STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH
254

Li-Tang Tsai

Walking, Physical Activity and Life-Space Mobility among Older People

JYVÄSKYLÄN YLIOPISTO

STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH 254

Li-Tang Tsai

Walking, Physical Activity and Life-Space Mobility among Older People

Esitetään Jyväskylän yliopiston liikuntatieteellisen tiedekunnan suostumuksella
julkisesti tarkastettavaksi yliopiston vanhassa juhlasalissa S212
helmikuun 17. päivänä 2017 kello 12.

Academic dissertation to be publicly discussed, by permission of
the Faculty of Sport and Health Sciences of the University of Jyväskylä,
in building Seminarium, auditorium S212, on February 17, 2017 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2017

Walking, Physical Activity and Life-Space Mobility among Older People

STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH 254

Li-Tang Tsai

Walking, Physical Activity and Life-Space Mobility among Older People

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2017

Editors
Ina Tarkka
Faculty of Sport and Health Sciences, University of Jyväskylä
Pekka Olsbo, Ville Korkiakangas
Publishing Unit, University Library of Jyväskylä

Permanent link to this publication: http://urn.fi/URN:ISBN:978-951-39-6965-3

URN:ISBN:978-951-39-6965-3
ISBN 978-951-39-6965-3 (PDF)

ISBN 978-951-39-6964-6 (nid.)
ISSN 0356-1070

Jyväskylä University Printing House, Jyväskylä 2017

ABSTRACT

Tsai, Li-Tang
Walking, physical activity and life-space mobility among older people
Jyväskylä: University of Jyväskylä, 2017, 75 p.
(Studies in Sport, Physical Education and Health
ISSN 0356-1070; 254)
ISBN 978-951-39-6964-6 (nid.)
ISBN 978-951-39-6965-3 (PDF)
Finnish Summary
Diss.

Autonomy in mobility is a central component of active ageing. Life-space mobility describes where, when, and how an individual reaches desired destinations. Walking, an important form of physical activity among older people, is a prerequisite for engaging in daily activities. This study explored the cross-sectional and longitudinal relationships between physical activity and life-space mobility. The associations of walking with reasons for going outdoors in different life-space areas, living arrangements, and environmental barriers to mobility were also examined.

Data from two larger studies were used: the Life-Space Mobility in Old Age (LISPE) accelerometer substudy (n=174, median age 79.7) and Screening and Counseling for Physical Activity and Mobility in Older People (SCAMOB) (n=657, median age 77.0). Participants were community-dwelling older people living in Central Finland. Physical activity and step count were measured by an accelerometer (Hookie, tri-axial, "AM20 Activity Meter") for 7 days. Life-space mobility was assessed with the University of Alabama at Birmingham Study of Aging Life-Space Assessment. Reasons for going outdoors, walking for errands and environmental mobility barriers were self-reported.

The cross-sectional analyses showed that life-space mobility correlated with objectively measured physical activity. Over the two-year follow-up, a lower step count and less moderate-intensity physical activity at baseline preceded a significantly steeper decline in life-space mobility. In old age, a higher amount of walking activity was associated with going outdoors for shopping or walking for exercise, living alone, and perceiving fewer environmental mobility barriers.

This study indicates more time spent walking outdoors and the accumulation of moderate-intensity physical activity may help to maintain higher life-space mobility, a correlate of good quality of life. In promoting walking activity among community-dwelling older people, both individual and environmental factors should be taken into account.

Keywords: Life-space mobility, accelerometer, physical activity, walking, mobility

Author's address Li-Tang Tsai, MSc, PT
Gerontology Research Center
Faculty of Sport and Health Sciences
University of Jyväskylä
P.O. Box 35 (viv)
40014 University of Jyväskylä, Finland
li-tang.tsai@jyu.fi

Supervisors Professor Taina Rantanen, PhD
Gerontology Research Center
Faculty of Sport and Health Sciences
University of Jyväskylä
Jyväskylä, Finland

Docent Merja Rantakokko, PhD
Gerontology Research Center
Faculty of Sport and Health Sciences
University of Jyväskylä
Jyväskylä, Finland

Erja Portegijs, PhD
Gerontology Research Center
Faculty of Sport and Health Sciences
University of Jyväskylä
Jyväskylä, Finland

Reviewers Associate Professor Bjørn Heine Strande, PhD
Department of Community Medicine & Global Health
University of Oslo
Oslo, Norway

Research Director Harri Sievänen, PhD
UKK institute
Tampere, Finland

Opponent Docent Sari Stenholm, PhD, Academy Research Fellow
Department of Public Health
University of Turku
Turku, Finland

ACKNOWLEDGEMENTS

This study was carried out at the Gerontology Research Center, Department of Health Sciences, University of Jyväskylä, Finland. I am thankful for the opportunity to work in the LISPE project since the beginning. By participating in all its phases, I have been fortunate to learn how to conduct scientific work within a large, multidisciplinary research group alongside many talented researchers.

My deepest gratitude and highest respect goes to my supervisors, Professor Taina Rantanen, Docent Merja Rantakokko, and postdoctoral researcher Erja Portegijs. Taina, thank you for your support and guidance during these years, both inside and outside academia. It has been an honor to learn from you both in my master and PhD studies. You are truly my role model as a world-class researcher. Merja, thank you for your guidance and advice on my work and I appreciate your cheerful spirit in our discussions. I always feel re-energized after meeting with you. Erja, thank you for your wise advice, which are always careful and precise. From you, I learned how to work meticulously as a researcher. I deeply appreciate the fact that all my supervisors could always find time to help me whenever I needed. I sincerely thank Professor Mirja Hirvensalo, a member of the steering group of my PhD project, for your interest in and comments on my work. I also want to thank Research Director Katja Kokko at the Gerontology Research Center, and Director of the Department of Health Sciences, Professor Ari Heinonen for giving me the opportunity to conduct this study in such a warm and inspiring working environment. Special gratitude goes to Professor Lasse Kannas, Dean of the Faculty of Sport and Health Sciences, and Professor Teppo Kröger, both of whom warmly encouraged me to apply for the master's program in Gerontology at University of Jyväskylä when we met in Taiwan. That was indeed a good advice; this journey has changed my life.

I want to express my sincere gratitude to the official reviewers of this dissertation, Associate Professor Bjørn Heine Strande and Research Director Harri Sievänen. I also want to thank Docent Sari Stenholm for agreeing to be my opponent in the public defense of this dissertation.

I want to thank my co-authors of the original publications for their contributions to this work: Anne Viljanen PhD, Milla Saajanaho PhD, Johanna Eronen PhD, and Markku Kauppinen MSc. Anne, thank you for always answering my questions and looking at my work from a different perspective. Milla and Johanna, I am happy to have been working in the same research project as PhD student with both of you. I especially enjoyed our common experiences in attending conferences and PhD symposiums. Markku, thank you very much for your statistical support, it is an important part of this work. I also want to thank Mr. Michael Freeman for language editing of the original papers as well as this dissertation.

I am grateful for the financial support that I have received during these years. This dissertation was financially supported by personal grants from the Juho Vainio Foundation, Helsinki, the University of Jyväskylä, and the Ministry of Education and Culture, Helsinki. The LISPE project is funded by the Academy of Finland, Helsinki (future of living and housing program ASU-LIVE; grant number 255403), and the Ministry of Education and Culture. The SCAMOB project was funded by the City of Jyväskylä, Ministry of Education, Helsinki, and the Ministry of Social Affairs and Health, Helsinki.

These past years would not have been the same without dear friends and colleagues in GEREC. Thank you for making our work place so alive and warm, for letting me into this group, for practicing Finnish with me, and for making me laugh. I really appreciate the open and sincere atmosphere in our work place: we celebrate together when someone published an article or succeeded in a grant application; we also share together the stress when facing uncertain situations. I have really enjoyed working and being with all of you!

I want to thank all my dear friends (in Finland, back at home, or wherever you are) for your support and friendship through these years. Especially during my first two years of study in Jyväskylä, your company helped me through the long winter.

Finally, I want to thank my dearest family and dedicate this dissertation to you. Thank you, mum and dad, for your endless and unconditional love, for your encouragements and support during my decisions in life, and for showing me how to be kind to others. I am grateful for the love from my grandparents and appreciate the years when my grandmother lived with us. She has taken great care of me since my childhood and has taught me valuable things in life. I believe these affectionate feelings toward my grandparents have subconsciously spurred me to study Gerontology. I would like to thank my brother, Han-Tang, and my sister, Cherry, for their love and company since my childhood. You two have been, and always will be my best buddies. I have been truly fortunate and blessed to be able to start my own family during these busy years of PhD studies. For this, I deeply thank my loving and caring husband, Chengcong, for his dedication to our family. To our dear son Song-Pu, thank you for coming into the world, you have brought so much happiness into our lives and have inspired us to work harder for a better tomorrow.

Jyväskylä, December, 2016
Li-Tang Tsai 蔡立棠

FIGURES

FIGURE 1 International Classification of Functioning, Disability and Health. 23
FIGURE 2 The conceptual model of physical activity walking and life-space mobility with the definitions used in the present study. 25
FIGURE 3 Analytical framework of the study. 27
FIGURE 4 Flow chart of the LISPE-project used in Studies I, II, and III. 30
FIGURE 5 Trajectory of life-space mobility score grouped according to tertiles of the physical activity measures at baseline (n=165). 43

TABLES

TABLE 1 Summary of the study variables 35
TABLE 2 Participant characteristics in the LISPE and SCAMOB datasets used in the study 38
TABLE 3 Participant characteristics according to the ability to independently reach beyond the neighborhood (restricted vs. unrestricted life-space) (n=174). 40
TABLE 4 Linear regression analysis of objectively measured physical activity and life-space mobility (n=174) 40
TABLE 5 Baseline characteristics according to tertiles of the physical activity measures (n=165) 41
TABLE 6 Odds ratios for developing restriction in life-space mobility during the two-year follow-up (n=117) 44
TABLE 7 Reported reasons for going outdoors at least once per week (n=174) 45
TABLE 8 Average daily steps (thousands) according to life-space areas reached when going outdoors for the four most common reasons (n= 174) 46
TABLE 9 Participant characteristics according to amount of walking for errands and living arrangements 48
TABLE 10 Weekly distance and frequency of walking for errands by participants reporting environmental mobility barriers in the SCAMOB study 50
TABLE 11 Odds ratios for low and moderate amount of walking for errands with perceived environmental mobility barriers among those living alone and living with others 50
TABLE 12 Combined effect of living arrangements and perceived environmental mobility barriers on odds for a low and a moderate amount of walking for errands among older people 51

LIST OF ORIGINAL PUBLICATIONS

The dissertation is based on the following original articles, which will be referred to in the text by their Roman numerals.

I. Tsai L-T, Portegijs E, Rantakokko M, Viljanen A, Saajanaho M, Eronen J, Rantanen T. The association between objectively measured physical activity and life-space mobility among older people. Scandinavian Journal of Medicine & Science in Sports 2015; 25:e368-e373.

II. Tsai L-T, Rantakokko M, Rantanen T, Viljanen A, Kauppinen M, Portegijs E. Objectively measured physical activity and changes in life-space mobility among older people. Journals of Gerontology Series A: Medical Sciences 2016; 7(11):1466-1471.

III. Tsai L-T, Rantakokko M, Viljanen A, Saajanaho M, Eronen J, Rantanen T, Portegijs E. Associations between reasons to go outdoors and objectively measured walking activity in various life-space areas among older people. Journal of Aging and Physical Activity 2016; 24(1):85-91.

IV. Tsai L-T, Rantakokko M, Portegijs E, Viljanen A, Saajanaho M, Eronen J, Rantanen T. Environmental mobility barriers and walking for errands among older people who live alone vs. with others. BMC Public Health 2013; 13:1054.

ABBREVIATIONS

ADL	Activities of daily living
CAT	Categorical variable
CES-D	Center for Epidemiologic Studies Depression Scale
CI	Confidence Interval
GEE	Generalized Estimating Equations
FU1	Follow-up 1
FU2	Follow-up 2
HIGWER	High Amount of Walking for Errands
ICF	International Classification of Functioning, Disability and Health
IQR	Interquartile Range
LISPE	Life-Space Mobility in Old Age
LSA	Life-Space Assessment
LOWER	Low Amount of Walking for Errands
MICE	Multivariate Imputation by Chained Equations
MODWER	Moderate Amount of Walking for Errands
OR	Odds Ratio
P	P-value, indicator of statistical significance
SCAMOB	Screening and Counseling for Physical Activity and Mobility
SES	Socioeconomic status
SPPB	Short Physical Performance Battery
UAB	The University of Alabama at Birmingham
WHO	World Health Organization

CONTENTS

ABSTRACT
ACKNOWLEDGEMENTS
FIGURES AND TABLES
LISTS OF ORIGINAL PUBLICATIONS
ABBREVIATIONS
CONTENTS

1 INTRODUCTION 13

2 REVIEW OF THE LITERATURE 15
2.1 Mobility 15
2.2 Life-space mobility 16
2.3 Physical activity in old age 18
2.3.1 Assessment of physical activity 19
2.3.2 Walking - an important form of physical activity among older people 21
2.4 Study framework and the conceptual model 22

3 AIM OF THE STUDY 26

4 METHODS 28
4.1 Study design and participants 28
4.2 Ethics 31
4.3 Measurements 31
4.3.1 Life-space mobility 31
4.3.2 Accelerometer-assessed and physical activity 31
4.3.3 Reasons for going outdoors 32
4.3.4 Walking for errands 33
4.3.5 Environmental mobility barriers 34
4.3.6 Covariates 34
4.4 Statistical methods 36

5 RESULTS 38
5.1 Characteristics of participants 38
5.2 Step counts, physical activity and life-space mobility (Study I and II) 39
5.3 Reasons for going outdoors in various life-space areas and objectively measured walking (Study III) 45
5.4 Environmental mobility barriers and walking for errands among older people living alone vs. with others (Study IV) 47

6 DISCUSSION 52
6.1 Physical activity and life-space mobility 52

6.2 Factors underlying walking activity in old age 54
6.3 Methodological considerations 57
6.4 Future directions 60

7 MAIN FINDINGS AND CONCLUSIONS 62

YHTEENVETO (FINNISH SUMMARY) 63

REFERENCES 64

ORIGINAL PUBLICATIONS

1 INTRODUCTION

Mobility refers to a person moving by him/herself from one place to another (Rantakokko, Mänty & Rantanen 2013) and is associated with autonomy, freedom and the possibility to make choices (Hjorthol 2013). Conceptually, mobility entails two dimensions: an individual's ability to move (e.g. by walking, driving, use of assistive devices and transportation) and the amount of movement (e.g. walk 2 km or climb a flight of stairs). For community-dwelling older people, mobility plays a key role in maintaining independence and active social participation (Satariano et al. 2012, Rantakokko, Mänty & Rantanen 2013). With increasing age, mobility tends to decline; however, the speed, extent, and course of mobility decline can vary greatly between individuals.

Life-space mobility describes the spatial areas an individual purposefully moves through in daily activities within a specific timeframe, taking into account the level of independence (e.g. need of personal assistance, assistive mobility devices, and use of transportation) (Baker, Bodner & Allman 2003, Barnes et al. 2007). The smallest life-space is within one's bedroom when an individual is practically homebound and the largest life-space extends to unlimited, desired destinations. Life-space mobility is the result of interaction between individual capability and environmental demand (Lawton & Nahemow 1973), and has the potential to reflect early signs of mobility decline and difficulty in social participation (Baker, Bodner & Allman 2003, Barnes et al. 2007). Older people with higher life-space mobility are better able to move freely outdoors and reach desired destinations safely. Higher frequency of moving outdoors correlates with more opportunities to engage in physical activity (Davis et al. 2011a) and better preservation of functional and cognitive capacity (Crowe et al. 2008, Shimada et al. 2010), which in turn could contribute to maintaining life-space mobility. From a psychosocial perspective, the ability to freely move through various life-space areas empowers an individual with a higher sense of autonomy, the feeling of having control over where, when, and how one wants to go. This sense of autonomy in mobility is the foundation of active social participation (Portegijs et al. 2014a) and can also pave the way to fulfilling personal goals in old age (Saajanaho et al. 2015).

Physical activity in old age refers to any bodily movement that results in energy expenditure in the context of daily, family, and community activities (Caspersen, Powell & Christenson 1985, World Health Organization 2010). Physical activity can be assessed by subjective (e.g. physical activity questionnaire and diary) and objective methods (e.g. accelerometer, heart rate monitor, and Global Positioning System (GPS)) (Strath et al. 2013). Typically, with increasing age, the total amount of physical activity declines, especially among persons over 65 (Evenson, Buchner & Morland 2012, Hansen et al. 2012, Jefferis et al. 2015). The results of longitudinal study on age-related changes in physical activity patterns among older men showed a significant decrease in moderate-to-vigorous physical activity and a significant increase in sedentary behavior over two years (Jefferis et al. 2015). For older people, physical activity is important for maintaining function and independent mobility; similarly, engaging in physical activity is more likely among individuals with better functional capacity (Brach et al. 2004, Lim & Taylor 2005, Simonsick et al. 2005). With a growing number of people living in their own homes in old age, there is an evident need for older people to become more physically active with activities that can be easily integrated into everyday life.

Physical activity may influence life-space mobility in at least two ways. First, by maintaining health and functioning (Pahor et al. 2014), physical activity helps to preserve the individual prerequisites for life-space mobility. Second, physical activity, especially walking, constitutes an important component of the life-space mobility assessment. Walking is a prerequisite for moving through the desired life-space areas independently (Collia, Sharp & Giesbrecht 2003, Satariano et al. 2012). Even when traveling by motorized vehicles, the physical capacity to walk at least short distances is required (e.g. to access the parking lot) (Viljanen et al. 2016).

It is worth noting that although physical activity, walking and life-space mobility correlate, they do not completely overlap. Physical activity can be accumulated even with minimal spatial movement (e.g., gardening, strengthening exercises, or jogging on a treadmill) whereas walking typically takes the individual to another location. Life-space mobility is an even broader concept, which encompasses all movements, including the use of compensation strategies and transportation. This study was conducted to investigate the relationship between walking, physical activity and life-space mobility among community-dwelling older people, a topic that has not been much studied thus far. Environmental mobility barriers, living arrangements and the life-space areas in which older people carry out their daily activities were studied as correlates of walking activity. How objectively measured physical activity predict changes in life-space mobility was also examined.

2 REVIEW OF THE LITERATURE

2.1 Mobility

Mobility is defined as the ability to move about, including transferring from a bed to a chair, walking for leisure or errands, driving and use of various means of transportation (Mollenkopf et al. 2004, Rantakokko, Mänty & Rantanen 2013). For community-dwelling older people, mobility plays a key role in maintaining independence. Leading forms of mobility for older people are walking and driving (Satariano et al. 2012). Conceptually, mobility comprises two dimensions: the "ability" dimension (what one can do) and the "movement" dimension (what one actually does). Mobility is usually assessed through performance-based measures or through self-report. Performance-based measures reflect an individual's upper limit in a specific mobility task (e.g., gait speed), whereas self-report measures reflect what and how an individual actually does in everyday life (e.g., difficulty in walking 2 km) (Rantakokko, Mänty & Rantanen 2013). The advantage of self-reports is that they provide subjective assessment of an individual's mobility in an environment relevant to the subject in question. However, they may also reflect environment-specific mobility challenges that are not comparable across different cultures or countries (Rantanen 2013). The advantage of performance-based measures is that they can be administered in a standardized environment and provide comparable results. However, the cost may be higher than self-reports and therefore more difficult to carry out. Overall, self-report and performance-based measures of mobility reflect different dimensions of mobility and should be used to complement each other.

