walking modifications and using indicators of different aspects of outdoor mobility as outcomes.

According to the ecological theory of aging, maladaptive behavior occurs when environmental press is higher than the level of individual competence, whereas in the adaptive stage, a person has matched his/her performance to the demands of the task or environment (12). Our results show that in the early phases of declining health and physical performance, some older people lower the task demands of walking by using adaptive walking modifications and thus optimize their walking in relation to their capabilities, thereby postponing the decline in outdoor mobility. This notion is in line with the model of selection, optimization and compensation, which posits that older people use these three strategies to maintain participation in their valued activities (25). The fact that differences in health and physical performance explained the differences between those with no and those with adaptive walking modifications supports this explanation. For those with maladaptive walking modifications, differences in health and physical performance did not attenuate the results. This suggests, first, that the task demands of walking longer distances exceed their capabilities and, second, that factors other than health and physical performance underlie the result. An earlier study has shown that, for example, fear of falling or fear of crime, living alone, and ambient conditions such as poor weather correlate with lower outdoor mobility and especially affect people with lower physical capabilities (26). Another recent study suggested that older people who tenaciously pursue their goals but are also able to change them when needed, report better possibilities to participate in outdoor activities and are more often able to maintain their outdoor mobility at a higher level (7). Moreover, some features of the environment may restrict possibilities for outdoor activities (17,27,28), whereas others may support the use of assistive devices or provide places to rest during the outdoor activity. However, precisely how environmental features influence the choice of walking modifications warrants further study.

Another departure from earlier studies is that our analysis included people who reported walking difficulties. Previous studies have used self-reported walking modifications as indicators of preclinical disability and assessed them solely among those without walking difficulty to establish which came first (11,29). However, our aim was to evaluate whether some modifications could postpone or help maintain outdoor mobility among people who may experience walking difficulties but who are nevertheless able to continue walking. It is possible that some older people interpret the use of walking modifications as difficulties in walking (30); thus, the distinction between walking modifications and walking difficulties may be artificial. For example, a person who needs to rest when walking longer distances will probably report difficulty walking longer distances, even though optimizing the performance by resting in the middle of it helps to maintain the ability to walk longer distances. There might also be differences in reporting walking difficulties between those who have recently experienced pronounced functional decline and those whose functional ability has decreased over a longer period of time (31). In our sensitivity analyses, we excluded participants who reported that they were no longer able to walk 2 km independently or with help from others from the GEE models. Although most of the exclusions were from the category of maladaptive walking modifications, the results did not materially change. Consequently, we believe that the actual inability to walk does not explain the differences observed between the walking modification categories. Some individuals had stopped walking 2-km distances even though they could have continued walking.

The strengths of this study include the large population-based sample of community-dwelling older people. In addition, the possibility to utilize 2-year follow-up data in longitudinal analyses allowed us to study changes in three outdoor mobility variables in three walking modifications categories. Moreover, our categorization of walking modifications into adaptive and maladaptive was based on a self-reported walking modifications measure that has been shown to be a validated and reliable indicator of preclinical disability (10). Use of three different outdoor mobility variables that are conceptually different from walking difficulty or walking modifications enabled us to acquire knowledge that will help lay the foundation for actions to prevent or delay mobility limitation and restrictions on participation. However, the study also has its limitations. We did not have an opportunity to study the reasons behind the use of walking modifications. In addition, all the covariates in the models were assessed at baseline and changes in them were not accounted for.

The findings of the study indicate that categorizing walking modifications into two categories—adaptive and maladaptive—was meaningful as it showed that some older people may postpone age-related decline in outdoor mobility by using adaptive walking modifications, whereas for others, the use of maladaptive walking modifications reduces their outdoor mobility. Because the majority of people experience age-related functional decline, it is important to identify their individual mobility needs to support their full participation in society. Encouraging the use of adaptive walking modifications when needed and designing age-friendly environments, for example, by providing suitable transportation options and opportunities to rest when walking outdoors, may help older people to maintain their life-space mobility and autonomy to participate in outdoor activities, and protect them from unmet physical activity need. Future studies should bear in mind that different walking modifications may have different effects on people.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

Ta.R. serves on the *Journal of Gerontology: Medical Sciences* editorial board. Otherwise, the authors declare no conflicts of interest.