Mobility reflects the result of interaction between personal competence and environmental demand (Lawton & Nahemow 1973). Mobility decline in old age is common; however, the speed, extent, and course of mobility decline varies greatly between individuals. Restrictions in mobility are typically caused by the interaction of multiple risk factors, both at the individual and environmental level (Webber, Porter & Menec 2010). It is well established that the prevalence of mobility disability increases with aging (Brault et al. 2009). For example, only 11.3% of adults aged 45 to 64 years reported difficulty in walking three blocks, whereas the corresponding proportion of adults aged 65 years and older was 31.7% (Brault et al. 2009). With an increasing number of older people living in their own homes until the late stage of life, the number of people whose mobility is confined to within their home is also expected to grow.

Satariano (2012) proposed four public health burdens resulting from limited or restricted mobility among older people. These burdens can be understood in the context of the ICF model (International Classification of Functioning, Disability and Health), (World Health Organization 2001). At the "body functions and structures" level, mobility limitation is independently associated with adverse health outcomes, such as obesity, diabetes, cancer, and depression (Simonsick et al. 2005, Lee & Buchner 2008). At the "activity" level, older adults with mobility limitation are also likely to have lower physical activity level and impaired balance. Consequently, risk and incidence of falls are also elevated (Mänty et al. 2009b). At the "participation" level, first, it is more difficult for older people with mobility limitation to reach shops and services, which may affect their health due to reduced possibility to gain access to fresh food and health services (including preventive health services). Second, restricted mobility may reduce older peoples' possibilities to make social contact with family and friends. Finally, older adults with mobility limitation are less able to actively participate in civic life, which has adverse effects both on themselves and their community.

From a public health perspective, it is important to optimize opportunities for older people to maintain their independence in mobility, and hence in social participation, for as long as possible (World Health Organization 2002). Older people most often go outdoors for the purposes of shopping, running daily errands and visiting friends, with shopping accounting for 30% to 40% of all trips (Davis et al. 2011a, Transport statistics 2014). Going outdoors into the neighborhood at least once a week is beneficial for maintaining physical function among frail older people (Shimada et al. 2010). For community-dwelling older people, the frequency of going outdoors predicts both the onset of and recovery from mobility disability (Fujita et al. 2006).

2.2 Life-space mobility

Before the term "life-space" was first used in the clinical gerontological literature (May, Nayak & Isaacs 1985), activity researchers had already investigated the relationships between personal competence, environmental demand and the spatial areas through which individuals move. For example, Lawton (1983) found that older people with higher function spent more time outside the home and engaging in interpersonal activities or recreation while older people with the least personal competence spent more time in their homes either resting or being cared of. Rowles and Ohta (1983) observed that older people with more sensory and motor deficits showed greater reliance on support located closer to home. Starting in the 1980s, life-space questionnaires have been developed as an instrument to capture the extent and frequency of mobility among older adults living at home (May, Nayak & Isaacs 1985) and in nursing homes (Tinetti & Ginter 1990). May et al. defined life-space as "the area through which the subject moved in each 24 hour period" with five concentric zones ranging from the bedroom, inside and outside the home to the area across a traffic-bearing street (May, Nayak & Isaacs 1985). More recent versions of the life-space questionnaire have covered a broader range of environmental regions (extending to the neighborhood, town and beyond) with the aim of characterizing the mobility patterns of community-dwelling older people (Stalvey et al. 1999, Baker, Bodner & Allman 2003).

In this study, life-space mobility was measured with the University of Alabama at Birmingham (UAB) Study of Aging Life-Space Assessment (LSA). The LSA allows assessment of the full range of mobility: starting from bed-ridden and dependent on another's assistance to being able to travel when, where, and how one wishes to go, safely and reliably (optimal mobility) (Satariano et al. 2012). With the elements of assistance and compensation strategies, life-space mobility captures the interaction between individual capacity and environmental demand more comprehensively (Lawton & Nahemow 1973) than the traditional measures of mobility (Baker, Bodner & Allman 2003, Allman et al. 2004, Peel et al. 2005).

In previous studies, life-space mobility has been shown to correlate with physical health, activities of daily living (Peel et al. 2005), and quality of life among community-dwelling older people (Baker, Bodner & Allman 2003, Rantakokko et al. 2013). Smaller life-space correlated with needs for transportation and less opportunities to socialize (Murata et al. 2006), whereas larger life-space was associated with active social participation (Barnes et al. 2007). Constriction of life-space mobility can be viewed as a behavioral adaption responding to inadequate physiologic reserve and environmental challenges. Older age, being female, more depressive symptoms, obesity, lower cognitive level, and disability in activities of daily living (ADL) are associated with smaller life-space mobility (Snih et al. 2012, Curcio et al. 2013). One advantage of LSA is that the measures are sensitive to change and can be used to identify individuals in an early stage of mobility decline, leaving room for intervention (Baker, Bodner & Allman 2003). For example, slightly constricted life-space predicted the development of ADL (activities of daily living) disability (Portegijs et al. 2016) while severely constricted life-space correlated with high risk for mortality (Xue et al. 2008). Lower life-space mobility score can also be used to identify older people at higher risk for nursing home admission and cognitive decline (Crowe et al. 2008, Sheppard et al. 2013). To date, relatively few studies have investigated the correlates of changes in life-space mobility over time. Among older people, decline in life-space mobility has been found to be associated with decline in quality of life (Rantakokko et al. 2015), hospitalization (Brown et al.

2009), unintentional weight loss (Ritchie et al. 2008), and the development of ADL disability (Portegijs et al. 2016).

2.3 Physical activity in old age

In Finland, older people report physical activity as their most important hobby and walking as the most popular form of physical activity. Other popular physical activities include home gymnastics, cycling, skiing, swimming, and gathering wild berries and mushrooms. Men and women are active in different kinds of physical activities: older men enjoy hunting and fishing more while older women more often attend guided exercises and dancing (Karvinen, Kalmari & Koivumäki 2012). A recent study using data from a nationally representative British birth cohort found that people in early old age most commonly engage in walking, swimming, floor exercises, and cycling as leisure-time physical activity (Martin et al. 2014).

The health benefits of regular physical activity include prevention of premature death and several chronic diseases: cardiovascular disease, diabetes, cancer, hypertension, obesity, depression and osteoporosis (Warburton, Nicol & Bredin 2006). Longitudinal studies showed that a higher level of physical activity as well as engaging in more diverse physical activities was associated with lower risk for dementia (Podewils et al. 2005, Larson et al. 2006, de Bruijn et al. 2013). Results from a randomized controlled trial showed that over a 2.6-year follow-up period, a structured, moderate-intensity physical activity program reduced major mobility disability among older adults who were at risk for disability (Pahor et al. 2014).

Physical activity is important for older people in the maintenance of function and independent mobility (Brach et al. 2004, Lim & Taylor 2005, Simonsick et al. 2005). Older people aged 65 and above are recommended by the WHO to engage in at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic physical activity (in bouts ≥ 10 minutes) per week. In addition, muscle-strengthening exercises should be done on 2 or more days per week. Those who cannot meet these recommendations due to poor health should nevertheless try to be as physically active as they can (World Health Organization 2010). Similar recommendations for physical activity in old age have been made in the US and Finland (Nelson et al. 2007, Karvinen, Kalmari & Koivumäki 2012). However, recent studies showed that a very low proportion of older people adhere to these recommendations. In Finland, around 20% of older people do not exercise regularly and under 10% of people aged 75 and above meet the physical activity recommendations; the corresponding proportion among community-dwelling older people aged 75-90 in the UK is around 10 to 15% (Koskinen, Lundqvist & Ristiluoma 2012, Jefferis et al. 2014). There is an apparent need to find feasible and effective physical activities that older adults can undertake in in daily life. One approach is encouraging older people to engage in a wide variety of physical activity and exercise routines, which can be integrated into their daily activities. For example, in strength training, a greater emphasis should be placed on functional movements such as squats and lunges, as these involve multi-directional movements similar to those people perform in their daily lives (Chodzko-Zajko 2014).

Older people with lower functional capacity are predisposed to physical inactivity. On the other hand, good balance, stronger lower limbs, and better performance in activities of daily living (ADL) have been observed among older people who are more physically active (Stessman et al. 2009, Cooper et al. 2015). Mobility plays a key role in the maintenance of an adequate physical activity level among older people (Satariano et al. 2012). Mobility limitations, such as difficulty of moving outdoors, make it challenging to travel to exercise facilities and may hinder the individual's willingness to engage in physical activity (Rasinaho et al. 2007). Making trips away from home as part of daily activities was associated with increased walking distance and time spent in moderate to vigorous physical activity (Davis et al. 2011a). Being able to move beyond one's neighborhood correlated with higher physical and cognitive function (Crowe et al. 2008, Shimada et al. 2010) and better life-space mobility correlated with higher amount of self-reported physical activity (Allman et al. 2004).

Among community-dwelling older people, opportunities for physical activity usually occur in the close vicinity of home (Glass & Balfour 2003). This makes home and neighborhood environment especially important for engaging in outdoor physical activity. Environmental barriers subjectively reported by older adults include poor transportation, discontinuous or uneven surfaces, noise, inadequate lighting, heavy traffic, lack of resting places, sloping terrain, long distances to services and adverse weather conditions (Wahl & Weisman 2003, Rantakokko et al. 2009). Among older people, environmental mobility barriers increase unmet physical activity need (the feeling that one has an inadequate level of physical activity) and fear of moving outdoors (Rantakokko et al. 2009, Rantakokko et al. 2010).

2.3.1 Assessment of physical activity

Both in research and clinical settings, reliable assessment of physical activity is crucial in furthering our understanding of its effect on health and in minimizing physical inactivity. The four dimensions of physical activity assessment generally used are (1) mode: e.g., walking, cycling, gardening, (2) frequency: number of sessions or bouts (e.g., ≥ 10 minutes) per day or per week, (3) duration: time of the physical activity during a specified timeframe, (4) Intensity: rate of energy expenditure (Strath et al. 2013). Physical activity-related energy expenditure derives from the body's oxygen consumption (1 liter of oxygen consumption ≈ 5 kcal of energy) (McArdle, Katch & Katch 2006). Quantifying units commonly used to measure physical activity-related energy expenditure include kilocalories, metabolic equivalent (MET) of the activity (resting level = 1 MET), and time spent engaged in specific intensities of physical activity (e.g., moderate-to-vigorous physical activity). Physical activity can be assessed using two broad categories of methods: subjective and objective. Subjective methods mainly rely on participant reports of their previous physical activity or records of their physical activity during a specific time frame, for example by using physical activity questionnaires and diaries/logs. Subjective methods of assessing physical activity vary in accordance with the domain of assessment (e.g., occupational, domestic, transportation, and leisure), mode of administration (i.e., self-reported or interview), target population (i.e., children, adults, older people), and the timeframe of recall. Objective methods of assessing physical activity include wearable monitors that measure one or more biosignals, including measures of energy expenditure (e.g., indirect calorimetry, the doubly labeled water method), physiological measures (e.g., heart rate monitoring), motion sensors (e.g., pedometers and accelerometers), and the geographical position of the individual (e.g., Global Positioning System (GPS)) (Strath et al. 2013).

Factors to consider when selecting a physical activity assessment method include the size of the population to be studied, the resources available (financial and personnel), the burden on the participants, data processing requirements, the estimated time frame of the study, and the need to provide immediate feedback to the participants (Strath et al. 2013). The strengths of subjective methods of physical activity assessment include low cost, ease of administration, and the acquisition of detailed information. However, among older populations, the use of subjective methods to capture the amount of habitual physical activity can be challenging, as older people often find this, especially low-intensity physical activity, difficult to recall (Washburn 2000), while reporting bias due to social desirability may also exist. In recent years, accelerometers have been shown to be a sensitive and feasible method of measuring physical activity among free-living older adults (Pruitt et al. 2008, Copeland & Esliger 2009). Compared to using subjective measures or pedometers to monitor physical activity, accelerometers generally show higher sensitivity, and have the advantage of differentiating between the intensity of physical activity and inactivity, i.e., sedentary behavior (Le Masurier & Tudor-Locke 2003). Most accelerometers measure movement along the vertical axis (uniaxial) with a piezoelectric acceleration sensor, which generates an output voltage signal in proportion to the acceleration detected. Movement can also be measured in multiple planes by mounting several sensor units together orthogonally to one another. For example, tri-axial accelerometers measure movements in the vertical, mediolateral, and anterior-posterior planes. Raw data measured by an accelerometer are typically output voltage signals of acceleration expressed as meters per second squared (m/s^2). After measurement, the raw data usually undergo analytical processing to be transformed into other units, e.g. counts per second, per minute, or per day. Accelerometer data can be further converted into meaningful physical activity outcomes (e.g. daily step counts, time spent walking, running, and different intensities of physical activity) and energy expenditure (e.g. metabolic equivalents, METs). The data transformation process is largely dependent on the default settings of the accelerometer, which vary between manufacturers and models (Chen & Bassett Jr 2005, Strath et al. 2013).

2.3.2 Walking - an important form of physical activity among older people

Walking can be viewed as one type of mobility and is assessed by physical capacity to perform a certain walking task (e.g., the ability to walk 2km). The amount of walking, in turn, is often used as a measure of physical activity (e.g., step counts, weekly frequency of walking and distance walked). In this study, walking is studied as a form of physical activity, and is assessed by both objective (accelerometer-measured step count) and subjective (self-reported walking for errands) methods.

Walking is inexpensive, easy to engage in, and requires no specialized equipment, making it one of the most popular and feasible form of physical activity among older people. Another advantage of walking as physical activity is that it can be easily integrated into the daily routine of community-dwelling older people, for example, in connection with shopping and running daily errands (Murtagh, Murphy & Boone-Heinonen 2010). Furthermore, habitual walking has been found to be associated with lower mortality rate and better cardiorespiratory fitness among older people (Hakim et al. 1998, Wong et al. 2003).

Individual factors

Individual factors related to walking in old age include health, functioning, psychological factors, and socioeconomic status (SES). Better health and functioning, especially lower limb function and balance, have been found to be associated with more walking among older people (Varma et al. 2014, Fox et al. 2015). Psychosocial factors such as loneliness and depression accounted in part for the associations found between two strong correlates of walking: perceived neighborhood environment and health (Wen, Hawkley & Cacioppo 2006), implying that psychosocial factors likely also affect walking. An individual's knowledge, motives, attitudes, and beliefs towards walking can also facilitate or impede the decision of going out for a walk (King 2001). For example, among older people, having exercise-related goals was associated with engaging in more physical activity (Saajanaho et al. 2014). SES represents a person's social status achieved through education, occupation, and income, and may thus reflect personal resources in society (Alwin & Wray 2005). Adults with low SES tend to walk more for transportation and less for recreation (Kruger et al. 2008). SES differences in walking likely emerge from disparity in health literacy and the physical environments of different neighborhood areas (Yang et al. 2012). It is worth noticing that interactions can occur between different factors; for example, one study found that the psychosocial correlates of leisure-time walking differed by SES (Janssen et al. 2010).

Environmental factors

Environmental factors related to walking in old age include living arrangements and the social and physical environment. A growing number of older people live alone in their own homes. With no other person to take care of their daily errands, older people living alone may need to go outdoors more often and thus may accumulate more daily steps (Simonsick, Guralnik & Fried 1999).

However, this phenomenon may partly be explained by the healthy survivor effect, as truly frail older people are less likely to be living alone in their own homes. An encouraging social environment with occasional formal or informal social support could motivate older people to walk more. For example, one study showed that counseling by a nurse and having a companion to walk with led to the initiation and maintenance of a home-based walking program (Dubbert et al. 2002). Compared to younger adults and children who travel regularly to school or work, older people tend to spend a greater amount of time closer to home in their neighborhood area. Therefore, environmental barriers and facilitators in the neighborhood area are likely to have a greater impact on the older people than on those in other age groups (Glass & Balfour 2003). In a review article on the urban built environment and mobility in older adults, the authors summarized three main domains of the built environment for which their health effect has been conceptualized: physical infrastructure, land use patterns, and urban design (Rosso, Auchincloss & Michael 2011).

The physical infrastructure may influence how easily an individual can get about in the neighborhood to desired destinations (e.g., street network, trails for jogging or biking). A higher amount of daily walking was observed among those living closer to walking paths and trails (Hall & McAuley 2010) and those living in an area where no motorized vehicles were allowed on Sundays and holidays (Gómez et al. 2010). Land use patterns refer to how residential, commercial, and industrial areas are distributed in the neighborhood. Density of land use varies across urban, suburban, and rural areas and can affect the walkability of the area. An earlier study found that older people make more trips on foot or by bike in neighborhoods when several amenities are within five minutes' walk from home (Davis et al. 2011a). The presence of shopping malls and overall retail destinations were also associated with more walking among older people (Michael et al. 2006, Nagel et al. 2008). Having access to services and mixed land use were positively related to walking for errands among older people (Shigematsu et al. 2009, Frank et al. 2010). Urban design (e.g., entrance characteristics, presence and condition of sidewalks, number and width of traffic lanes) have a direct impact on the attractiveness and safety of mobility (Rosso, Auchincloss & Michael 2011). Walking has been associated with the presence of safety measures for pedestrians, but not with the presence or condition of sidewalks in many studies. The associations between the presence of parks and walking are also inconsistent: some studies found positive associations between the two while others did not (Rosso, Auchincloss & Michael 2011).

2.4 Study framework and the conceptual model

International Classification of Functioning, Disability and Health (ICF)

The WHO's ICF model provides a framework for examining different factors relating to health, at both the individual and environmental levels. The ICF model addresses physical, psychological, social, and environment components of disability (World Health Organization 2001). The ICF model comprises 3 mutually interacting functional components: body functions & structure, activity, and participation. These 3 functional components in turn interrelate with the individual's health condition (disorder or disease) and under the influence of the contextual (environmental and personal) factors. The components of the ICF model are viewed as interactive and dynamic. Although not a tool for the measurement of disability, it allows for assessment of the degree of disability in individuals with varying health conditions. When the ICF model was being designed an important consideration was achieving a level of neutrality that would enable it to be used across different cultures, age groups and genders. When applied in a clinical context, the ICF model helps medical practitioners to identify different aspects of disability, rather than focusing solely on the diagnosis. In this study, the ICF model offers a theoretical link between activity, participation, and environment (Figure 1).

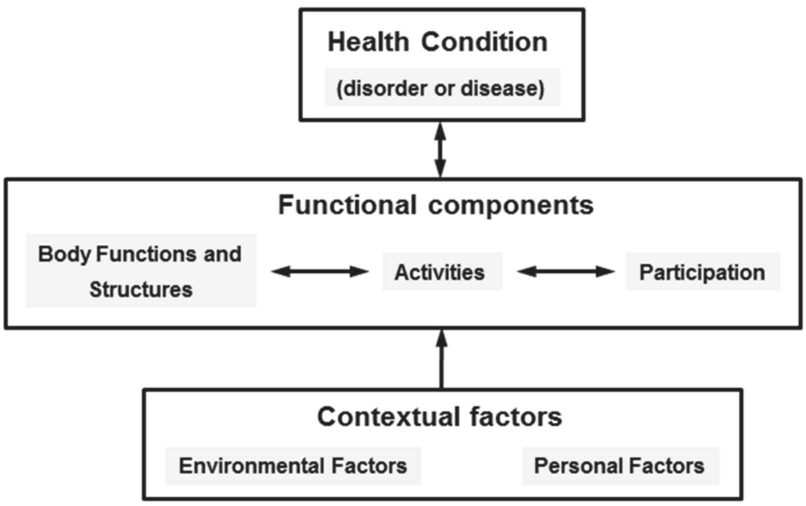


FIGURE 1 International Classification of Functioning, Disability and Health (Adopted from WHO 2011).

Ecological model of aging

The ecological model (also known as the "Competence-Press model") by Lawton and Nahemow (1973) describes the relationship and interaction between personal competence and environmental demand. Personal competence includes physical health, functional capacity, cognitive and sensory functions. Environmental demand refers to challenges deriving from both the physical and social environment. For any individual, the combination of personal competence and environmental demand defines the extent of person-environment fit (P-E fit). Optimal P-E fit is the point where an individual's competences are sufficient to meet the environmental demands while, at the same time, the environmental demands are sufficient to stimulate the individual to maintain his/her functional capacity. When an imbalance in P-E fit occurs, compensation strategies such as modification of the environment or proactive behaviors of the person can be used to regain the optimal state of functioning. The ecological model has been applied across various disciplines: in the biologic, social, behavioral, and health sciences (Satariano 2006). The ecological model has been widely used in environmental gerontology to investigate how well older people adapt and function in their surrounding environment (Wahl & Weisman 2003). Studies of physical activity among people in all age groups have also applied the ecological model (Bauman et al. 2012). In the context of promoting outdoor physical activity, such as walking among older people, both the individual (e.g., physical health, perceived competence) and environmental components (e.g., condition of the street, sidewalks, and crossings) need to be considered (Satariano & McAuley 2003, Rantanen 2013).

Both the ICF model (International Classification of Functioning, Disability and Health) and the ecological model of aging take account of interactions between environmental and personal factors as well as how they jointly affect different functional components. The main difference between these two models is that the ICF model is a broad framework encompassing health and human functioning generally, whereas the ecological model of aging focuses more on the individual and describes how the individual interacts with the surrounding environment.

The conceptual model

In this study, we examined the relationship between walking, physical activity and life-space mobility among older people. Figure 2 depicts the study's conceptual model.

Conceptually, while physical activity, walking and life-space mobility correlate with each other, they do not overlap completely. Walking can be depicted as the smallest circle within physical activity as it includes the least variety of movement (e.g., walking for errands, for exercise, or for leisure) and is studied here as one kind of physical activity. The mid-layer circle, physical activity, includes the much wider range of activities a person performs in the context of daily, family, and community life. Life-space mobility, the outer circle, is the broadest concept of the three, encompassing all movements, including the use of transportation. These three concepts, walking, physical activity and life-space mobility, can also be compared in terms of spatial movement. Physical activity can be accumulated even with minimal spatial movement (e.g., in strengthening exercise or jogging on a treadmill) whereas walking typically takes the individual to another location. Higher life-space mobility is usually achieved when the individual moves across larger spatial areas.

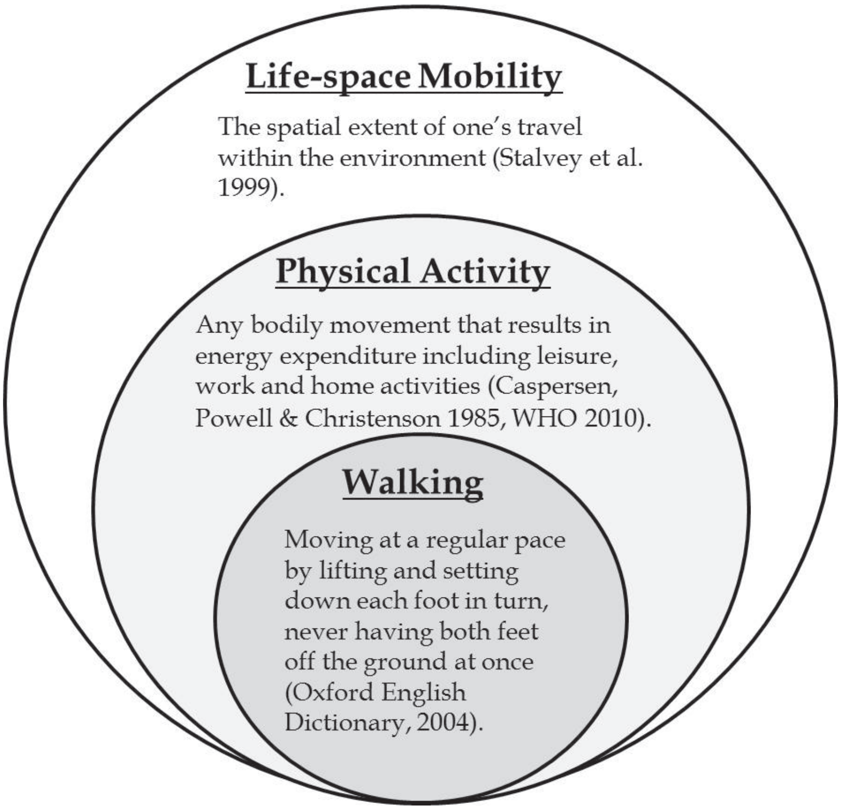


FIGURE 2 The conceptual model of physical activity (Caspersen, Powell & Christenson 1985, World Health Organization 2010) walking and life-space mobility with the definitions used in the present study.

3 AIM OF THE STUDY

The aim of the study was to investigate the relationship between walking, physical activity and life-space mobility among community-dwelling older people. Environmental barriers, living arrangements and the life-space areas where older people carry out their daily activities were studied as correlates of walking activity. The study also examined whether, and if so in what ways, the amount of objectively measured physical activity predicts changes in life-space mobility.

The research questions were:

1. What is the association between objectively measured physical activity and life-space mobility? (Study I)

2. Does the amount of objectively measured physical activity predict changes in life-space mobility among older people? (Study II)

3. What is the association between going outdoors for different reasons into various life-space areas and walking activity? (Study III)

4. How do environmental barriers affect walking for errands among older people who live alone compared to those who live with others? (Study IV)

The analytical frame of the study, which derives from the ICF model (World Health Organization 2001) is presented in Figure 3. The study variables used are listed under the corresponding categories (health condition, functional components, and contextual factors) in the model.

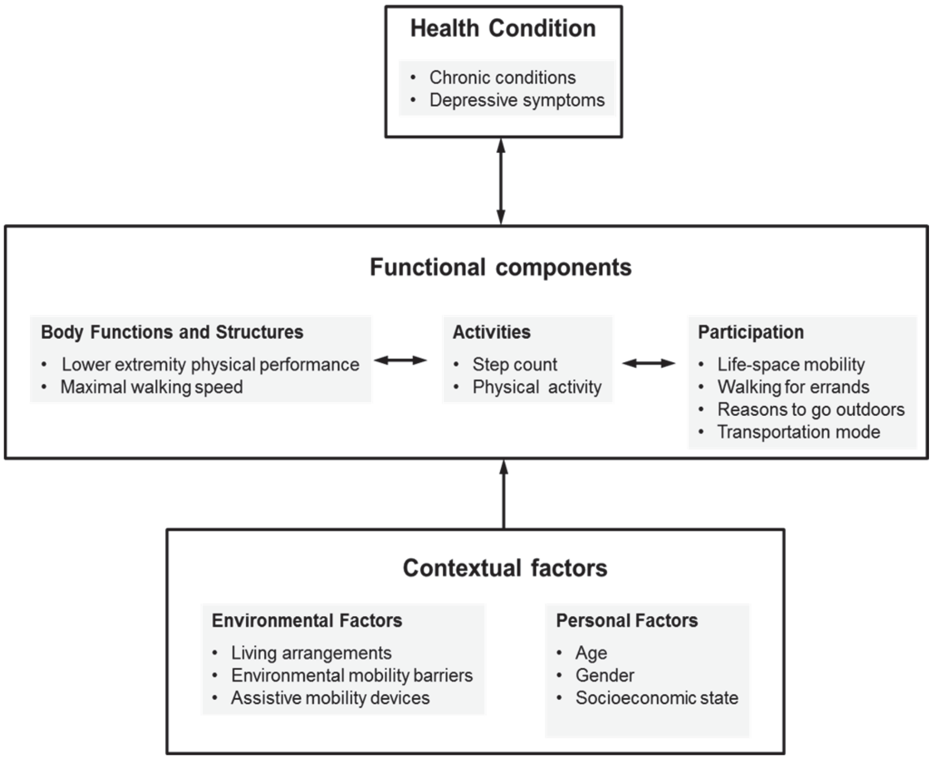


FIGURE 3 Analytical framework of the study; adopted from the ICF model (WHO, 2011); study variables in shaded text.

4 METHODS

4.1 Study design and participants

Data from two larger research projects, Life-Space Mobility in Old Age (LISPE) and Screening and Counseling for Physical Activity and Mobility in Older People (SCAMOB), were used in this study. Both projects focused on mobility and physical activity among older people, and thus their data were suitable for this study. In both projects, the participants were community-dwelling older people living in Jyväskylä or Muurame. Jyväskylä is a city situated in central Finland with a population of just over 141 500. Muurame is a neighboring municipality with a population of 9 800. The areas where the study was conducted are characterized by small hills and the concentration of most shops and services in the city/municipal center.

LISPE was a two-year prospective cohort study carried out in 2012-2014. The focus was on the outdoor mobility of older people. The participants were community-dwelling people aged 75 to 90 years, and, as in SCAMOB, living in Jyväskylä and Muurame. The LISPE participants were recruited from a sample drawn from the national population register (N=2 550). They were sent a letter describing the study and then received a telephone call inquiring about their willingness and eligibility to participate in the study. Those who were interested in participating, were able to communicate and were living independently in their own homes were included. Baseline assessments were conducted for 848 people and included face-to-face interviews and tests on physical performance and sensory functions conducted in the participants' homes and observation of the neighbourhood.

The LISPE *accelerometer substudy* included completing a 7-day activity diary and use of an accelerometer, in addition to the other baseline assessments (Rantanen et al. 2012). Accelerometers were available during the period from March 26th to June 15th, 2012. Of the participants interviewed during that period (n=461), 190 agreed to take part in the accelerometer substudy (Rantanen et al. 2012). Telephone follow-up interviews were conducted one (FU1) and two years (FU2) after the baseline assessment to study changes in life-space mobility.

Participants who died during the two-year follow-up period were excluded from the longitudinal analyses (n=9). This study utilized cross-sectional and longitudinal data from the LISPE accelerometer substudy. A flow chart describing Studies I, II, and III is presented in Figure 4.

The SCAMOB project (2003-2005) was a population-based two-year randomized controlled trial on the effectiveness of individualized physical activity counseling among community-dwelling older people. The target population comprised people aged 75-81 who were able, at least, to move outdoors independently and were living in the Jyväskylä city center area (N=1 310). In accordance with the SCAMOB main goal, the inclusion criteria, set to recruit persons who would potentially benefit the most from physical activity counseling, were: (1) the ability to walk at least 0.5 km without assistance, (2) at most moderately physically active, (3) no memory impairment, (4) no medical contraindications for physical activity and (5) informed consent (Leinonen et al. 2007, Mänty et al. 2009a). After the initial screening, 727 people were interviewed in their homes at baseline. Of these, 657 subjects participated in the physical assessments and interviews conducted by a nurse in the study centre (focusing on mobility and underlying determinants) and formed the sample used in Study IV. The SCAMOB participants represented the mid-range of the older population in terms of functioning, as the most active and the most disabled individuals were excluded.

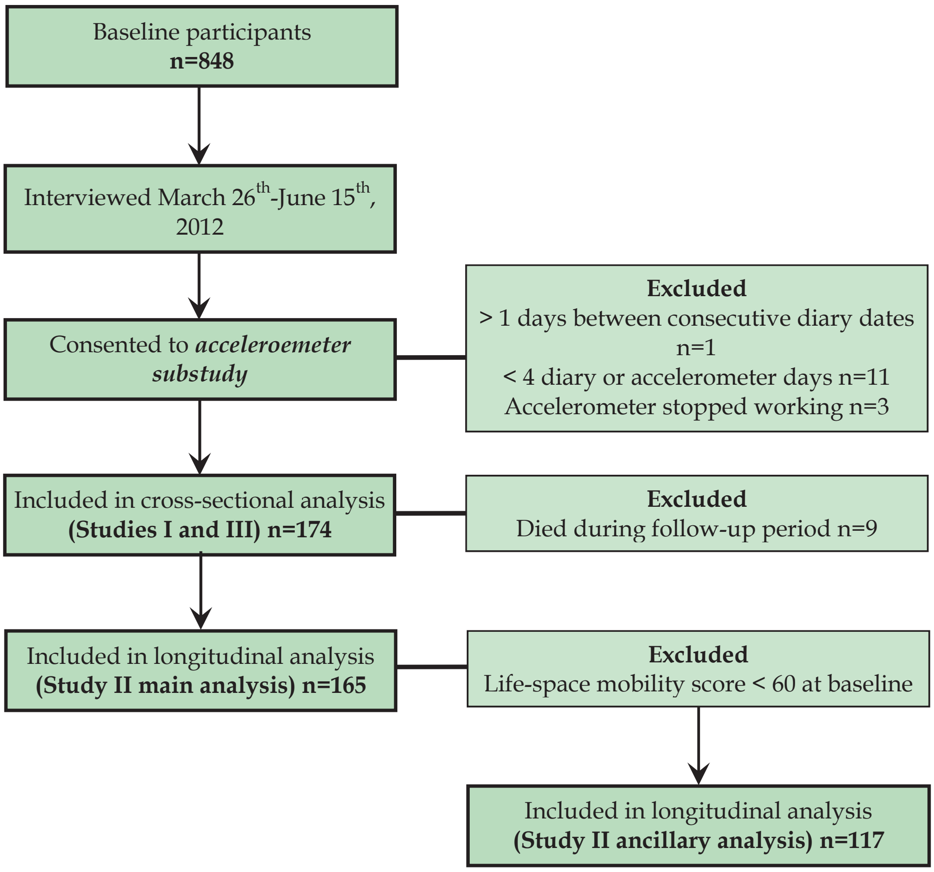


FIGURE 4 Flow chart of the LISPE-project used in Studies I, II, and III.

4.2 Ethics

SCAMOB and LISPE projects complied with the principles of good scientific conduct and good clinical practice in all aspects (Helsinki declaration). Permission for the SCAMOB project was granted by the Ethical Committee of Jyväskylä Central Hospital. The LISPE project was approved by the ethical committee of the University of Jyväskylä. In both the SCAMOB and LISPE projects, participants were informed about the research and they signed an informed consent.

4.3 Measurements

4.3.1 Life-space mobility

Life-space mobility was measured with the University of Alabama at Birmingham Study of Aging Life-Space Assessment (LSA) (Baker, Bodner & Allman 2003) in a face-to-face interview at baseline and in the telephone interviews at FU1 and FU2. Participants were asked how often they moved through the six life-space levels (bedroom, home, outside home, neighborhood, town, distant locations) during the past four weeks and with what kind of assistance. Two indicators of life-space mobility were used in this study: 1) Independent life-space (Study I), indicating the highest level of life-space attained without help from any devices or persons; 2) Life-space mobility score (Studies I, II), which was calculated taking into account distance, frequency and level of independence, with a higher score indicating higher life-space mobility (range 0-120). The reliability of the Finnish translation of life-space assessment was found to be acceptable (Portegijs et al. 2014b). A life-space mobility score of 60 or less indicates that the respondent is no longer able to move out of the neighborhood independently (without help from any devices or persons) (Sawyer & Allman 2010); these individuals are defined as having restriction in life-space mobility (Study II).

4.3.2 Accelerometer-assessed and physical activity

Step counts and different intensities of physical activity was measured by an accelerometer (Hookie, tri-axial, "AM20 Activity Meter", Hookie Technologies Ltd, Espoo, Finland), which was worn by the participants for 7 consecutive days following the LISPE project baseline home interview. The accelerometer was given with detailed instructions provided orally and on paper. Participants were asked to wear the accelerometer on the right hip during waking hours except when bathing, taking sauna or engaging in other water-related activities. They were encouraged to maintain their usual daily routines during the measurement period. Participants were given an activity diary (section 4.3.3) in which they recorded the times they put on and took off the accelerometer (accelerometer wear time) during the 7 days. Previously, self-reports of accelerometer wear time have been used as a criterion to identify an appropriate time window for automated estimates of wear/nonwear time (Hutto et al. 2013). After a week, the accelerometer was returned in a prepaid envelope by mail or if necessary, picked up from the participant's home.

The criteria for valid accelerometer data were set on the basis of earlier studies (Troiano et al. 2008, Matthews et al. 2012). When the diary reported at least 10 hours of accelerometer wear time the day in question was considered valid. Data on participants with less than 4 valid days or more than one day between consecutive diary dates were excluded (n=15: 3 accelerometers stopped working, 12 (6%) participants did not comply with the study protocol) and one accelerometer was lost in the mail (Rantanen et al. 2012).

We retrieved and handled the accelerometer data as recommended by Matthews et al. (2012). Default settings for thresholds and formulas for calculating step count and the amount of time spent on different activities set by the manufacturer were used (Hookie Technologies LTD). The Hookie AM 20 accelerometer has a sampling frequency of 100 Hz and a measurement range of ± 15 g_0 (gravity of the earth). The algorithms used to identify different patterns of physical activity have been developed scientifically (Parkka et al. 2007). The categories identified were walking (rhythmic moderate intensity, at least 2g), running (rhythmic higher intensity, at least 4g), and other activities (non-rhythmic moderate to higher intensity, at least 2.5g, e.g. jumps or squats). Due to the extremely low amount of recorded running activity (94% ≤ 30 seconds per day), running was merged with walking and other activities into the category "moderate activity". Also identified were the categories low activity (non-rhythmic low intensity, e.g. housework) and sedentary behavior (no activity detected for 5 seconds or longer, e.g. lying in bed, watching TV). The accelerometer has been found to be accurate and generates output comparable to that of the Actigraph GTX3 and Gulf coast X6-1A (Vähä - Ypyä et al. 2015). Day averages for each physical activity measure were calculated by dividing the total values by the number of valid days.

Finally, four physical activity measures were used in the analyses: daily step counts (Studies I, II, III) and time spent in moderate activity (Studies I, II), low activity (Studies I, II), and sedentary behavior (Studies I, II).

4.3.3 Reasons for going outdoors

In the LISPE project, along with an accelerometer, participants were given an activity diary, which they filled in for seven days. In the diary, for each day, the participant marked whether he/she moved in a specific life-space area (home, yard, neighborhood, town, beyond town). The life-space areas were adopted from the LSA (Baker, Bodner & Allman 2003). Description and examples for each life-space area were printed in the activity diary. Neighborhood is defined as the immediate vicinity, i.e., about 500 meters, from one's home. Activities within the neighborhood might include visiting a friend, shopping, walking the dog, strolling in the park, etc. The town and beyond is defined as more distant locations beyond the neighborhood. Activities in the town and beyond might include visits to the city center, a health center, or a relative in another city, a summer cottage, etc. For each life-space area from neighborhood to beyond town, an open-ended question on the reason for going outdoors was asked.