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IV

USE OF WALKING MODIFICATIONS, PERCEIVED WALKING DIFFICULTY AND CHANGES IN OUTDOOR MOBILITY AMONG COMMUNITY-DWELLING OLDER PEOPLE DURING COVID-19 RESTRICTIONS

by

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ORIGINAL ARTICLE

Use of walking modifications, perceived walking difficulty and changes in outdoor mobility among community-dwelling older people during COVID-19 restrictions

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Abstract

Background Outdoor mobility enables participation in essential out-of-home activities in old age.

Aim To compare changes in different aspects of outdoor mobility during COVID-19 restrictions versus two years before according to self-reported walking.

Methods Community-dwelling participants of AGNES study (2017–2018, initial age 75–85) responded to AGNES-COVID-19 postal survey in spring 2020 ($N=809$). Life-space mobility, autonomy in participation outdoors, and self-reported physical activity were assessed at both time points and differences according to self-reported walking modifications and difficulty vs. intact walking at baseline were analyzed.

Results Life-space mobility and autonomy in participation outdoors had declined (mean changes -11.4, SD 21.3; and 6.7, SD 5.3, respectively), whereas physical activity had increased (5.5 min/day, SD 25.1) at follow-up. Participants perceiving walking difficulty reported the poorest baseline outdoor mobility, a steeper decline in life-space mobility ($p=0.001$), a smaller increase in physical activity ($p<0.001$), and a smaller decline in autonomy in participation outdoors ($p=0.017$) than those with intact walking. Those with walking modifications also reported lower baseline life-space mobility and physical activity, a steeper decline in life-space mobility and a smaller increase in physical activity those with intact walking ($p<0.001$ for both).

Discussion Participants reporting walking modifications remained the intermediate group in outdoor mobility over time, whereas those with walking difficulty showed the steepest decline in outdoor mobility and hence potential risk for accelerated further functional decline.

Conclusion Interventions should target older people perceiving walking difficulty, as they may be at the risk for becoming homebound when environmental facilitators for outdoor mobility are removed.

Keywords Aging · Compensation · Mobility · Participation · Social isolation · SARS-CoV-2

Introduction

Outdoor mobility indicates an individual's actual mobility behavior and perceived possibilities for participation in essential out-of-home activities [1, 2]. The concept includes all types of journeys outside home, whether on foot or by other means of transportation, and thus requires some level of walking ability [2]. During the aging process, age-related diseases and functional decline may increase the risk for walking difficulty [3], in turn hindering possibilities to participate in out-of-home activities and leading to further decline in outdoor mobility [4]. However, before perceiving actual walking difficulty, older people noticing the first signs of functional decline may

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seek to maintain their outdoor mobility by modifying their walking behavior, for example, using an aid or walking more slowly [4].

During spring 2020, multiple actions were taken globally to slow down the spread of the SARS-CoV-2 virus responsible for COVID-19, especially among high-risk populations. In Finland, the government announced a state of emergency and, as a general guideline, advised older people to limit their physical contacts and avoid crowded areas. Restaurants, libraries, and indoor sport facilities were closed, and many cultural and civic society events and organized classes were canceled. Particular concerns were expressed regarding the potentially adverse consequences of these restrictions on older people's outdoor mobility and physical activity, as older people typically accumulate most of their physical activity while running daily errands, attending various events or making social visits [5–7].

Thus far, studies evaluating the effects of the COVID-19 restrictions and lockdowns have focused on changes in one aspect of outdoor mobility at a time among older people and have mostly utilized cross-sectional data based on convenience samples [8–11]. In these studies, the majority of older people reported a decrease in their physical activity during the COVID-19 restrictions [8–10]. Lower scores for life-space mobility, referring to individuals' actual mobility behavior in daily life, and for active aging were observed in our previous study comparing data collected during the COVID-19 restrictions with data collected two years earlier [11]. In our previous prospective study [4] conducted prior to the COVID-19 pandemic, perceived walking difficulty preceded the decline in life-space mobility. However, the use of walking modifications enabled older people to postpone the decline in life-space mobility and in autonomy in participation outdoors [12]. It is thus possible that the COVID-19 restrictions have had different effects on older people's life-space mobility, autonomy in participation outdoors and physical activity, according to their use of walking modifications or perceived walking difficulty. We hypothesized that older people who perceived walking difficulty prior to the COVID-19 pandemic would show a steeper decline in various aspects of their outdoor mobility during the COVID-19 restrictions compared to those with intact walking.

The first aim of this study was to examine levels and changes in life-space mobility, autonomy in participation outdoors, and self-reported physical activity among older people during the COVID-19 restrictions compared to two years earlier. The second aim was to investigate whether the levels and changes in these various aspects of outdoor mobility differed between those reporting intact walking, walking modifications, or difficulty in walking a 2-km (km) distance at baseline.

Methods

Study design and participants

This study presents longitudinal results of the 'Active Aging – resilience and external support as modifiers of the disablement outcome' (AGNES) observational cohort study. Follow-up data (AGNES-COVID-19) were collected via postal questionnaires during the COVID-19 restrictions (May and June 2020) and these data were compared to baseline data (collected 2017–2018). The study protocol of the AGNES study [13] and non-respondent analyses of both datasets have been reported previously [11, 14]. Briefly, the AGNES study is an observational study of three birth cohorts (aged 75, 80 and 85 years). A random sample based on age and residence in specific postal code areas in Jyväskylä (Finland) was drawn from the Digital and Population Data Services Agency in Finland. Inclusion criteria were being resident in the study area, community-dwelling, willing to participate, able to communicate, and provide an informed consent. At baseline, structured personal interview was conducted in participants homes (N = 1 018). At follow-up, a postal questionnaire was sent to the 985 baseline participants not known to have died or been transferred to an institutional care facility, and who had not withdrawn their consent [11]. Altogether, 809 responses were received. Seven participants had difficulty answering the questionnaire or preferred an interview and were thus interviewed over the phone. During collecting the follow-up data, the number of confirmed COVID-19 cases was low in the study area (102 cases, population 253 000, 21 municipalities) [11].

Measurements

Self-reported walking modifications and difficulty in 2-km were assessed at baseline [15, 16]. First, perceived difficulty in walking a distance of 2-km was asked with the question: "*Do you have difficulty in walking 2-km?"* The response alternatives varied from "able to manage without difficulty" to "unable to manage even with help". Second, those using walking modifications at baseline were identified by asking those who reported being able to walk without difficulty an additional question: "*Have you noticed any of the following changes due to your health or physical functioning when walking 2-km?*" The response options were walking slower, taking rest breaks during walking, using an aid, having reduced the frequency of walking, and having given up walking distances of 2-km ("yes" or "no"). For the analyses, participants were categorized as follows: 1) *intact walking* (no difficulty nor modifications, reference), 2) *walking modifications* (no difficulty and at least one modification), and 3) *walking difficulty* (at least some difficulty).

Life-space mobility, autonomy in participation outdoors and self-reported physical activity were measured at baseline and during the COVID-19 restrictions. *Life-space mobility* was measured with the Finnish version of the University of Alabama at Birmingham Study of Aging Life-Space Assessment [17, 18]. The Life-Space Mobility Assessment is a validated measure designed to capture individuals' actual mobility behavior in daily life. Participants were asked on how many days per week during the four weeks preceding the assessment they reached each life-space level, and if they needed help from other people or assistive devices. A higher life-space composite score indicates greater life-space mobility (range 0–120) [17].

Autonomy in participation outdoors was measured using the respective subscale of the Impact on Participation and Autonomy Questionnaire (IPA) [19]. The IPA is a validated measure for assessing participation and autonomy in clinical populations and older people and can be used as a whole questionnaire or as subscales [19, 20]. The autonomy outdoors subscale comprises five items assessing a person's satisfaction with his/her possibilities to take part in activities outside the home: visiting relatives and friends, making trips and traveling, spending leisure time, meeting other people, and living life the way one wants to. Each item is scored from 0 (very good possibilities) to 4 (very poor possibilities). A higher sum score indicates more restrictions in autonomy in participation outdoors (range 0–20).

Self-reported physical activity was assessed using the Yale Physical Activity Survey for older adults [21]. Participants were asked how many times they had performed vigorous physical activity and leisure walking for at least 10 min during the past month and the usual duration of these sessions. Total minutes per day were calculated using the following formula [14]: (frequency*duration)/7. Finally, mean daily vigorous physical activity and leisure walking minutes were summed.