Reasons for going outdoors were grouped into 18 categories: 1) shopping, e.g., grocery shops, department stores; 2) running errands , e.g., bank, post office, pharmacy; 3) social visits; 4) walking for exercise; 5) other exercise, e.g. swimming, gym, ball games; 6) healthcare; 7) entertainment, e.g., movies, theater; eating out 8) personal services, e.g., hairdresser; 9) summer cottage; 10) regular hobbies, e.g. fishing (seasonal), singing/practicing musical instruments; 11) church-related activities; 12) cemetery; 13) helping others; 14) social gatherings; 15) participating in meetings; 16) working; 17) taking courses; and 18) miscellaneous. Weekly frequency (days) of going outdoors was calculated for each reason taking into account the number of days for which the information was available.

We focused our analysis on the four most common reasons for going outdoors, i.e, those reported as occurring at least once a week by more than 50% of the participants: shopping, walking for exercise, social visits, and running errands. Additionally, we categorized the responses into four mutually exclusive categories according to the life-space area reported: 1) activity reported only in the neighborhood, 2) activity reported only in the town or beyond, 3) activity reported in multiple life-space areas (both in the neighborhood and town or beyond), and 4) activity not reported in any life-space area.

4.3.4 Walking for errands

Frequency and distance of walking for errands per week (Study IV) were self-reported in the SCAMOB project with the question "How much do you walk outdoors (km) in the course of your daily activities, such as shopping, walking to the bus stop, etc.?" We categorized the amount of walking for errands into three levels (low, moderate, and high) based on the following criteria: a low amount of walking for errands was defined as walking no more than 1.5 km/week or at most walking for errands once a week; this level has been found to be associated with elevated mortality and functional capacity decline among older people (Hakim et al. 1998, Shimada et al. 2010). A high amount of walking for errands was defined according to the amount walked by those in the highest quartile of distance walked/week, which in our study population corresponded to more than 8.5 km/week. Distribution-based grouping criteria were used to identify those at the higher end of walking for errands; a similar method has been used in recent studies on walking for errands and neighborhood walkability (Menai et al. 2015, Hajna et al. 2015). Those who did not fall into the above two categories were defined as doing a moderate amount of walking for errands. The reliability for the categorization assessed with Kendall's tau-b was found to be good (r = 0.93) in a study among 29 older people interviewed two weeks apart.

4.3.5 Environmental mobility barriers

In the SCAMOB project, environmental mobility barriers were self-reported during an interview with standardized questions. Participants were asked whether a certain environmental mobility barrier hindered their possibility of moving outdoors independently (yes/no). Self-reported environmental mobility barriers were categorized into four groups: Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places) (Rantakokko et al. 2012) and Entrance (outdoor/indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting). For the data analysis, environmental mobility barriers were dichotomized according to their presence/absence (Study IV).

4.3.6 Covariates

Sociodemographic indicators included age (Studies I-IV), gender (Studies I-IV), perceived financial status (Study IV), and years of education (Study IV). *Physician-diagnosed chronic conditions* were self-reported by selecting from a list of the 22 most common chronic conditions and an additional open question (Study II) or first self-reported (physician-diagnosed chronic conditions lasting more than 3 months), and then further confirmed by the study nurse in the clinical examination (Study IV). *Daily accelerometer wear time* was calculated from the activity diary records (Hutto et al. 2013) (Studies II-IV). A validity check showed that the intra class correlation coefficient between accelerometer wear time determined by objective and diary methods was 0.96, indicating a near perfect correspondence. *Use of assistive mobility devices* was self-reported for seven listed assistive mobility devices (a cane, crutches, Nordic walking poles, a rollator, a kick sled, a wheelchair, a scooter) with the response options: a) no; b) yes, only indoors; c) yes, only outdoors, and d) yes, both indoors and outdoors. For the data analysis, we dichotomized the variable according to whether or not the respondent used an assistive mobility device (Study II). In Study IV, use of a cane (yes/no) was self-reported. *Depressive symptoms* were assessed on the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff 1977) (Study IV). *Maximal walking speed* was measured with a stopwatch over a distance of 10m in the study center corridor. Participants wore suitable footwear for walking and used a walking aid if needed (Study IV). *Lower-extremity physical function* was objectively assessed by the Finnish version of the Short Physical Performance Battery (SPPB) (Guralnik et al. 1994, Mänty et al. 2007). The battery consists of three tests that assess standing balance, walking speed over 2.44 meters, and sit-to-stand from a chair. Each task was rated from 0 to 4 points and a SPPB sum score was used in the data analysis (range 0-12) (Study III). *Transportation mode* was assessed with questions on how often the participants drove a car, travelled by car as a passenger, and used public transport, a taxi, or special transportation services. The response options were a) daily or almost daily; b) a few times a week; c) a few times a month; d) a few times a year; e) less than once a year; and f) never. For the data analysis, we dichotomized each variable according to whether or not each mode of transport was used by the respondent at least a few times a month (Study I).

The study variables are summarized in Table 1

TABLE 1 Summary of the study variables.

Variables	Study	Methods and reference
Life-space mobility		LSA; (Baker, Bodner & Allman 2003)
-Restricted/non-restricted independent life-space	I	
-Composite score	I, II	
Physical activity	I, II	Accelerometer (Hookie"AM20 Activity Meter")
-Moderate activity time		
-Low activity time		
-Sedentary behavior		
Walking activity		
-Step count	I, II, IIII	Accelerometer (Hookie"AM20 Activity Meter")
-Walking for errands	IV	Self-reported
Reasons for going outdoors	III	Self-reported in activity diary
Environmental mobility barriers	IV	Self-reported; (Rantakokko et al. 2012)
Covariates		
-Age (by year)	I-IV	National registers
-Gender	I-IV	National registers
-Perceived financial status (cat)	IV	Self-reported; (Pohjolainen et al. 1997)
-Years of education	IV	Self-reported; (Pohjolainen et al. 1997)
-Physician-diagnosed chronic conditions (number)	III, IV	Self-reported
-Accelerometer wear time	I, II, III	Activity diary records; (Hutto et al. 2013)
-Use of assistive mobility devices (cat)	III, IV	Self-reported
-Depressive symptoms (sum score)	IV	CES-D Score (Radloff 1977)
-Maximal walking speed (m/s)	IV	Measured in study-center; (Leinonen et al. 2007)
-Lower extremity physical per formance (sum score)	III	SPPB; (Guralnik et al. 1994)
-Transportation mode (cat)	I	Self-reported

LSA=University of Alabama at Birmingham Study of Aging Life-Space Assessment
CES-D=Center for Epidemiologic Studies Depression Scale
SPPB=Short Physical Performance Battery
cat=categorical variable

4.4 Statistical methods

Descriptive statistics
In studies I-IV, participants' characteristics were described using means and standard deviations (SD) or medians and interquartile ranges (IQRs) and percentages. Group differences were compared using *t*-test or one-way analysis of variance (ANOVA) for continuous variables and chi-square tests for categorical variables. Mann-Whitney U and Kruskal-Wallis H tests were used for the same purpose for non-normally distributed variables. All tests were performed two-tailed and the level of significance was set at $p<0.05$.

Linear regression models
In Study I, Linear regression models were used to study the association between the physical activity measures (average daily step count, moderate activity time, low activity time, and sedentary behavior) and life-space mobility. Model I was adjusted for age, gender, and accelerometer wear time; Model II was additionally adjusted for number of chronic conditions, years of education, independent driving, and use of taxi or special transportation services.

Generalized Linear Models
In Study III, generalized Linear Models were used to study group differences in average daily step counts according to the life-space areas reached for the four most common reasons for going outdoors. Log link transformation was used for the step counts due to its skewed distribution. The analyses estimating the step counts were adjusted for age, gender, and accelerometer wear time. Owing to the low number of people in some categories of the independent variables, we added number of chronic conditions, use of assistive mobility devices, use of a car, and SPPB score into the models one at a time to control for health differences (models not shown).

Multinominal regression analyses
In study IV, two sets of multinominal regression analyses were performed to identify the associations between environmental mobility barriers and walking for errands. In the first set of analysis, participants were stratified according to their living arrangements (living alone or living with others). For each environmental mobility barrier, the odds for a *low amount of walking for errands* and a *moderate amount of walking for errands* were computed separately with *high amount of walking for errands* used as the reference value.

In the second set of multinominal regression analysis, we included all the participants in the same analysis by creating a combined distribution for the independent variables. For living arrangements, and for each environmental mobility barrier, the following categorization was computed: (1) lives alone and reports a barrier, (2) lives with others and reports a barrier, (3) lives alone and does not report a barrier, and (4) lives with others and does not report a barrier. As the reference group, we used those who lived alone and did not report a barrier, as they had the lowest prevalence of *low amount of walking for errands*. The odds for *low amount of walking for errands* and *moderate amount of walking for errands* vs. *high amount of walking for errands* were calculated separately for each environmental mobility barrier by living status categorization.

All the multinominal regression analyses were adjusted for age and gender. Owing to the low number of people in some categories of the independent variables, we added walking speed, number of chronic conditions, and CES-D score into the models one at a time to control for health differences (models not shown). Men and women were included in the same models, as gender-stratified analyses produced practically identical results. Results are reported as odds ratios (OR) and 95% confidence intervals (CI).

Generalized estimating equations

In Study II, generalized estimating equations (GEE) models (Liang & Zeger 1986) were used to compare changes in life-space mobility over time between participants categorized according to tertiles of the physical activity measures (step count, moderate activity time, low activity time, and sedentary time) at baseline. Models were carried out separately for each physical activity measure and adjusted for age, gender, and accelerometer wear time. In the case of missing data on the outcome variable (change in life-space mobility), the multivariate imputation by chained equations (MICE) procedure in SPSS/GEE (version 20.0) was used in the GEE modeling (Azur et al. 2011) .

Logistic regression models

In Study IV, an ancillary analysis was carried out with logistic regression models to determine the odds ratio for developing restriction in life-space mobility during the two-year follow-up period (either at FU1 or FU2). For this purpose, we excluded participants whose life-space mobility score was below 60 at baseline (n=48). Hence, 117 participants were included in this ancillary analysis. For each physical activity measure, the odds for developing restriction in life-space mobility were computed separately for participants in the low and middle tertiles with those in the high tertile, which was used as the reference value. All models were adjusted for age, gender, and accelerometer wear time.

Data imputation

Missing data on accelerometer wear time (I, II, III) was imputed for people who had at most two days of missing recordings (n=15) by replacing the missing values with the average accelerometer wear time of the existing recordings of the individual in question. For one person, who had no data on accelerometer wear time, all values were replaced with the average accelerometer wear time of the whole study population.

The analyses for this study were made using SPSS version 20 (Armonk, NY: IBM Corp.).

5 RESULTS

5.1 Characteristics of participants

A total of 831 persons participated in the present study. Table 2 summarizes the baseline characteristics of the participants in the LISPE accelerometer substudy (Studies I, II, III) and SCAMOB (Study IV).

TABLE 2 Participant characteristics in the LISPE and SCAMOB datasets used in the study.

	Study I,II, III LISPE substudy (n= 174)		Study IV SCAMOB (n=657)	
	Median	IQR	Median	IQR
Age	79.7	3.0	77.0	7.1
Chronic conditions (number)	4.0	2.0	3.0	4.0
Education (years)	9.0	5.0	8.0	5.0
	%		%	
Women	64		74.9	
Living alone	54.6		58.0	
Use of assistive mobility devices	14.0		26.3	

5.2 Step counts, physical activity and life-space mobility (Study I and II)

In this study, both cross-sectional (Study I) and longitudinal (Study II) associations between step counts, physical activity, and life-space mobility were explored. The number of participants differed slightly between studies I and II as those who died during the two-year follow-up were excluded from Study II (n=9). Participants' baseline characteristics were examined according to the ability to reach areas beyond the neighborhood independently in Study I (restricted vs. unrestricted life-space; Table 3) and according to the tertiles of the accelerometer measures in Study II (Table 5). Participants wore the accelerometer for a median of 13.9 (2.3) hours/day and performed a median of 2249 (3309) daily steps, with 20.4 (30.3) minutes/day of moderate activity, 2.5 (1.1) hours/day of low activity time and 10.7 (1.9) hours/day of sedentary behavior. In Study I, the median life-space mobility score was 72.0 (26.0), and for 16% of participants independent life-space was restricted to the neighborhood level. Those with restricted independent life-space were older, had more chronic conditions, a lower life-space mobility score and a lower level of physical activity (Table 3). Cross-sectional associations between step counts, physical activity and life-space mobility were studied by linear regression analysis, which showed that daily steps, moderate activity time, and low activity time were positively associated with life-space mobility; sedentary time was inversely associated with life-space mobility (Table 4).

In Study II, the median life-space mobility score was 72.0 (27.0) at baseline, 71.5 (27.5) at FU1, and 66.0 (28.0) at FU2. Participants with higher step counts, more time spent in moderate or low activity, and less sedentary behavior were younger and had higher life-space mobility than those who were physically less active (Table 5). Longitudinal analysis were conducted with GEE models, which showed that the changes observed in the life-space mobility score over two years differed across the tertiles of step count and moderate activity time measured at baseline (Figure 5). Among the participants in the low tertiles of step count and moderate activity time, the decline in the life-space mobility score was significantly steeper over the two-year period (group by time interaction, low vs. high tertile p=0.005). The changes in the life-space mobility score over two years did not differ between the participants with different levels of low activity and sedentary behavior at baseline (group by time interaction, low vs. high tertile p=0.358, and 0.972, respectively).

TABLE 3 Participant characteristics according to the ability to independently reach beyond the neighborhood (restricted vs. unrestricted life-space) (n=174).

	Restricted (n=28)	Unrestricted (n=146)	
	Median (IQR)	Median (IQR)	P-value
Age (years)	83.4 (5.5)	78.9 (6.8)	0.001*
Chronic conditions (number)	6.0 (3.0)	4.0 (3.3)	0.001*
Education (years)	8.0 (4.0)	9.0 (5.0)	0.133*
Life-space mobility score	42.5 (18.8)	75.0 (23.0)	< 0.001†
Wear time (hours/day)	13.5 (1.8)	14.0 (2.2)	0.241†
Step (counts/day)	239 (2198)	2404 (2864)	< 0.001*
Moderate activity (minutes/day)	3.4 (18.6)	22.7 (26.0)	< 0.001*
Low activity (hours/day)	2.4 (0.9)	2.6 (1.1)	0.129*
Sedentary behavior (hours/day)	10.8 (1.6)	10.6 (2.2)	0.488†
	%	%	P-value
Female	82	60	0.032‡
Independent driving	21	48	0.012‡
Use of private car as a passenger	79	60	0.087‡
Use of public transportation	39	38	1.000‡
Use of taxi or special transportation services	50	12	< 0.001‡

IQR=Interquartile range
*Mann-Whitney U test for non-normally distributed variables; †t-test, and ‡Chi-square for normally distributed variables

TABLE 4 Linear regression analysis of objectively measured physical activity and life-space mobility (n=174).

Physical activity measures	Model I		Model II	
	β *	P-value	β *	P-value
Step count	0.249	< 0.001	0.199	0.004
Moderate activity	0.247	< 0.001	0.199	0.004
Low activity	0.218	0.002	0.172	0.010
Sedentary behavior	- 0.292	0.003	- 0.242	0.010

Models conducted separately for each physical activity measures

* β stands for standardized regression coefficient (regression coefficients obtained when all variables are standardized with a standard deviation of 1).

Model I: adjusted for age, gender, and accelerometer wear time

Model II: adjusted for age, gender, accelerometer wear time, number of chronic conditions, years of education, independent driving, and use of taxi or special transportation services

TABLE 5 Baseline characteristics according to tertiles of the physical activity measures (n=165*).

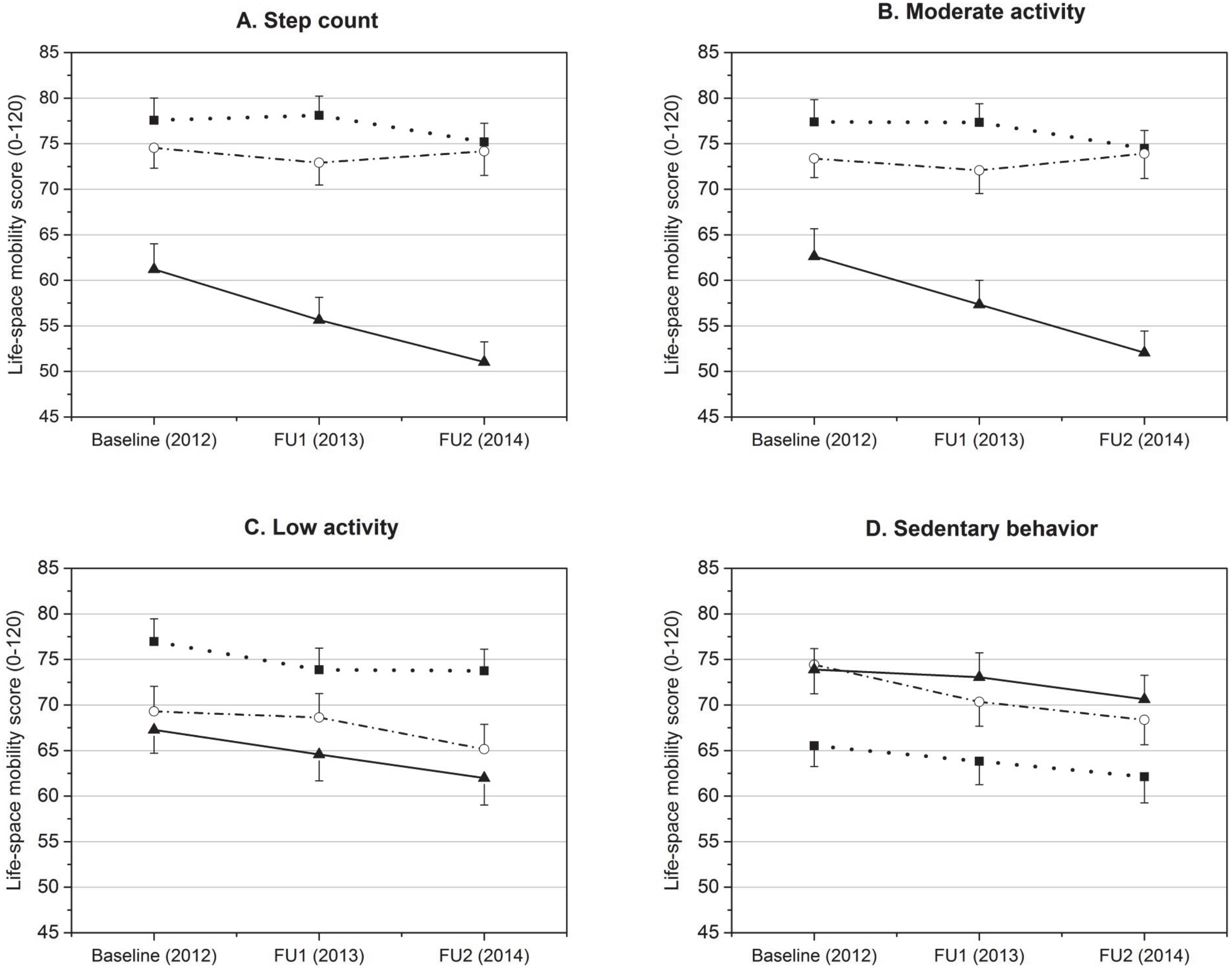
Physical activity measures [Median (IQR)/day)] Range: min-max	Tertile	Age (years)	Female	Life-space mobility score (0-120)	Accelerometer wear time (h/day)
		Median (IQR)	(%)	Median (IQR)	Median (IQR)
Step count [2300 (3293) steps] Range: 23-18176	High	78.0 (6.3)	64	82.0 (24.0)	14.2 (1.6)
	Middle	78.9 (6.3)	66	74.0 (20.0)	14.0 (2.4)
	Low	81.7 (7.6)	64	62.0 (24.5)	13.6 (2.2)
	p-value	0.005¶	0.974†	< 0.001‡	0.199‡
Moderate activity [20.7 (30.3) minutes] Range: 0.7-151.7	High	78.1 (6.3)	64	82.0 (24.0)	14.2 (1.6)
	Middle	78.9 (6.3)	66	74.0 (25.0)	14.0 (2.6)
	Low	81.7 (8.4)	64	62 (26.5)	13.6 (2.2)
	p-value	0.019¶	0.974†	< 0.001‡	0.221‡
Low activity [2.5 (1.1) hours] Range: 1.0-5.2	High	77.7 (5.9)	66	80.0 (26.0)	14.3 (1.4)
	Middle	80.8 (7.7)	67	68.0 (30.0)	13.8 (2.4)
	Low	79.6 (8.0)	60	66.0 (26.0)	13.5 (2.4)
	p-value	0.038¶	0.710†	0.022‡	0.074‡
Sedentary behavior [10.6 (1.9) hours] Range: 5.8-14.0	High	79.7 (6.4)	67	66.0 (26.0)	15.0 (1.4)
	Middle	78.5 (8.1)	67	74.0 (32.0)	13.9 (1.3)
	Low	80.6 (6.8)	58	74.0 (26.0)	12.4 (2.0)
	p-value	0.338¶	0.517†	0.037‡	< 0.001‡