Age and sex were obtained from the Finnish National Population Register at the sampling stage. In addition, information on years of education, number of chronic conditions, depressive symptoms, and lower extremity function were collected at baseline during structured home interviews by trained interviewers and used only for descriptive purposes. *Years of education,* as an indicator of socioeconomic status, was self-reported. *Number of chronic conditions* was calculated as the sum of individual chronic conditions from a list of physician-diagnosed chronic conditions followed by an open-ended question on any other chronic diseases the participant might have [13]. *Depressive symptoms* were assessed with the Center for Epidemiologic Studies Depression Scale, CES-D (range 0–60, with higher scores indicating more depressive symptoms) [22]. The Short Physical Performance Battery, SPPB (range 0–12, with higher scores indicating better lower extremity function) including balance, walking speed and chair stands were used to assess *lower extremity function* [23].

Statistical analyses

Baseline characteristics were compared between the self-reported walking categories using cross-tabulation with chi-square test for categorical variables and one-way ANOVA with a Bonferroni test (post hoc comparisons) for normally distributed continuous variables. Overall longitudinal changes in life-space mobility and autonomy in participation outdoors scores, and in physical activity minutes were calculated using paired samples *t*-test. Generalized Estimation Equations (GEE) linear models [24] with an unstructured working correlation matrix were used to compare changes in life-space mobility, autonomy in participation outdoors and self-reported physical activity over the follow-up between the self-reported walking categories. We estimated main effects (group difference) and time interaction effects (group by time). Adjusting the models for age and sex did not change the main and time interaction effects, and thus only age- and sex-adjusted models are reported. The models were adjusted only for age and sex, because the purpose was to study changes over time at the individual level in life-space mobility, autonomy in participation outdoors and self-reported physical activity related to the COVID-19 restrictions according participants' self-reported walking at baseline.

This study comprised AGNES participants who also participated in the AGNES-COVID-19 survey ($N = 809$). Age and sex were available for all participants, whereas information on self-reported walking was missing for 12 participants; hence, the final models comprised 797 participants. Missing autonomy in participation outdoors scores was imputed for follow-up participants with only one missing item ($n = 14$) using the mean of the available items. In addition, in the GEE models, multivariate imputation by chained equations was used to calculate scores for missing baseline and follow-up total scores for life-space mobility (baseline $n = 4$, follow-up $n = 6$), autonomy in participation outdoors (baseline $n = 13$, follow-up $n = 27$) and minutes for self-reported physical activity (baseline $n = 14$, follow-up $n = 16$). Including participants with imputed items, total scores or, minutes did not change the results based on the sensitivity analyses (data not shown). IBM SPSS version 24 for Windows (IBM Corp., Armonk, NY) was used for statistical analyses. The results were regarded as statistically significant if the p value was < 0.05.

Results

Baseline characteristics according to self-reported walking are shown in Table 1. Based on the post hoc comparisons, those reporting walking difficulty ($n = 268$) were older, less educated and had more chronic conditions, depressive symptoms, and poorer lower extremity function than those reporting intact walking ($n = 396$) ($p < 0.008$ for all). Participants with walking modifications ($n = 133$) did not differ from those with intact walking in years of education ($p = 0.097$) or number of chronic conditions ($p = 0.139$). They formed an intermediate group in their lower extremity function and depressive symptoms scores between those with intact walking and those with walking difficulty ($p < 0.015$ for all) and had fewer chronic conditions than those with walking difficulty ($p < 0.001$).

Life-space mobility scores decreased on average − 11.4 points (SD 21.3) in all participants during the COVID-19 restrictions when compared to their scores two years before (72.6, SD 18.6 vs. 61.2, SD 24.7). Those with walking difficulty had a lower life-space mobility score at baseline (Table 1 and Fig. 1) and showed a steeper decline over time than those with intact walking. Those with walking modifications also had a lower life-space mobility score at baseline and showed a steeper decline over the follow-up than those with intact walking.

Participants were less satisfied with their possibilities to participate in activities outside their homes than two years earlier (5.1, SD 3.7 vs. 11.7, SD 5.1), as their autonomy in participation outdoors scores increased on average by 6.7 (SD 5.4) points over the follow-up. While those with walking difficulty reported poorer opportunities to participate in out-of-home activities than those with intact walking at baseline (Table 1 and Fig. 1), the decrease in autonomy in participation outdoors at follow-up was greater among those reporting intact walking at baseline. In turn, while those with walking modifications perceived worse autonomy in participation outdoors at baseline than those reporting intact walking, the change at follow-up in these two groups was similar.