* 9 participants died during 2-year follow-up and thus were excluded from the analysis

IQR=Interquartile range

¶Kruskal-Wallis H test, for non-normally distributed variables; †Chi-square, and ‡one-way ANOVA for normally distributed variables

NOTE: Minor differences in sample size and consequently statistical outcome can be seem between this dissertation summary and the original journal article attached for Study II, detailed explanation can be found on section 6.3 Methodological considerations



A. Step count
B. Moderate activity
C. Low activity
D. Sedentary behavior
Life-space mobility score (0-120)
85
80
75
70
65
60
55
50
45
Baseline (2012)
FU1 (2013)
FU2 (2014)

FIGURE 5 Trajectory of life-space mobility score (with standard error) grouped according to tertiles of the physical activity measures at baseline (n=165): A. stepcount B. moderate activity C. low activity D. sedentary behavior.
Models adjusted for age, gender, and accelerometer wear time

■ = High tertile; ○ = Middle tertile; ▲ = Low tertile

Group by time interaction:

Step count:	Low vs. High tertile, p=0.005; Middle vs. High tertile, p=0.422
Moderate activity:	Low vs. High tertile, p=0.005; Middle vs. High tertile, p=0.196
Low activity:	Low vs. High tertile, p=0.358; Middle vs. High tertile, p=0.491
Sedentary behavior:	Low vs. High tertile, p=0.972; Middle vs. High tertile, p=0.369

NOTE: Minor differences in sample size and consequently statistical outcome can be seem between this dissertation summary and the original journal article attached for Study II, detailed explanation can be found on section 6.3 Methodological considerations.

In Study II, an ancillary analysis was carried out with logistic regression models to determine the odds ratio for developing restriction in life-space mobility during the two-year follow-up period (either at FU1 or FU2). For this purpose, we excluded participants whose life-space mobility score was already below 60 at baseline (n=48). Hence, 117 participants were included in this ancillary analysis.

The odds for developing restriction in life-space mobility over two years were more than six-fold for participants in the low tertiles of step counts and moderate activity compared to those in the high tertiles at baseline (Table 6). Being in the low tertile of low activity and high tertile of sedentary behavior were not associated with the odds for developing restriction in life-space mobility over two years.

TABLE 6 Odds ratios for developing restriction in life-space mobility during the two-year follow-up (n=117*)

Objectively measured physical activity	Low vs. high tertile		Middle vs. high tertile	
	OR	95% CI	OR	95% CI
Step count	6.96	1.90-25.47	1.85	0.56-6.11
Moderate activity	6.10	1.73-21.57	1.35	0.42-4.35
Low activity	0.94	0.32-2.81	0.53	0.16-1.71
Sedentary behavior	0.50	0.12-2.01	0.43	0.12-1.56

* 48 participants, who had a life-space mobility score below 60 at baseline, were excluded
OR=Odds ratio, CI=Confidence interval

Logistic regression adjusted for age, gender, and accelerometer wear time
NOTE: Minor differences in sample size and consequently statistical outcome can be seem between this dissertation summary and the original journal article attached for Study II, detailed explanation can be found on section 6.3 Methodological considerations.

5.3 Reasons for going outdoors in various life-space areas and objectively measured walking (Study III)

Table 7 presents reasons for going outdoors at least once per week among those who participated in the LISPE project accelerometer substudy. The most common reasons for going outdoors were shopping, walking for exercise, social visits, and running errands.

TABLE 7 Reported reasons for going outdoors at least once per week (n=174).

Reasons for going outdoors	n	%	Maximal reported frequency (days)
Shopping	150	86	7
Walking for exercise	117	67	7
Social visits	96	55	6
Running errands	88	51	5
Miscellaneous	77	44	6
Healthcare	66	38	4
Entertainment	60	34	6
Other exercise	50	31	7
Cottage	25	14	7
Cemetery	22	13	2
Personal services	22	13	2
Church-related activities	18	10	4
Helping others	17	10	2
Social gatherings	12	7	2
Participating in meetings	11	6	1
Regular hobbies	9	5	3
Taking courses	3	2	2
Working	2	1	6

Average daily step counts according to the life-space areas reached for the four most common reasons for going outdoors are shown in Table 8. Overall, those who went outdoors to shop or to walk for exercise accumulated more daily steps than those who did not go outdoors for those reasons. People who shopped or walked for exercise in multiple life-space areas had the highest number of daily step counts. Those who shopped only in their neighborhood accumulated more daily steps than those who shopped only in town and beyond. The number of daily step counts did not differ between the life-space areas reached for social visits or while running daily errands. Adding number of chronic conditions, use of assistive mobility devices, use of a car, and the SPPB score into the models one at a time had no material influence on the results (data not shown).

TABLE 8 Average daily steps (thousands) according to life-space areas reached when going outdoors for the four most common reasons (n= 174).

Most common reasons for going outdoors	Life-space area where activity was reported: Only in neighborhood		Only in town and beyond		Multiple life-space areas (both in neighborhood and town or beyond)		Activity not reported at any life-space area		
	n (%)	Mean (95% CI)	n (%)	Mean (95% CI)	n (%)	Mean (95% CI)	n (%)	Mean (95% CI)	P-value
Shopping	20 (11)	3.0 (1.9-4.7)	64 (37)	2.3 (1.8-2.9)	66 (38)	3.5 (2.8-4.5) *	24 (14)	1.7 (1.1-2.6)	0.013
Walking for exercise	40 (23)	2.4 (1.8-3.2) *	43 (25)	3.6 (2.7-4.8) *	34 (19)	4.6 (3.3-6.3) *	57 (33)	1.3 (1.0-1.6)	< 0.001
Social visits	15 (8)	2.1 (1.3-3.5)	59 (34)	3.3 (2.6-4.3)	22 (13)	2.8 (1.9-4.3)	78 (45)	2.4 (1.9-3.0)	0.236
Running errands	14 (8)	4.1 (2.4-7.0)	66 (38)	2.7 (2.1-3.4)	8 (5)	3.9 (1.9-7.9)	86 (49)	2.5 (2.0-3.1)	0.311

CI=Confidence interval
* Significant difference from ”Activity not reported in any life-space area”
Statistical method: Generalized linear models (step count was log link transformed), adjusted for age, gender, and accelerometer wear time

5.4 Environmental mobility barriers and walking for errands among older people living alone vs. with others (Study IV)

The participants walked on average 4.0 ± 2.2 times and 6.4 ± 5.1 kilometers per week for errands (including shopping). Those who lived alone reported more environmental mobility barriers and walked more for errands than those living with others. Terrain was the most common environmental mobility barrier (33%), followed by Traffic (21%), Entrance (20%) and Distances (18%) (Table 9). Mean weekly distance and frequency of walking for errands differed among individuals reporting different environmental mobility barriers. The presence of distance-related environmental mobility barriers was associated with a low amount of walking for errands (Table 10).

When stratified according to living arrangements, the presence of an environmental mobility barrier generally increased the odds for a *low amount of walking for errands* among people living alone, although not all the associations reached statistical significance. For those living alone and those living with others, Distances consistently increased the odds for a *low amount of walking for errands* (Table 11).

In the final analyses, two sets of multinominal regression models were carried out to explore the combined effect of living arrangements and perceived environmental mobility barriers on odds for low and moderate amount of walking for errands. Four mutually exclusive environmental mobility barriers and amount of walking for errands categories were formed (lives alone and reports a barrier, lives with others and reports a barrier, lives alone and does not report a barrier, and lives with others and does not report a barrier) (Table 12). For each model, people living alone and not reporting the environmental mobility barrier were assigned as the reference group. In general, the presence of environmental mobility barriers increased the odds for a *low amount of walking for errands* (vs. *high amount of walking for errands*), with the majority of associations reaching statistical significance. For Traffic and Terrain, living with others and not reporting mobility barriers in these categories resulted in the highest odds for *low amount of walking for errands*. Reporting Distances as a mobility barrier increased the odds for a *low amount of walking for errands* almost eight-fold among those living alone and more than thirty-fold among those living with others compared with the reference group.

Adding the number of chronic conditions and CES-D score into the models one at a time had no material influence on the odds ratios. Adding walking speed into the models attenuated the odds to some extent, but the pattern of associations remained similar to those in the models adjusted for age and gender (data not shown).

TABLE 9 Participant characteristics according to amount of walking for errands and living arrangements.

	Low amount of walking for errands	Moderate amount of walking for errands	High amount of walking for errands	p-value*	Living alone	Living with others	p-value†
	n = 96	n = 381	n = 166		n = 381	n = 276	
	Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
Age (years)	77.5 ± 2.0	77.6 ± 2.0	77.6 ± 1.9	0.875	77.8 ± 2.0	77.3 ± 1.9	0.002
Education (years)	8.9 ± 4.2	9.1 ± 4.0	9.3 ± 4.8	0.723	8.6 ± 4.1	9.8 ± 4.3	0.001
Chronic conditions (number)	3.8 ± 2.3	3.0 ± 1.9	2.7 ± 1.8	< 0.001	3.1 ± 2.0	2.9 ± 1.9	0.051
Walking speed (m/s)	1.2 ± 0.4	1.3 ± 0.4	1.5 ± 0.3	< 0.001	1.3 ± 0.3	1.4 ± 0.4	< 0.001
CES-D (score)	11.2 ± 8.2	10.5 ± 7.5	8.8 ± 7.2	0.020	10.4 ± 7.6	9.9 ± 7.6	0.375
Walking for errands							
Distance/week	1.2 ± 1.0	4.6 ± 1.8	13.5 ± 4.5	< 0.001	6.6 ± 4.5	6.2 ± 5.9	0.456
Frequency/week	1.4 ± 1.9	3.8 ± 1.7	5.9 ± 1.5	< 0.001	4.3 ± 2.0	3.6 ± 2.3	< 0.001
	%	%	%		%	%	
Female	56	83	69	< 0.001	90	54	< 0.001
Living alone	30	65	59	< 0.001			
Use of a cane (in-doors or outdoors)	22	12	8	0.003	14	10	0.075
Perceived financial situation				0.604			< 0.001
Good or very good	40	41	45		35	50	
Very bad, bad or moderate	60	59	55		65	50	

Environmental mobility barriers							
Distances	31	18	8	< 0.001	21	15	0.049
Terrain	28	36	29	0.131	38	27	0.004
Traffic	19	22	19	0.542	22	20	0.534
Entrance	25	22	15	0.107	23	16	0.020
Amount of walking for errands							< 0.001
Low					8	24	
Moderate					85	66	
High					7	10	

*one-way ANOVA & Chi-square; † t-t est & Chi-square

SD = Standard Deviation

CES-D = Center for Epidemiologic Studies Depression Scale

LOWER = Low amount of walking for errands; MODWER = Moderate amount of walking for errands; HIGWER = High amount of walking for errands

NOTE: Environmental mobility barriers studied were Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places), and Entrance (outdoor stairs present, indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting). LOWER: ≤ 1.5 km/week or at most once a week; HIGWER: ≥ 8.5 km/week (highest quartile); MODWER: those who did not fall into LOWER or HIGWER categories.

TABLE 10 Weekly distance and frequency of walking for errands by participants reporting environmental mobility barriers in the SCAMOB study.

Environmental mobility barriers		Weekly distance (km) walked for errands (n=642)	p-value*	Weekly frequency of walking for errands (n=649)	p-value*
		Mean ± SD		Mean ± SD	
Traffic			0.675		0.179
	Yes	6.3 ± 5.0		4.2 ± 2.2	
	No	6.5 ± 5.2		3.9 ± 2.2	
Terrain			0.173		0.685
	Yes	6.0 ± 5.1		4.0 ± 2.1	
	No	6.6 ± 5.2		4.0 ± 2.2	
Distances			< 0.001		< 0.001
	Yes	4.5 ± 4.4		3.1 ± 1.9	
	No	6.8 ± 5.2		4.2 ± 2.2	
Entrance			0.120		0.469
	Yes	5.8 ± 5.1		3.9 ± 2.1	
	No	6.6 ± 5.1		4.0 ± 2.2	

* t-test
NOTE: Environmental mobility barriers studied were Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places), and Entrance (outdoor stairs present, indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting).

TABLE 11 Odds ratios* for low and moderate amount of walking for errands with perceived environmental mobility barriers among those living alone and living with others.

	Living alone		Living with others	
	LOWER (n = 29)	MODWER (n = 248)	LOWER (n = 67)	MODWER (n = 133)
Environmental mobility barrier	OR (95% Cl)	OR (95% Cl)	OR (95% Cl)	OR (95% Cl)
Traffic	1.95 (0.76-5.01)	1.32 (0.72-2.40)	0.64 (0.25-1.64)	1.25 (0.59-2.62)
Terrain	1.83 (0.78-4.31)	1.38 (0.83-2.29)	0.75 (0.34-1.66)	1.12 (0.58-2.17)
Distances	7.77 (2.94-20.56)	1.93 (0.96-3.91)	7.35 (2.00-26.99)	2.86 (0.80-10.22)
Entrance	8.76 (3.37-22.80)	2.13 (1.09-4.20)	0.59 (0.22-1.57)	0.75 (0.34-1.64)

OR=Odds ratio, CI=Confidence interval
LOWER = Low amount of walking for errands; MODWER = Moderate amount of walking for errands; HIGWER = High amount of walking for errands
*Adjusted for age and gender from multinominal logistic regression: LOWER and MODWER each compared to HIGWER. Models are computed separately for those living alone and those living with others.
Environmental mobility barriers studied were Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places), and Entrance (outdoor stairs present, indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting).
LOWER: ≤ 1.5 km/week or at most once a week; HIGWER: ≥ 8.5 km/week (highest quartile); MODWER: those who did not fall into LOWER or HIGWER categories.

TABLE 12 Combined effect of living arrangements and perceived environmental mobility barriers on odds for a low and a moderate amount of walking for errands among older people.

	LOWER vs. HIGWER			
	Living alone (n = 29)		Living with others (n = 67)	
Environmental mobility barrier	n	OR (95% Cl)	n	OR (95% Cl)
Traffic				
Yes	9	2.00 (0.78-5.10)	9	2.76 (1.00-7.59)
No	20	1.00	58	4.18 (2.16-8.08)
Terrain				
Yes	13	1.85 (0.79-4.33)	14	3.27 (1.33-8.07)
No	16	1.00	53	4.45 (2.19-9.03)
Distances				
Yes	14	7.55 (2.88-19.78)	16	30.45 (7.83-118.44)
No	15	1.00	51	4.18 (2.06-8.47)
Entrance				
Yes	16	8.82 (3.41-22.82)	8	3.98 (1.37-11.57)
No	13	1.00	59	6.97 (3.34-14.54)
	MODWER vs. HIGWER			
	Living alone (n = 248)		Living with others (n = 133)	
Traffic				
Yes	55	1.30 (0.71-2.35)	30	1.22 (0.59-2.54)
No	193	1.00	103	1.04 (0.66-1.64)
Terrain				
Yes	98	1.41 (0.85-2.33)	40	1.23 (0.64-2.34)
No	50	1.00	93	1.10 (0.68-1.79)
Distances				
Yes	51	1.98 (0.98-3.98)	17	2.78 (0.79-9.84)
No	197	1.00	116	1.03 (0.67-1.59)
Entrance				
Yes	59	2.15 (1.10-4.23)	23	0.94 (0.45-1.97)
No	189	1.00	110	1.21 (0.77-1.91)

R=Odds ratio, CI=Confidence interval

LOWER = Low amount of walking for errands; MODWER = Moderate amount of walking for errands; HIGWER = High amount of walking for errands

*Odds ratios adjusted for age and gender, calculated using multinomial logistic regression analyses comparing the odds of LOWER vs. HIGWER (upper panel) and MODWER vs. HIGWER (lower panel). Each environmental mobility barrier forms a separate model. Environmental mobility barriers studied were Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places), and Entrance (outdoor stairs present, indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting).

LOWER: ≤ 1.5 km/week or at most once a week; HIGWER: ≥ 8.5 km/week (highest quartile); MODWER: those who did not fall into LOWER or HIGWER categories.

6 DISCUSSION

The findings of the present study showed that life-space mobility correlated with objectively measured physical activity cross-sectionally. Over the two-year follow-up, a lower step count and lower amount of moderate-intensity physical activity at baseline preceded a significantly steeper decline in life-space mobility. The results demonstrate not only that older people actively participate in a variety of different daily activities, but also that the extent to which engagement in these activities translates into the amount of outdoor walking performed and the life-space areas reached varies widely according to the activity in question. Shopping and walking for exercise in multiple life-space areas, both closer and further away from home, was associated with accumulating more step counts. In connection with promoting walking activity, this study, by taking account of different factors both at the individual and environmental level, contributes new knowledge on the importance of integrating walking into the daily routines of community-dwelling older people (Murtagh, Murphy & Boone-Heinonen 2010). One interesting finding was that the associations between perceived environmental mobility barriers and walking for errands differed by living arrangements. Compared to those who live with others, older people who live alone reported a higher amount of walking for errands and perceived more environmental mobility barriers.

6.1 Physical activity and life-space mobility

This study is the first to show that larger life-space mobility is associated with objectively measured physical activity indicators: step count, moderate and low activity time, and sedentary time. In addition, our results extend current knowledge on the association between physical activity and life-space mobility among older people, which has thus far been based mainly on cross-sectional studies (Allman et al. 2004, Portegijs et al. 2015). The earlier studies on the association between life-space mobility and self-reported physical activity have yielded conflicting results (Allman et al. 2004, Barnes et al. 2007). Both the study by Allman et al. and the present study found a linear cross-sectional association between physical activity and life-space mobility. Barnes et al., in turn, found no association between life-space area and physical activity; this may be due to the use of different physical activity and life-space measures.

Life-space mobility can be used to identify individuals at an early stage of mobility decline, leaving room for intervention (Baker, Bodner & Allman 2003). The findings of Study II suggest that, among community-dwelling older people, individuals with a low step count and a low level of moderate-intensity physical activity could be at increased risk for developing restriction in life-space mobility. Having a life-space mobility score of 60 or less indicates that the respondent is no longer able to move out of the neighborhood independently and strongly correlates with a lower level of social participation and increased risk for mortality (Sawyer & Allman 2010). As the number of older people living in their own homes until a late stage of life increases, the number of people whose mobility is confined to within the home can also be expected to increase. Constriction of life-space can be viewed as a behavioral adaption responding to a combination of a decline in personal competence and increasing environmental challenges. At baseline, around 70% of the participants with restricted independent life-space (the largest life-space they were able to reach without help from any devices or persons was at the neighborhood level) had very low daily step counts and a low amount of daily moderate activity time, suggesting that they were highly sedentary and possibly almost homebound.

Central themes of active ageing include recognition of older people's potential for improved physical, social, and mental well-being as well as encouraging their social participation (World Health Organization 2002). By exploring the predictive value of physical activity for life-space mobility, this study explored the importance of physical activity in old age across a broader spectrum of mobility and participation. In Study II, we found that, over the two-year period, the extent of the decline in life-space mobility differed according to the step count and physical activity measures at baseline. A steeper decline in these measures was observed among older people in the low tertiles of step count and moderate activity when compared to those in the higher tertiles. These observed changes in the life-space mobility score were clinically meaningful (>10 points) (Baker, Bodner & Allman 2003, Portegijs et al. 2014b). There are plausible explanations for the association between low physical activity and decline in life-space mobility. Mobility limitation, poorer health, and low physical activity are often observed in the same individuals (Brown & Flood 2013). Previous cross-sectional studies have also identified associations between restrictions in life-space mobility and poorer physical health, including poorer lower limb function, which is a major risk factor for developing walking impairment (Allman, Sawyer & Roseman 2006, Bowling et al. 2013, Portegijs et al. 2014a). By maintaining health and functioning (Pahor et al. 2014), physical activity helps to preserve individual prerequisites for maintaining life-space mobility.

Among older people, opportunities for moderate-intensity physical activity mainly occur outside the home (Davis et al. 2011a). Individuals with a lower physical activity level are thus less likely to move outdoors, and are consequently at higher risk for losing functional and cognitive capacity (Crowe et al. 2008, Shimada et al. 2010), which may further accelerate the shrinking of their life-space area (Peel et al. 2005). Restricted life-space mobility correlates with reduced sense of autonomy, and may indicate withdrawal from meaningful activities in society (Sawyer & Allman 2010, Portegijs et al. 2014a), which in turn can lead to reduced physical activity, forming a vicious cycle.

Our participants spent only around 20% of their waking hours engaged in some level of physical activity (mostly low-intensity), and hence, unsurprisingly, the greatest amount of daily activity recorded was sedentary behavior. These results resemble those observed in other accelerometer-based studies among older people in western countries (Buman et al. 2010, Davis et al. 2011b, Hansen et al. 2012, Arnardottir et al. 2013, Husu, 2016). Sedentary behavior has been found to be associated with adverse health outcomes independent of an individual's level of physical activity (Tremblay et al. 2010). Among older people, a reduction in sedentary behavior achieved by replacing it with even light-intensity physical activity correlated with better physical health (Buman et al. 2010). Our findings show that time spent engaged in low activity and sedentary behaviors were not associated with changes in life-space mobility over time, despite the linear associations between these variables found in our cross-sectional analyses. It is possible that the most sedentary participants in these groups (people in the highest sedentary behavior tertile and the lowest low activity tertile) were approaching the life-space mobility threshold needed to maintain independent living, and thus were not showing further decline. It is also possible that by using compensation strategies, such as motorized transportation or personal help, the more sedentary older people were able to maintain their life-space mobility to the extent that no steeper decline occurred (Satariano et al. 2012). We have to bear in mind that the participants in this study were rather well-functioning older people living independently in their own homes. The effect of sedentariness on changes in life-space mobility is likely to be very different for frail older people or those living in institutions.

6.2 Factors underlying walking activity in old age

Reasons for going outdoors and the life-space areas reached

The present research findings indicate that older people go outdoors for a wide variety of reasons, among which shopping and walking for exercise in multiple life-space areas (both close to and further away from home) was associated with accumulating higher step counts. Larger life-space is associated with active social participation (Barnes et al. 2007). By supporting older peoples' opportunities to go outdoors into different life-space areas during the course of their daily activities, two key components of active aging, physical activity and social participation, could potentially be promoted at the same time.

Our results are in line with earlier findings that have identified shopping as the most common reason for older people to go outdoors (Davis et al. 2011a, Transport statistics 2014, Barnett et al. 2015). Shopping malls and retail destinations in general were associated with more time spent on walking among older people (Michael et al. 2006, Nagel et al. 2008). Additionally, we observed that older people who shopped only at places further away from home (town and beyond) walked less than those who only shopped close to home (i.e. in the immediate neighborhood) or those who shopped in multiple life-space areas (both in the neighborhood and in town and beyond). This is in line with earlier studies showing that older people are less likely to walk to shops located further away from home (Patterson & Chapman 2004, Millward, Spinney & Scott 2013, Barnett et al. 2015) .

For those who went shopping or walked for exercise, reaching multiple life-space areas (both the neighborhood and beyond town) during the course of these daily activities was associated with accumulating the highest daily step counts. A possible explanation is that while engaging in daily activities in the neighborhood may provide more opportunities for active transport (e.g. walking and cycling), (Sawyer & Allman 2010, Millward, Spinney & Scott 2013, Barnett et al. 2015), the ability and opportunity to reach larger life-space areas is also relevant to accumulating total physical activity (Allman et al. 2004). Among the wide variety of reasons for going outdoors reported by our participants, some contributed more to daily step counts than others did. When going outdoors, opportunities to accumulate step counts usually occur during traveling between home and the destination of interest. Some activities may require older people to walk more (e.g. shopping and walking for exercise), while other activities are more likely to happen further away from home (e.g. social visits and running errands), and alternatively provide the opportunity to reach larger life-space areas by motorized vehicles (Transport statistics 2014). Motorized transportation may decrease physical activity if it is used to replace active transportation. However, it may also increase physical activity by compensating for potential deficits in physical functioning and by providing older people with more opportunities to participate in a wider range of activities (Michael, Green & Farquhar 2006).

Living arrangements and perceived environmental mobility barriers

An important finding in this connection was that the association between self-reported environmental barriers and the amount of walking for errands differed by living arrangements. Compared to those living with others, older people who lived alone were less likely to report a *low amount of walking for errands* but were more likely to report environmental mobility barriers. In Study IV, we focused only on walking for errands, which encompassed all activities related to taking care of oneself in daily life (e.g., shopping for groceries, going to the post office, walking to the bus stop etc.). It is possible that when living alone, the need to run daily errands personally is greater than when living with others, which increases the need to go outdoors and reduces the odds for a *low amount of walking for errands*. In contrast, older people who live with others may rely more on their companions to run daily errands, which may increase the risk for a *low amount of walking for errands*. These findings are in line with earlier observations that walking outside the home was more common for older women living alone than those living with another person (Simonsick, Guralnik & Fried 1999) and that almost 40% of older people receive help from their spouse when their functional capacity declines (Wolff & Kasper 2006).

For older people, environmental features may be more closely associated with walking for errands than with walking for other purposes (e.g. for leisure) (Shigematsu et al. 2009, Shimura et al. 2012) because it is usually the last form of walking to be given up. Intuitively, we might think that compared to those living with others, older people who live alone and are still capable of running errands by themselves are in better health and thus would report fewer environmental mobility barriers. However, we observed quite the opposite: older people who lived alone were more likely to report environmental mobility barriers than those living with others. We speculate that, owing to their greater walking activity, those who live alone are more exposed to, and therefore better aware of, the environmental mobility barriers, which led to more reporting of them. As those living with others walk outdoors less, they are likely to have less experience of negotiating their immediate environment, which likely makes them less aware of the environmental mobility barriers that exist and results in their reporting fewer of them (Fänge & Iwarsson 2003).

Reporting Distances as a mobility barrier was consistently associated with a *low amount of walking for errands* regardless of whether the person lived alone or with others. It is possible that people reporting Distances as a mobility barrier live in places where their destinations of interest are too far away to walk to. Earlier studies have reported that older people who live closer to destinations of interest walk more for transportation (Nagel et al. 2008, Shigematsu et al. 2009, Barnett et al. 2015). It is also possible that perceiving Distances as a mobility barrier reflects poorer health and physical functioning. In support of this assumption, we observed that walking speed – an objective measure reflecting physical functioning – attenuated the odds ratios to some extent, although the results remained significant. However, adding the number of chronic conditions into the models had no material influence on the odds ratios. Consequently, we concluded that the association between reporting Distances as a mobility barrier and a *low amount of walking for errands* was not completely explained by poorer physical functioning.

One interesting finding was that Entrance as a mobility barrier was a stronger correlate of a *low amount of walking for errands* for people living alone than for those living with others. As Entrance barriers may be easily overcome with the help of another person, it is reasonable to assume that people living alone more often need to negotiate Entrance barriers by themselves. Consequently, for older people who live alone, Entrance barriers may literally prevent them from going outdoors independently.

Earlier studies on how different living arrangements affect older peoples' physical health and physical activity have produced mixed results. One study showed comparable physical activity levels for those living with a spouse and those living alone (Satariano, Haight & Tager 2002) while in another study older people living alone were more likely to report a lower physical activity level (Kharicha et al. 2007). A British cross-sectional study with a rather large sample (n=2641) of community-dwelling older adults showed that living alone was associated with functional impairment and higher risk for social isolation (Kharicha et al. 2007). However, prospective studies showed that older women living alone had less functional decline than, and a risk for poor health outcomes comparable to, those living with a spouse (Sarwari et al. 1998, Michael et al. 2001). We have not found any earlier studies that have addressed the simultaneous associations of environmental mobility barriers with living arrangements and physical activity. Very low walking activity has been identified as a risk factor for further functional decline (Simonsick et al. 2005). In the present study, people living alone walked more for errands when compared to those living with others, which may indicate a lower risk for further functional decline. However, this needs to be confirmed in future studies.

6.3 Methodological considerations

The present study is based on data from the SCAMOB and the LISPE projects, both comprising of a rather large sample of well-functioning community-dwelling older people. Walking activity was assessed by both subjective (SCAMOB) and objective (LISPE) methods.

In Studies I, II, and III, accelerometers were used to measure walking in terms of step counts and time spent engaged in physical activity at different intensities. As most accelerometers were developed to measure the physical activity patterns of younger individuals, their sensitivity when used among older people who walk at slower sp eeds or take shorter steps remains unclear (Pruitt et al. 2008, Davis et al. 2011b). Underestimation of the number of steps taken by older people is possible, especially among those who regularly use a walker or those whose gait pattern lacks a clear swing phase (i.e. the foot drags on the floor during the swing phase of the gait cycle). It is also possible that the accelerometer did not record all the steps taken indoors due to the reduced impact on the floor when people are not wearing shoes. However, it is unlikely that this would have a major influence on the physical activity indicators as distances indoors tend to be short. The daily step counts recorded in the present study were somewhat lower than those reported in earlier studies, probably due to older age and the higher proportion of women in our study (Harris et al. 2009, Davis et al. 2011b, Evenson, Buchner & Morland 2012).

In Study IV, walking was studied only in the context of running errands. It is possible, therefore, that other important forms of walking, such as walking for leisure or fitness, were not included in the analysis. However, it is unlikely that a meaningful proportion of people would have been wrongly assigned to the *low amount of walking for errands* category, as walking for errands is usually the last form of walking to be given up by community-dwelling older people. It should be noted that, owing to the design of the SCAMOB study, both the most active and the most disabled individuals were excluded. Therefore, the distribution of functioning and walking for errands in Study IV may be somewhat truncated and the actual strength of the associations is likely to be underestimated. Careful interpretation of the results is warranted due to small sample size in the stratified analysis, which is a limitation of Study IV.

It is important to note that in Study III shopping was analyzed as a separate category from "running errands" whereas in Study IV shopping was included under "running errands". This difference is largely attributable to the method of data collection and analysis. In Study III, a data-driven method was used to form the categories of the reasons for going outdoors reported in the activity diaries. In Study IV, the data drawn from the SCAMOB project had already been collected by asking the participants to report how much they walked during the course of their daily activities. In previous studies where similar analyses have been conducted, "Shopping" and "errands" are commonly used categories (Davis et al. 2011a, Barnett et al. 2015). In one study, the author combined shopping, visiting other commercial services, and going to the doctor all into the "errands" category (Barnett et al. 2015). As shopping has been identified as one of the most important reasons for older people to go outdoors, we decided to use it as a separate category (when data allowed) to gain a deeper understanding of how it associates with daily physical activity in different life-space areas.

Some of the variables were self-reported, such as environmental mobility barriers, accelerometer wear time and reasons for going outdoors, and thus may be subject to reporting bias. The environmental mobility barriers used were based on an earlier Finnish study (Heikkinen 1998), and can be considered relevant for mobility in this age group. In a Swedish study on housing accessibility, self-reports of environmental features were comparable to professional assessments among older people who had recent experiences of moving about in the environment (Fänge & Iwarsson 2003). In Study IV, all the participants were able to move outdoors independently, suggesting that they most probably had recent experiences of their environment and that their reports of environmental mobility barriers were likely to be reliable.

Determining the amount of wear/non-wear time is a crucial step in analyzing accelerometer data, as different methods could lead to different results. Objective or data-driven analysis is typically done by assigning a time window of consecutive 0 activity counts as non-wear time. So far, studies aimed at identifying an optimal time window to determine accelerometer wear/non-wear time have produced varied results, and very few of them have focused on older people. Additionally, these time windows also need to be paired with brand- and model-specific algorithms to produce an optimal classification of wear/non-wear time (Choi et al. 2012, Hutto et al. 2013). Although self-reports may be subject to reporting bias, the method also has its strengths. Self-reports of accelerometer wear time have been used as a criterion to identify an appropriate time window for automated estimates of wear/non-wear time (Hutto et al. 2013, Murphy 2009). Self-reported diary records were especially helpful in identifying intermittent non-wear time intervals, which are often misclassified by objective methods (Murphy 2009). Additionally, our validity check shows that the intra class correlation coefficient between accelerometer wear time determined by objective and diary methods was 0.96. Therefore, we believe that self-reported accelerometer wear time in the current study is a valid measure.

Our method of administrating the structured activity diary is comparable to those reported by others (Hutto et al. 2013). Participants were asked to complete daily a one-page activity log detailing the life-space areas visited and the activities performed. In addition, they also recorded the time they put on and took off the accelerometer and potential breaks during the day. The majority (98%) of the activity diaries were completed meticulously. Furthermore, cognitive impairment in our study population was not pronounced: the mean Mini-Mental State Examination (MMSE) score was 26.5 ± 2.6 and 87% of our study population scored ≥ 24 (range 0-30, with 24 as a commonly used cut point for indicating cognitive decline) (Folstein, Folstein & Fanjiang 2002). Therefore, we are confident of the integrity of the data collected by our activity diary.

Accelerometer wear time in the present study was self-reported from the activity diary. The imputation methods used were "person mean" and "population mean". Both of these methods are often advised in questionnaire manuals (Eekhout et al. 2014), and the sensitivity analyses did not reveal a marked effect of imputation (Portegijs et al. 2015). For Study II, minor differences between this dissertation summary and the original journal article attached to it were found in the size of study population and the statistical outcomes. The reason for this is that during the review process, we were recommended to exclude all days of accelerometer data with missing wear time from the analysis presented in the submitted manuscript (for 15 people, 1 or 2 days were deleted and 1 person with wear time missing for all days was excluded from the study). However, these changes did not alter the conclusions drawn from Study II, and therefore we decided to present the original data in this dissertation summary.

The participants of our prospective analyses represent a group of relatively well-functioning older people. Thus, the predictive value of objectively measured physical activity for changes in life-space mobility needs to be further confirmed in older people with more diverse physical function. However, the results of this study are highly relevant in the context of primary prevention: a low step count and less time spent in moderate physical activity can lead to a clinically meaningful decrease in life-space mobility among independent-living older adults.

The strengths of present study on topics related to walking, physical activity, and life-space mobility are the large, population-based sample and the incorporation of both a cross-sectional and a longitudinal study design. No previous study has focused specifically on how objectively measured physical activity predicts changes in life-space mobility. Moreover, we obtained accelerometer data for 88% of the participants over seven days, which is a suitable time span for capturing between-subject variance in physical activity among the elderly (Togo et al. 2008). The heterogeneity of our participants in age and gender increases the generalizability of our results among community-dwelling older people living independently in their own homes. It is worth noting that some of the associations found in this study are cross-sectional, and therefore do not allow conclusions to be drawn on their causality. Nevertheless, these cross-sectional results can serve as basis for future study hypotheses and directions.

6.4 Future directions

The present study has highlighted the susceptibility of older people, especially those who have difficulty moving independently beyond their immediate neighborhood, to an inactive lifestyle. The facilitation of independent mobility in and across different life-space levels may thus be important in promoting physical activity, particularly community walking, among older people. This is supported by another study from our research group, which found that older people are more physically active on days when they move through more distant life-space areas (Portegijs et al. 2015).

The shrinking of the life-space area can lead to being confined to one's home in old age, which in turn could give rise to a series of adverse health effects and withdrawal from social participation. A feasible way to promote walking and mobility among older people is by creating opportunities for them to engage in daily activities in different life-space areas. The results of this study suggest that shops and walkways both within the neighborhood and further away from residential areas could help older people to accumulate more daily steps. In future studies, categorization of reasons for going outdoors can be reconsidered in accordance with different study aims. For example, walking the dog could be a common form of physical activity for some older people that has not been studied here. Owing to the small number of reasons for going outdoors reported in several of the data-driven categories, it was not possible to investigate the relationship between walking and these specific reasons in this study. To do this requires more detailed longitudinal studies with larger sample size. For example, it would be useful to investigate simultaneously the relationship between the destinations of daily trips, the modes of transportation used and objectively measured physical activity. In addition, it would be interesting to study how, using Geographical Information Systems (GIS), objective features of the built environment, such as the proximity of community amenities, influence step counts in different residential areas.

This study showed that compared to those who live alone, older people living with others walked less for errands. It is natural that people take care of their companions in all aspects of life. However, our results imply that to prevent a growing disparity in physical activity levels between persons living together, a better way to offer help is to encourage or accompany the person with poorer physical function to go outdoors more instead of running all their errands on their behalf. The number of older people who live alone is projected to increase in the coming decades. Special attention should be given to barriers to and facilitators of mobility for older people who live alone because, as the functional threshold for them to remain independent-living is likely to be lower than it is for those who live with others. For example, this study identified entrance barriers as a major environmental mobility barrier for older people living alone; this could be an important future target for environmental modification and should also be taken into account during the construction of new housing. All in all, this topic warrants further study if we are to better understand how older people with different living arrangements might be encouraged to become more physically active.

Strategies for promoting better life-space mobility should employ a holistic view; stakeholders and researchers need to acknowledge that physical activity and walking activity in old age are influenced by multiple factors as well as the interaction between these factors. For example, older people may not necessarily want to go outdoors even when they are physically capable of doing so. When shops and services are too far away to be reached on foot, the problem could be lack of transportation or that the available transportation is too expensive. In such cases, personal mobility goals also need be considered (Saajanaho et al. 2015). It may be that the individual quite simply does not want to go anywhere without a companion or that he/she feels quite happy staying at home. In practice, it may be too challenging to take everything into account at once, but taking more than a single factor at a time into account would already be a good start. Qualitative research on perceived barriers to mobility and physical activity could help to identify potential factors to be tested in future quantitative studies.