Daily time spent in vigorous physical activities and in leisure walking had increased on average by 5.3 (SD 25.0) minutes among all participants at follow-up during the COVID-19 restrictions (35.3, SD 20.8 vs. 40.6, SD 27.5). At baseline, those reporting walking difficulty or use of walking modifications accumulated less daily vigorous physical activity and walking minutes than those with intact walking (Table 1 and Fig. 1). Among those with intact walking, daily vigorous physical activity and walking minutes had increased from baseline to the COVID-19 restrictions, whereas it remained more stable among those with walking difficulty and those with walking modifications.

Discussion

The present findings indicate that while life-space mobility and autonomy in participation outdoors declined, physical activity increased among community-dwelling older people between the pre-COVID baseline and the follow-up two years later during the COVID-19 restrictions. People with intact walking in 2-km distance had the most favorable baseline scores for life-space mobility, autonomy in participation outdoors and physical activity. Moreover, although their life-space mobility and autonomy in participation outdoors declined, the amount of time spent in vigorous physical activity and walking increased. In turn, those reporting

Table 1 Participants' Background Characteristics by Self-Reported Ability to Walk 2-km at Baseline ($n = 797$)

Characteristics	Intact Walking ($n = 396$) Mean (SD)	Modifications ($n = 133$) Mean (SD)	Difficulty ($n = 268$) Mean (SD)	*P* value
Age, years	77.7 (3.2)	78.8 (3.6)	79.7 (3.7)	< 0.001 [a]
Education, years	12.3 (4.3)	11.3 (4.3)	11.2 (4.2)	0.005 [a]
SPPB, score	11.0 (1.2)	10.2 (1.7)	8.8 (2.7)	< 0.001 [a]
CES-D, score	6.6 (5.9)	8.5 (7.2)	10.7 (7.7)	< 0.001 [a]
No. of chronic diseases	2.8 (1.7)	3.1 (1.8)	4.4 (2.2)	< 0.001 [a]
Life-space mobility, score	79.8 (14.9)	73.5 (14.9)	61.4 (19.7)	< 0.001 [a]
Autonomy in participation outdoors, score	4.0 (3.2)	5.4 (3.3)	6.6 (4.0)	< 0.001 [a]
Self-reported physical activity, minutes	43.3 (20.4)	35.0 (18.1)	24.1 (16.9)	< 0.001 [a]
Women, % (n)	52.3 (207)	57.1 (76)	68.3 (183)	< 0.001 [b]

SD Standard Deviation, *CES-D* Center for Epidemiologic Studies Depression Scale, *SPPB* Short Physical Performance Battery

[a] Tested with one-way analysis of variance

[b] Tested with chi-square test

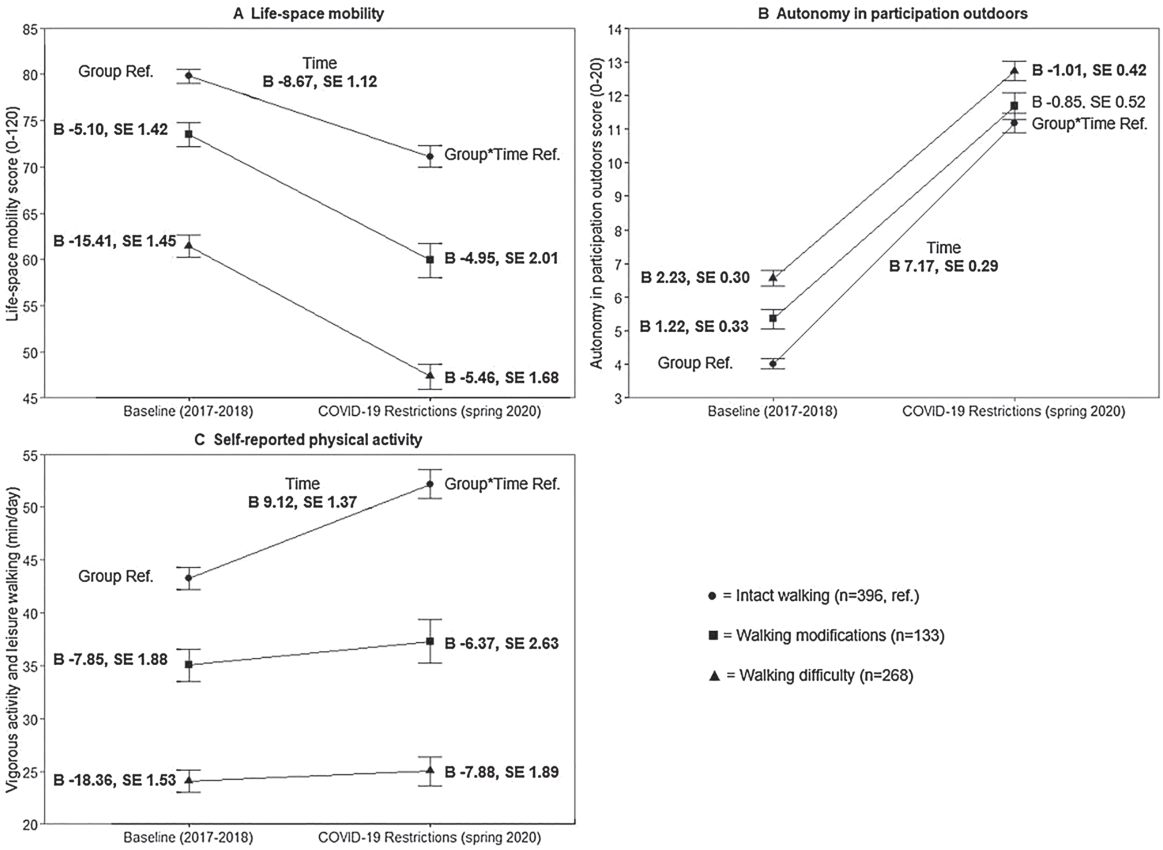

Fig. 1 Differences at baseline and in changes over time in (**A**) life-space mobility (higher scores indicate greater life-space mobility), (**B**) autonomy in participation outdoors (higher scores indicate more restrictions in autonomy) and (**C**) self-reported physical activity, vigorous activity, and leisure walking minutes (with standard error) according to self-reported walking at baseline. GEE models are adjusted for age and sex

walking difficulty showed a more unfavorable level of outdoor mobility at baseline and the steepest decline in life-space mobility at follow-up during the COVID-19 restrictions. The participants with walking modifications remained in an intermediate position in all three outcome variables at both measurement points.

The decline in life-space mobility during the COVID-19 restrictions compared to two years before the pandemic was clinically meaningful [17] and notably steeper (on average 6–18 points) than in our previous study (on average 1–5 points) with a similar cohort and follow-up period [12]. Reduced life-space mobility may have a significant influence on older persons' everyday lives, as it is associated with multiple adverse health outcomes, such as increased risk for further functional decline [25], nursing home admission [26] and mortality [27]. Older people with walking difficulty and those with walking modifications showed the steepest decline in life-space mobility and were at the highest risk for restricted life-space mobility (from 61 to 47 points, 74 to 60, respectively) during the COVID-19 restrictions, meaning that they rarely moved outside of their immediate neighborhood [18]. The observed change in life-space mobility among those using walking modifications suggests that the compensatory effect of using walking modifications decreased during COVID-19 restrictions. Thus, in the present study, instead of postponing the decline in outdoor mobility [4], the use of walking modifications was an indicator of preclinical disability and a further reduction in walking activity [28]. Walking difficulty often coexists with cognitive impairments [29] and fear of moving outdoors [30], which may also compromise participation in everyday activities and accelerate the decline in life-space mobility [31]. Older people with walking difficulty may have been and may continue to be at heightened risk of becoming homebound during the COVID-19 restrictions especially if the restrictions on outdoor mobility are prolonged and effective interventions are not offered. Being homebound is a serious situation, as it is associated with a high mortality rate [32] and dependency in self-care [33].