7 MAIN FINDINGS AND CONCLUSIONS

The main findings and conclusions of this dissertation can be summarized as follows:

1. The majority of older people with restricted life-space mobility had a low level of physical activity.

2. Life-space mobility correlated positively with objectively measured step count and physical activity in the cross-sectional setting.

3. Over a two-year follow-up, a lower step count and lower amount of moderate-intensity physical activity at baseline preceded a significantly steeper decline in life-space mobility.

4. For older people, shopping and walking for exercise in multiple life-space areas, both closer and further away from home, were associated with accumulating more step counts.

5. Among older people, the associations of environmental mobility barriers and walking for errands differed between those living alone vs. living with others. Those living alone reported a higher amount of walking for errands while also perceived more environmental mobility barriers than those living with others.

YHTEENVETO (FINNISH SUMMARY)

Iäkkäiden ihmisten kävely, fyysinen aktiivisuus ja liikkuminen elinpiirissä

Mahdollisuus liikkua ulkona on keskeistä aktiivisen ikääntymisen edistämisessä. Elinpiirissä liikkuminen kuvastaa missä, milloin ja millaisen avun turvin yksilö saavuttaa haluamansa päämäärän. Kävely on tärkeä fyysisen aktiivisuuden muoto ikäännyttäessä ja se on myös edellytys sille, että henkilö pystyy suoriutumaan päivittäisistä toiminnoistaan itsenäisesti. Tässä tutkimuksessa selvitettiin poikittais- ja pitkittäisasetelmissa fyysisen aktiivisuuden ja elinpiirissä liikkumisen välisiä yhteyksiä. Tutkimuksessa selvitettiin myös miten kävely on yhteydessä asumisjärjestelyihin, ympäristössä oleviin liikkumisen esteisiin, sekä ulkona liikkumisen syihin eri elinpiirin tasoilla.

Tutkimuksessa käytettiin kahta aineistoa; Life-space mobility in old age (LISPE) projektin kiihtyvyysmittari-aineistoa (n=174, mediaani ikä 79.7) sekä Screening and Counselling for Physical Activity and Mobility in Older People (SCAMOB) - projektin aineistoa (n=657, mediaani ikä 77.0). Osallistujat olivat Keski-Suomen alueella kotona asuvia 75-90-vuotiaita ihmisiä. Fyysinen aktiivisuus ja askelten määrä mitattiin kiihtyvyysmittarilla (Hookie, tri-axial, “AM20 Activity Meter”) seitsemän päivän ajan. Kävely, ulkona liikkumisen syyt sekä ympäristön esteet olivat itseraportoituja. Elinpiirissä liikkuminen mitattiin University of Alabama at Birmingham Study of Aging Life-Space Assessment mittarin suomenkielisellä versiolla.

Tutkimus osoitti, että elinpiirissä liikkuminen oli yhteydessä objektiivisesti mitattuun fyysiseen aktiivisuuteen poikittaisasetelmassa. Alkutilanteessa mitattu vähäinen askelten määrä ja vähäinen kohtuukuormitteinen fyysinen aktiivisuus edelsi jyrkempää elinpiirin pienenemistä kahden vuoden seurannassa. Ostosten tekeminen sekä kävelylenkkeily olivat yhteydessä korkeampaan itseraportoituun kävelyaktiivisuuteen usealla elinpiirin tasolla, sekä lähellä että kaukana kotoa. Henkilöt, jotka asuivat yksin, kokivat enemmän liikkumisen esteitä ympäristössä ja liikkuivat ulkona pidempiä matkoja sekä useammin, kuin henkilöt, jotka asuivat jonkun toisen kanssa.

Yhteenvetona voidaan todeta, että ulkona kävely ja kohtuukuormitteinen fyysinen aktiivisuus auttavat säilyttämään laajemman elinpiirin, jonka tiedetään olevan yhteydessä hyvään elämänlaatuun. Kotona asuvien iäkkäiden ihmisten kävelyaktiivisuuden edistämisessä tulisi huomioida sekä yksilö- että ympäristötekijät. Kannustamalla ikääntyviä ihmisiä lähtemään ulos ja liikkumaan eri elinpiirin alueilla, kävelyn ja liikunnan määrää voidaan kerryttää hoitamalla päivittäisiä askareita.

Avainsanat: Elinpiirissä liikkuminen, kiihtyvyysmittari, fyysinen aktiivisuus, kävely, liikkuminen

REFERENCES

Allman, R. M., Baker, P. S., Maisiak, R. M., Sims, R. V. & Roseman, J. M. 2004. Racial similarities and differences in predictors of mobility change over eighteen months. Journal of General Internal Medicine 19 (11), 1118-1126.

Allman, R. M., Sawyer, P. & Roseman, J. M. 2006. The UAB Study of Aging: Background and insights into life-space mobility among older Americans in rural and urban settings. Aging Health 2 (3), 417-429.

Alwin, D. F. & Wray, L. A. 2005. A life-span developmental perspective on social status and health. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences 60 (Special Issue 2), S7-S14.

Aoyagi, Y. & Shephard, R. J. 2010. Habitual physical activity and health in the elderly: the Nakanojo Study. Geriatrics and Gerontology International 10 (s1), S236-S243.

Arnardottir, N. Y., Koster, A., Van Domelen, D. R., Brychta, R. J., Caserotti, P., Eiriksdottir, G., Sverrisdottir, J. E., Launer, L. J., Gudnason, V. & Johannsson, E. 2013. Objective measurements of daily physical activity patterns and sedentary behaviour in older adults: Age, Gene/Environment Susceptibility-Reykjavik Study. Age and Ageing 42 (2), 222-229.

Azur, M. J., Stuart, E. A., Frangakis, C. & Leaf, P. J. 2011. Multiple imputation by chained equations: what is it and how does it work? International Journal of Methods in Psychiatric Research 20 (1), 40-49.

Baker, P. S., Bodner, E. V. & Allman, R. M. 2003. Measuring Life-Space Mobility in Community-Dwelling Older Adults. Journal of the American Geriatrics Society 51 (11), 1610-1614.

Barnes, L. L., Wilson, R. S., Bienias, J. L., Mendes de Leon, Carlos F, Kim, H. N., Buchman, A. S. & Bennett, D. A. 2007. Correlates of life space in a volunteer cohort of older adults. Experimental Aging Research 33 (1), 77-93.

Barnett, A., Cerin, E., Cheung, M. & Chan, W. 2015. An In-Depth Pilot Study on Patterns, Destinations, and Purposes of Walking in Hong Kong Older Adults. Journal of Aging and Physical Activity 23 (1), 142-152.

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F. & Martin, B. W. 2012. Correlates of physical activity: why are some people physically active and others not? The Lancet 980 (9838), 258-271.

Bowling, C. B., Muntner, P., Sawyer, P., Sanders, P. W., Kutner, N., Kennedy, R. & Allman, R. M. 2013. Community Mobility Among Older Adults With Reduced Kidney Function: A Study of Life-Space. American Journal of Kidney Diseases 63 (3), 429-436.

Boyle, P. A., Buchman, A. S., Barnes, L. L., James, B. D. & Bennett, D. A. 2010. Association between life space and risk of mortality in advanced age. Journal of the American Geriatrics Society 58 (10), 1925-1930.

Brach, J. S., Simonsick, E. M., Kritchevsky, S., Yaffe, K. & Newman, A. B. 2004. The association between physical function and lifestyle activity and exercise in the health, aging and body composition study. Journal of the American Geriatrics Society 52 (4), 502-509.

Brault, M., Hootman, J., Helmick, C., Theis, K. & Armour, B. 2009. Prevalence and most common causes of disability among adults-United States, 2005. Morbidity and Mortality Weekly Report 58 (16), 421-426.

Brown, C. J. & Flood, K. L. 2013. Mobility limitation in the older patient: a clinical review. The Journal of the American Medical Association 310 (11), 1168-1177.

Brown, C. J., Roth, D. L., Allman, R. M., Sawyer, P., Ritchie, C. S. & Roseman, J. M. 2009. Trajectories of life-space mobility after hospitalization. Annals of Internal Medicine 150 (6), 372-378.

Buman, M. P., Hekler, E. B., Haskell, W. L., Pruitt, L., Conway, T. L., Cain, K. L., Sallis, J. F., Saelens, B. E., Frank, L. D. & King, A. C. 2010. Objective light-intensity physical activity associations with rated health in older adults. American Journal of Epidemiology 172 (10), 1155-1165.

Caspersen, C. J., Powell, K. E. & Christenson, G. M. 1985. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Reports 100 (2), 126-131.

Chen, K. Y. & Bassett Jr, D. R. 2005. The technology of accelerometry-based activity monitors: current and future. Medicine and Science in Sports and Exercise 37 (11), S490-S500.

Chodzko-Zajko, W. J. 2014. Exercise and physical activity for older adults. Kinesiology Review 3, 101-106.

Choi, L., Ward, S. C., Schnelle, J. F. & Buchowski, M. S. 2012. Assessment of wear/nonwear time classification algorithms for triaxial accelerometer. Medicine and Science in Sports and Exercise 44 (10), 2009-2016.

Collia, D. V., Sharp, J. & Giesbrecht, L. 2003. The 2001 National Household Travel Survey: A look into the travel patterns of older Americans. Journal of Safety Research 34 (4), 461-470.

Cooper, A. J., Simmons, R. K., Kuh, D., Brage, S. & Cooper, R. 2015. Physical activity, sedentary time and physical capability in early old age: British Birth Cohort Study. PloS one 10 (5), e0126465.

Copeland, J. L. & Esliger, D. W. 2009. Accelerometer assessment of physical activity in active, healthy older adults. Journal of Aging and Physical Activity 17 (1), 17-30.

Crowe, M., Andel, R., Wadley, V. G., Okonkwo, O. C., Sawyer, P. & Allman, R. M. 2008. Life-space and cognitive decline in a community-based sample of African American and Caucasian older adults. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 63 (11), 1241-1245.

Curcio, C., Alvarado, B. E., Gomez, F., Guerra, R., Guralnik, J. & Zunzunegui, M. V. 2013. Life-space assessment scale to assess mobility: validation in Latin American older women and men. Aging Clinical and Experimental Research 25 (5), 553-560.

Davis, M. G., Fox, K. R., Hillsdon, M., Coulson, J. C., Sharp, D. J., Stathi, A. & Thompson, J. L. 2011a. Getting out and about in older adults: the nature of daily trips and their association with objectively assessed physical activity.

International Journal of Behavioral Nutrition and Physical Activity 8 (1), 116-125.

Davis, M. G., Fox, K. R., Hillsdon, M., Sharp, D. J., Coulson, J. C. & Thompson, J. L. 2011b. Objectively measured physical activity in a diverse sample of older urban UK adults. Medicine and Science in Sports and Exercise 43 (4), 647-654.

de Bruijn, R. F., Schrijvers, E. M., de Groot, K. A., Witteman, J. C., Hofman, A., Franco, O. H., Koudstaal, P. J. & Ikram, M. A. 2013. The association between physical activity and dementia in an elderly population: the Rotterdam Study. European Journal of Epidemiology 28 (3), 277-283.

Dictionary, Concise Oxford English. "by Soanes C. and Stevenson A." 2004. Oxford University Press.

Dubbert, P. M., Cooper, K. M., Kirchner, K. A., Meydrech, E. F. & Bilbrew, D. 2002. Effects of nurse counseling on walking for exercise in elderly primary care patients. The journals of gerontology Series A: Biological Sciences and Medical Sciences 57 (11), M733-M740.

Eekhout, I., de Vet, H. C., Twisk, J. W., Brand, J. P., de Boer, M. R. & Heymans, M. W. 2014. Missing data in a multi-item instrument were best handled by multiple imputation at the item score level. Journal of Clinical Epidemiology 67 (3), 335-342.

Evenson, K. R., Buchner, D. M. & Morland, K. B. 2012. Objective measurement of physical activity and sedentary behavior among US adults aged 60 years or older. Preventing Chronic Disease 9, 110109.

Fänge, A. & Iwarsson, S. 2003. Accessibility and usability in housing: Construct validity and implications for research and practice. Disability & Rehabilitation 25 (23), 1316-1325.

Folstein, M. F., Folstein, S. E. & Fanjiang, G. 2002. Mini-mental state examination: Clinical guide. Psychological Assessment Resources Inc. Lutz, FL.

Fox, K. R., Ku, P. W., Hillsdon, M., Davis, M. G., Simmonds, B. A., Thompson, J. L., Stathi, A., Gray, S. F., Sharp, D. J. & Coulson, J. C. 2015. Objectively assessed physical activity and lower limb function and prospective associations with mortality and newly diagnosed disease in UK older adults: an OPAL four-year follow-up study. Age and Ageing 44 (2), 261-268.

Frank, L., Kerr, J., Rosenberg, D. & King, A. 2010. Healthy aging and where you live: community design relationships with physical activity and body weight in older Americans. Journal of Physical Activity & Health 7 (1), S82-S90.

Fujita, K., Fujiwara, Y., Chaves, P. H., Motohashi, Y. & Shinkai, S. 2006. Frequency of going outdoors as a good predictors for incident disability of physical function as well as disability recovery in community-dwelling older adults in rural Japan. Journal of Epidemiology 16 (6), 261-270.

Glass, T. A. & Balfour, J. L. 2003. Neighborhoods, aging, and functional limitations. In I. Kawachi & L. F. Berkman (Eds.) Neighborhoods and health.New York: Oxford University Press, 303-334.

Gómez, L. F., Parra, D. C., Buchner, D., Brownson, R. C., Sarmiento, O. L., Pinzón, J. D., Ardila, M., Moreno, J., Serrato, M. & Lobelo, F. 2010. Built environment attributes and walking patterns among the elderly population in Bogotá. American Journal of Preventive Medicine 38 (6), 592-599.

Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G., Scherr, P. A. & Wallace, R. B. 1994. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. Journal of Gerontology 49 (2), M85-M94.

Hajna, S., Ross, N. A., Joseph, L., Harper, S. & Dasgupta, K. 2015. Neighbourhood walkability, daily steps and utilitarian walking in Canadian adults. BMJ open 5 (11), e008964.

Hakim, A. A., Petrovitch, H., Burchfiel, C. M., Ross, G. W., Rodriguez, B. L., White, L. R., Yano, K., Curb, J. D. & Abbott, R. D. 1998. Effects of walking on mortality among nonsmoking retired men. New England Journal of Medicine 338 (2), 94-99.

Hall, K. S. & McAuley, E. 2010. Individual, social environmental and physical environmental barriers to achieving 10 000 steps per day among older women. Health Education Research 25 (3), 478-488.

Hansen, B. H., Kolle, E., Dyrstad, S. M., Holme, I. & Anderssen, S. A. 2012. Accelerometer-determined physical activity in adults and older people. Medicine and Science in Sports and Exercise 44 (2), 266-272.

Harris, T. J., Owen, C. G., Victor, C. R., Adams, R. & Cook, D. G. 2009. What factors are associated with physical activity in older people, assessed objectively by accelerometry? British Journal of Sports Medicine 43 (6), 442-450.

Heikkinen, E. 1998. Background, design, and methods of the Evergreen Project. Journal of Aging & Physical Activity 6, 106-120.

Hjorthol, R. 2013. Transport resources, mobility and unmet transport needs in old age. Ageing and Society 33 (07), 1190-1211.

Husu, P., Suni, J., Vähä-Ypyä, H., Sievänen, H., Tokola, K., Valkeinen, H., Mäki-Opas, T., Vasankari, T. 2016. Objectively measured sedentary behavior and physical activity in a sample of Finnish adults: a cross-sectional study. BMC Public Health 16: 920.

Hutto, B., Howard, V. J., Blair, S. N., Colabianchi, N., Vena, J. E., Rhodes, D. & Hooker, S. P. 2013. Identifying accelerometer nonwear and wear time in older adults. The International Journal of Behavioral Nutrition and Physical Activity 10 (1), 120.

Janssen, E., Sugiyama, T., Winkler, E., de Vries, H., te Poel, F. & Owen, N. 2010. Psychosocial correlates of leisure-time walking among Australian adults of lower and higher socio-economic status. Health Education Research 25 (2), 316-324.

Jefferis, B. J., Sartini, C., Lee, I., Choi, M., Amuzu, A., Gutierrez, C., Casas, J. P., Ash, S., Lennnon, L. T. & Wannamethee, S. G. 2014. Adherence to physical activity guidelines in older adults, using objectively measured physical activity in a population-based study. BMC Public Health 14 (1), 382.

Jefferis, B. J., Sartini, C., Ash, S., Lennon, L. T., Wannamethee, S. G., Lee, I. M. & Whincup, P. H. 2015. Trajectories of objectively measured physical activity in free-living older men. Medicine and Science in Sports and Exercise 47 (2), 343-349.

Karvinen, E., Kalmari, P. & Koivumäki, K. 2012. The National Policy Programme for Older People’s Physical Activity. Finnish Ministry of Education and Culture. Publications of the Ministry of Education and Culture 2012:17 .

Kharicha, K., Iliffe, S., Harari, D., Swift, C., Gillmann, G. & Stuck, A. E. 2007. Health risk appraisal in older people 1: are older people living alone an "at-risk" group? The British Journal of General Practice: the Journal of the Royal College of General Practitioners 57 (537), 271-276.

King, A. C. 2001. Interventions to promote physical activity by older adults. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 56 (suppl 2), 36-46.

Koskinen, S., Lundqvist, A. & Ristiluoma, N. 2012. Terveys, toimintakyky ja hyvinvointi Suomessa 2011. Tampere: Terveyden ja hyvinvoinnin laitos (THL). Terveyden ja Hyvinvoinnin Laitoksen Rapportteja 68.

Kruger, J., Ham, S. A., Berrigan, D. & Ballard-Barbash, R. 2008. Prevalence of transportation and leisure walking among US adults. Preventive Medicine 47 (3), 329-334.

Larson, E. B., Wang, L., Bowen, J. D., McCormick, W. C., Teri, L., Crane, P. & Kukull, W. 2006. Exercise is associated with reduced risk for incident dementia among persons 65 years of age and older. Annals of Internal Medicine 144 (2), 73-81.

Lawton, M. P. & Rowles, G. D. 1983. Time, space, and activity. In G. D. Rowles & R. J. Ohta (Eds.) Aging and milieu: Envirionmental perspectives on growing old. New York: Academic Press, 41-61.

Lawton, M. P. & Nahemow, L. 1973. Ecology and the aging process. In C. Eisdorfer & M. P. Lawton (Eds.) The psychology of adult development and aging.Washington DC: American Psychological Association, 619-674.

Le Masurier, G. U. Y. C. & Tudor-Locke, C. 2003. Comparison of pedometer and accelerometer accuracy under controlled conditions. Medicine and Science in Sports and Exercise 35 (5), 867-871.

Lee, I. M. & Buchner, D. M. 2008. The importance of walking to public health. Medicine and Science in Sports and Exercise 40 (7 Suppl), S512-S518.