Autonomy in participation outdoors indicates an individual's level of satisfaction with their opportunities to move outdoors and for instance to leave the home to visit relatives and friends as often as one wants [19]. Avoiding seeing other people was strongly recommended in Finland during the COVID-19 restrictions, and thus it is only logical that participants' perceived autonomy in participation outdoors declined (average change 6–7 points). In contrast, in our previous study, conducted during a period with no restrictions in place, perceived autonomy in participation outdoors remained almost unchanged (average change 0–1 points) with a cohort and follow-up time comparable to those in the present study [12]. Hence, it is likely that the observed changes in participants' autonomy in participation outdoors reflect the impact of the COVID-19 restrictions rather than the impacts of a person's individual ability [19]. Our observation that people with intact walking perceived a steepest decline in their autonomy in participation outdoors compared to those perceiving walking difficulty further supports this explanation. Autonomy is an essential goal of rehabilitation as it reflects participants' own perceptions of their possibilities to live life as they want to [19] and contributes to maintaining life satisfaction [34]. Therefore, although no cut-point for a meaningful change in the autonomy in participation outdoors score has been established, the observed seven-point mean decline may have had a meaningful negative effect on the participants' lives. However, how this decline in autonomy in participation outdoors, if prolonged, affects older people's lives warrants further research.

Older people's physical activity increased in the present study, whereas in previous studies conducted in Italy and Spain it decreased during the COVID-19 restrictions [8–10]. This unexpected inconsistency between findings may be explained by the different strategies used to prevent the spread of the virus. Italy and Spain were in nationwide lockdowns and their citizens were not allowed to leave their homes without a valid reason [35, 36], whereas in Finland, no curfew was imposed at any time during spring 2020. In addition, we assessed physical activity as time spent in vigorous activity and leisure walking. In addition to exercising outdoors, vigorous activity may have included at-home activities, such as indoor cycling or strength-training. Overall, our findings suggest, in line with a previous study [37], that older people with intact walking compensated, at least partly, for their lost participation in social activities by exercising at home or walking for leisure during the COVID-19 restrictions. In contrast, the lowest levels of physical activity were observed, as in previous study [38] among older people perceiving walking difficulty. Therefore, interventions aiming to increase physical activity should especially target people perceiving walking difficulty or using walking modifications.

The study has its limitations. Owing to the COVID-19 restrictions, the follow-up data were collected using postal questionnaires. Thus, we cannot be sure who responded to the questionnaire or whether some participants misunderstood some of the questions. In addition, physical activity was self-reported, which may have led to overestimation of physical activity levels. We cannot rule out the possibility that changes in health are affecting the associations found. However, considering the greater changes in outdoor mobility in the present study compared to an earlier cohort [12] and the low rates of markedly worsened health during the follow-up, we consider that effects of the COVID-19 restrictions likely to be of greater magnitude. Overall, the effects of these limitations to the results are likely to be small.

The strengths of this study include the large population-based sample of community-dwelling older people and the longitudinal study design with data collected prior to and during the COVID-19 restrictions. In addition, our study contributes further knowledge on the consequences of the COVID-19 restrictions: first, by assessing differences based on 2-km walking categories, second, by assessing three important aspects of older people's outdoor mobility, and third, by comparing the results over time. Previous studies, in contrast, have focused solely on changes in physical activity [8–10] or used a cross-sectional design and targeted self-selected convenience samples [8, 10]. Finally, the present study opens the way for future research.

Conclusion

Older people with intact walking coped better with the COVID-19-related restrictions than those with walking modifications or difficulty, as they were able to compensate for suspended social activities by increasing their physical activity. In future, special attention should be paid to older people perceiving walking difficulty, as they seem to be at the highest risk for becoming homebound when environmental facilitators to outdoor mobility are removed. When comparing our findings to previous study, with a similar cohort and living environment, we noticed that the decline in life-space mobility and autonomy in participation during the first wave of COVID-19 exceeded the decline that would naturally have occurred due to the aging process over a 2-year period. As this study describes the situation in the early phase of the pandemic, further studies are needed to investigate the effects of prolonged COVID-19 restrictions on older people's outdoor mobility. In addition, studies should examine how experiencing restricted life-space mobility and autonomy in participation outdoors during the first wave of COVID-19 affects older people's subsequent walking ability, and whether older peoples' life-space mobility and autonomy in participation outdoors returns to pre-COVID levels after the COVID-19 pandemic restrictions have been lifted.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Statement of human and animal rights The study protocols in both data collections were performed in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments. The ethical committee of the Central Finland hospital district provided an ethical statement of the AGNES study on August 23, 2017, and May 13, 2020.

Informed consent All participants signed an informed consent prior to the start of the study.

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