Leinonen, R., Heikkinen, E., Hirvensalo, M., Lintunen, T., Rasinaho, M., Sakari-Rantala, R., Kallinen, M., Koski, J., Möttönen, S., Kannas, S., Huovinen, P. & Rantanen, T. 2007. Customer-oriented counseling for physical activity in older people: study protocol and selected baseline results of a randomized-controlled trial (ISRCTN 07330512). Scandinavian Journal of Medicine & Science in Sports 17 (2), 156-164.

Liang, K. & Zeger, S. L. 1986. Longitudinal data analysis using generalized linear models. Biometrika 73(1), 13-22.

Lim, K. & Taylor, L. 2005. Factors associated with physical activity among older people—a population-based study. Preventive Medicine 40 (1), 33-40.

Mänty, M., Heinonen, A., Leinonen, R., Törmäkangas, T., Hirvensalo, M., Kallinen, M., Sakari, R., von Bonsdorff, M. B., Heikkinen, E. & Rantanen, T. 2009a. Long-term Effect of Physical Activity Counseling on Mobility Limitation Among Older People: A Randomized Controlled Study. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 64 (1), 83-89.

Mänty, M., Sihvonen, S., Hulkko, T. & Lounamaa, A. 2007. Iäkkäiden henkilöiden kaatumistapaturmat. opas kaatumisten ja murtumien ehkäisyyn. (2nd edition) Kansanterveyslaitoksen Julkaisuja.

Mänty, M., Heinonen, A., Viljanen, A., Pajala, S., Koskenvuo, M., Kaprio, J. & Rantanen, T. 2009b. Outdoor and indoor falls as predictors of mobility limitation in older women. Age and Ageing 38 (6), 757-761.

Martin, K. R., Cooper, R., Harris, T. B., Brage, S., Hardy, R. & Kuh, D. 2014. Patterns of Leisure-Time Physical Activity Participation in a British Birth Cohort at Early Old Age. PloS one 9 (6), e98901.

Matthews, C. E., Hagstromer, M., Pober, D. M. & Bowles, H. R. 2012. Best practices for using physical activity monitors in population-based research. Medicine and science in sports and exercise 44 (1 Suppl 1), S68-S76.

May, D., Nayak, U. & Isaacs, B. 1985. The life-space diary: a measure of mobility in old people at home. Disability & Rehabilitation 7 (4), 182-186.

McArdle, W. D., Katch, F. I. & Katch, V. L. 2006. Essentials of exercise physiology. (3rd edition) Lippincott Williams & Wilkins.

Menai, M., Charreire, H., Feuillet, T., Salze, P., Weber, C., Enaux, C., Andreeva, V. A., Hercberg, S., Nazare, J. & Perchoux, C. 2015. Walking and cycling for commuting, leisure and errands: relations with individual characteristics and leisure-time physical activity in a cross-sectional survey (the ACTI-Cités project). International Journal of Behavioral Nutrition and Physical Activity 12 (1), 150.

Michael, Y., Beard, T., Choi, D., Farquhar, S. & Carlson, N. 2006. Measuring the influence of built neighborhood environments on walking in older adults. Journal of Aging and Physical Activity 14 (3), 302-312.

Michael, Y. L., Berkman, L. F., Colditz, G. A. & Kawachi, I. 2001. Living arrangements, social integration, and change in functional health status. American Journal of Epidemiology 153 (2), 123-131.

Michael, Y. L., Green, M. K. & Farquhar, S. A. 2006. Neighborhood design and active aging. Health & place 12 (4), 734-740.

Millward, H., Spinney, J. & Scott, D. 2013. Active-transport walking behavior: destinations, durations, distances. Journal of Transport Geography 28, 101-110.

Mollenkopf, H., Marcellini, F., Ruoppila, I. & Tacken, M. 2004. Ageing and outdoor mobility: A European study. The Netherlands: IOS Press.

Murata, C., Kondo, T., Tamakoshi, K., Yatsuya, H. & Toyoshima, H. 2006. Factors Associated With Life Space Among Community-Living Rural Elders in Japan. Public Health Nursing 23 (4), 324-331.
Murphy, S. L. 2009. Review of physical activity measurement using accelerometers in older adults: considerations for research design and conduct. Preventive medicine 48 (2), 108-114.
Murtagh, E. M., Murphy, M. H. & Boone-Heinonen, J. 2010. Walking–the first steps in cardiovascular disease prevention. Current opinion in cardiology 25 (5), 490-496.
Nagel, C. L., Carlson, N. E., Bosworth, M. & Michael, Y. L. 2008. The relation between neighborhood built environment and walking activity among older adults. American Journal of Epidemiology 168 (4), 461-468.
Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., Macera, C. A. & Castaneda-Sceppa, C. 2007. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Medicine and Science in Sports and Exercise 39 (8), 1435-1445.
Pahor, M., Guralnik, J. M., Ambrosius, W. T., Blair, S., Bonds, D. E., Church, T. S., Espeland, M. A., Fielding, R. A., Gill, T. M. & Groessl, E. J. 2014. Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial. The Journal of the American Medical Association 311 (23), 2387-2396.
Parkka, J., Ermes, M., Antila, K., van Gils, M., Manttari, A. & Nieminen, H. 2007. Estimating intensity of physical activity: a comparison of wearable accelerometer and gyro sensors and 3 sensor locations. Conference Proceedings of IEEE Engineering in Medicine and Biology Society, 1511-1514.
Patterson, P. K. & Chapman, N. J. 2004. Urban form and older residents' service use, walking, driving, quality of life, and neighborhood satisfaction. American Journal of Health Promotion 19 (1), 45-52.
Peel, C., Baker, P. S., Roth, D. L., Brown, C. J., Bodner, E. V. & Allman, R. M. 2005. Assessing mobility in older adults: the UAB Study of Aging Life-Space Assessment. Physical Therapy 85 (10), 1008-1019.
Podewils, L. J., Guallar, E., Kuller, L. H., Fried, L. P., Lopez, O. L., Carlson, M. & Lyketsos, C. G. 2005. Physical activity, APOE genotype, and dementia risk: findings from the Cardiovascular Health Cognition Study. American Journal of Epidemiology 161 (7), 639-651.
Pohjolainen, P., Heikkinen, E., Lyyra, A. L., Helin, S. & Tyrkko, K. 1997. Socio-economic status, health and life-style in two elderly cohorts in Jyvaskyla. Scandinavian Journal of Social Medicine. Supplementum 52 (Suppl.), 1-65.
Portegijs, E., Rantakokko, M., Mikkola, M., Viljanen, A. & Rantanen, T. 2014a. Physical performance, sense of autonomy in outdoor activities and life-space mobility in community-dwelling older people. Journal of the American Geriatrics Society 62 (4), 615-621.

Portegijs, E., Iwarsson, S., Rantakokko, M., Viljanen, A. & Rantanen, T. 2014b. Life-space mobility assessment in older people in Finland; Measurement properties in winter and spring. BMC Research Notes 7 (1), 323.

Portegijs, E., Rantakokko, M., Viljanen, A., Sipilä, S. & Rantanen, T. 2016. Identification of older people at risk of ADL disability using the life-space assessment: a longitudinal cohort study. Journal of the American Medical Directors Association 17 (5), 410-414.

Portegijs, E., Tsai, L., Rantanen, T. & Rantakokko, M. 2015. Moving through Life-Space Areas and Objectively Measured Physical Activity of Older People. PloS one 10 (8), e0135308.

Pruitt, L. A., Glynn, N. W., King, A. C., Guralnik, J. M., Aiken, E. K., Miller, G. & Haskell, W. L. 2008. Use of accelerometry to measure physical activity in older adults at risk for mobility disability. Journal of Aging and Physical Activity 16 (4), 416-434.

Radloff, L. S. 1977. The CES-D scale: A self-reported scale for research in the general population. Applied Psychol Measurement 1, 385-401.

Rantakokko, M., Iwarsson, S., Hirvensalo, M., Leinonen, R., Heikkinen, E. & Rantanen, T. 2010. Unmet physical activity need in old age. Journal of the American Geriatrics Society 58 (4), 707-712.

Rantakokko, M., Mänty, M., Iwarsson, S., Törmäkangas, T., Leinonen, R., Heikkinen, E. & Rantanen, T. 2009. Fear of moving outdoors and development of outdoor walking difficulty in older people. Journal of the American Geriatrics Society 57 (4), 634-640.

Rantakokko, M., Iwarsson, S., Mänty, M., Leinonen, R. & Rantanen, T. 2012. Perceived barriers in the outdoor environment and development of walking difficulties in older people. Age and Ageing 41 (1), 118-121.

Rantakokko, M., Mänty, M. & Rantanen, T. 2013. Mobility decline in old age. Exercise and Sport Sciences Reviews 41 (1), 19-25.

Rantakokko, M., Portegijs, E., Viljanen, A., Iwarsson, S., Kauppinen, M. & Rantanen, T. 2015. Changes in life-space mobility and quality of life among community-dwelling older people: a 2-year follow-up study. Quality of Life Research , 1-9.

Rantakokko, M., Portegijs, E., Viljanen, A., Iwarsson, S. & Rantanen, T. 2013. Life-Space Mobility and Quality of Life in Community-Dwelling Older People. Journal of the American Geriatrics Society 61 (10), 1830-1832.

Rantanen, T. 2013. Promoting mobility in older people. Journal of Preventive Medicine and Public Health 46 (Suppl 1), S50-S54.

Rantanen, T., Portegijs, E., Viljanen, A., Eronen, J., Saajanaho, M., Tsai, L., Kauppinen, M., Palonen, E., Sipilä, S. & Iwarsson, S. 2012. Individual and environmental factors underlying life space of older people–study protocol and design of a cohort study on life-space mobility in old age (LISPE). BMC Public Health 12 (1), 1018.

Rasinaho, M., Hirvensalo, M., Leinonen, R., Lintunen, T. & Rantanen, T. 2007. Motives for and barriers to physical activity among older adults with mobility limitations. Journal of Aging and Physical Activity 15 (1), 90-102.

Ritchie, C. S., Locher, J. L., Roth, D. L., McVie, T., Sawyer, P. & Allman, R. 2008. Unintentional weight loss predicts decline in activities of daily living function and life-space mobility over 4 years among community-dwelling older adults. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 63 (1), 67-75.

Rosso, A. L., Auchincloss, A. H. & Michael, Y. L. 2011. The urban built environment and mobility in older adults: a comprehensive review. Journal of Aging Research 2011, 816106.

Rowles, G. D. & Ohta, R. J. 1983. Aging and milieu: Environmental perspectives on growing old. New York: Academic Press.

Saajanaho, M., Rantakokko, M., Portegijs, E., Törmäkangas, T., Eronen, J., Tsai, L., Jylhä, M. & Rantanen, T. 2015. Personal goals and changes in life-space mobility among older people. Preventive Medicine 81, 163-167.

Saajanaho, M., Viljanen, A., Read, S., Rantakokko, M., Tsai, L., Kaprio, J., Jylhä, M. & Rantanen, T. 2014. Older women's personal goals and exercise activity: an 8-year follow-up. Journal of Aging & Physical Activity 22 (3), 386-392.

Sarwari, A., Fredman, L., Langenberg, P. & Magaziner, J. 1998. Prospective study on the relation between living arrangement and change in functional health status of elderly women. American Journal of Epidemiology 147 (4), 370-378.

Satariano, W. 2006. Aging, health, and the environment: an ecological model. In Epidemiology of Aging: An Ecological Approach. Jones & Bartlett Learning, 39-84.

Satariano, W. A., Haight, T. J. & Tager, I. B. 2002. Living arrangements and participation in leisure-time physical activities in an older population. Journal of Aging and Health 14 (4), 427-451.

Satariano, W. A., Guralnik, J. M., Jackson, R. J., Marottoli, R. A., Phelan, E. A. & Prohaska, T. R. 2012. Mobility and aging: New directions for public health action. American Journal of Public Health 102 (8), 1508-1515.

Satariano, W. A. & McAuley, E. 2003. Promoting physical activity among older adults: from ecology to the individual. American Journal of Preventive Medicine 25 (3), 184-192.

Sawyer, P. & Allman, R. M. 2010. Resilience in mobility in the context of chronic disease and aging: Cross-sectional and prospective findings from the University of Alabama at Birmingham (UAB) Study of Aging. In P. S. Fry & C. L. M. Keyes (Eds.) New York: Cambridge University Press, 310-339.

Sheppard, K. D., Sawyer, P., Ritchie, C. S., Allman, R. M. & Brown, C. J. 2013. Life-space mobility predicts nursing home admission over 6 years. Journal of Aging and Health 25 (6), 907-920.

Shigematsu, R., Sallis, J., Conway, T., Saelens, B., Frank, L., Cain, K., Chapman, J. & King, A. 2009. Age differences in the relation of perceived neighborhood environment to walking. Medicine Science in Sports Exercise 41 (2), 314-321.

Shimada, H., Ishizaki, T., Kato, M., Morimoto, A., Tamate, A., Uchiyama, Y. & Yasumura, S. 2010. How often and how far do frail elderly people need to go outdoors to maintain functional capacity? Archives of Gerontology and Geriatrics 50 (2), 140-146.

Shimura, H., Sugiyama, T., Winkler, E. & Owen, N. 2012. High neighborhood walkability mitigates declines in middle-to-older aged adults' walking for transport. Journal of Physical Activity & Health 9 (7), 1004-1008.

Simonsick, E. M., Guralnik, J. M., Volpato, S., Balfour, J. & Fried, L. P. 2005. Just get out the door! Importance of walking outside the home for maintaining mobility: findings from the women's health and aging study. Journal of the American Geriatrics Society 53 (2), 198-203.

Simonsick, E. M., Guralnik, J. M. & Fried, L. P. 1999. Who walks? Factors associated with walking behavior in disabled older women with and without self-reported walking difficulty. Journal of the American Geriatrics Society 47 (6), 672-680.

Snih, S. A., Peek, K. M., Sawyer, P., Markides, K. S., Allman, R. M. & Ottenbacher, K. J. 2012. Life-Space Mobility in Mexican Americans Aged 75 and Older. Journal of the American Geriatrics Society 60 (3), 532-537.

Stalvey, B. T., Owsley, C., Sloane, M. E. & Ball, K. 1999. The Life Space Questionnaire: A measure of the extent of mobility of older adults. Journal of Applied Gerontology 18 (4), 460-478.

Stessman, J., Hammerman-Rozenberg, R., Cohen, A., Ein-Mor, E. & Jacobs, J. M. 2009. Physical activity, function, and longevity among the very old. Archives of Internal Medicine 169 (16), 1476-1483.

Strath, S. J., Kaminsky, L. A., Ainsworth, B. E., Ekelund, U., Freedson, P. S., Gary, R. A., Richardson, C. R., Smith, D. T., Swartz, A. M. & American Heart Association Physical Activity Committee of the Council on Lifestyle and Cardiometabolic Health and Cardiovascular, Exercise, Cardiac Rehabilitation and Prevention Committee of the Council on Clinical Cardiology, and Council 2013. Guide to the assessment of physical activity: Clinical and research applications: a scientific statement from the American Heart Association. Circulation 128 (20), 2259-2279.

Tinetti, M. E. & Ginter, S. F. 1990. The nursing home life-space diameter. A measure of extent and frequency of mobility among nursing home residents. Journal of the American Geriatrics Society 38 (12), 1311-1315.

Togo, F., Watanabe, E., Park, H., Yasunaga, A., Park, S., Shephard, R. J. & Aoyagi, Y. 2008. How many days of pedometer use predict the annual activity of the elderly reliably? Medicine and Science in Sports and Exercise 40 (6), 1058-1064.

Transport statistics 2014. National Travel Survey: England 2013. London: National Statistics: Department for Transport.

Tremblay, M. S., Colley, R. C., Saunders, T. J., Healy, G. N. & Owen, N. 2010. Physiological and health implications of a sedentary lifestyle. Applied Physiology, Nutrition, and Metabolism 35 (6), 725-740.

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T. & McDowell, M. 2008. Physical activity in the United States measured by accelerometer. Medicine and Science in Sports and Exercise 40 (1), 181-188.
Vähä-Ypyä, H., Vasankari, T., Husu, P., Suni, J. & Sievänen, H. 2015. A universal, accurate intensity-based classification of different physical activities using raw data of accelerometer. Clinical Physiology and Functional Imaging 35 (1), 64-70.
Varma, V. R., Tan, E. J., Wang, T., Xue, Q. L., Fried, L. P., Seplaki, C. L., King, A. C., Seeman, T. E., Rebok, G. W. & Carlson, M. C. 2014. Low-intensity walking activity is associated with better health. Journal of Applied Gerontology: the Official Journal of the Southern Gerontological Society 33 (7), 870-887.
Viljanen, A., Mikkola, T. M., Rantakokko, M., Portegijs, E. & Rantanen, T. 2016. The Association Between Transportation and Life-Space Mobility in Community-Dwelling Older People With or Without Walking Difficulties. Journal of Aging and Health 28(6), 1038-1054.
Wahl, H. W. & Weisman, G. H. 2003. Environmental gerontology at the beginning of the new millennium: Reflections on its historical, empirical, and theoretical development. The Gerontologist 43, 616-627.
Warburton, D. E. R., Nicol, C. W. & Bredin, S. S. D. 2006. Health benefits of physical activity: the evidence. Canadian Medical Association journal 174 (6), 801-809.
Washburn, R. A. 2000. Assessment of physical activity in older adults. Research Quarterly for Exercise and Sport 71 (2 Suppl), 79-87.
Webber, S. C., Porter, M. M. & Menec, V. H. 2010. Mobility in older adults: a comprehensive framework. The Gerontologist 50 (4), 443-450.
Wen, M., Hawkley, L. C. & Cacioppo, J. T. 2006. Objective and perceived neighborhood environment, individual SES and psychosocial factors, and self-rated health: An analysis of older adults in Cook County, Illinois. Social Science & Medicine 63 (10), 2575-2590.
Wolff, J. L. & Kasper, J. D. 2006. Caregivers of frail elders: updating a national profile. The Gerontologist 46 (3), 344-356.
Wong, C. H., Wong, S. F., Pang, W. S., Azizah, M. Y. & Dass, M. J. 2003. Habitual walking and its correlation to better physical function: implications for prevention of physical disability in older persons. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 58 (6), M555-M560.
World Health Organization 2010. Global recommendations on physical activity for health. Geneva: WHO.
World Health Organization 2002. *Active aging: a policy framework*. Geneva: WHO.
World Health Organization 2001. *International Classification of Functioning, Disability and Health*. Geneva: WHO.
Xue, Q. L., Fried, L. P., Glass, T. A., Laffan, A. & Chaves, P. H. 2008. Life-space constriction, development of frailty, and the competing risk of mortality:

the Women's Health And Aging Study I. American Journal of Epidemiology 167 (2), 240-248.

Yang, Y., Roux, A. V. D., Auchincloss, A. H., Rodriguez, D. A. & Brown, D. G. 2012. Exploring walking differences by socioeconomic status using a spatial agent-based model. Health & Place 18 (1), 96-99.

ORIGINAL PUBLICATIONS

I

THE ASSOCIATION BETWEEN OBJECTIVELY MEASURED PHYSICAL ACTIVITY AND LIFE-SPACE MOBILITY AMONG OLDER PEOPLE

by

Tsai L-T, Portegijs E, Rantakokko M, Viljanen A, Saajanaho M, Eronen J, Rantanen T.

Scandinavian Journal of Medicine & Science in Sports 2015; 25:e368-e373.

II

OBJECTIVELY MEASURED PHYSICAL ACTIVITY AND CHANGES IN LIFE-SPACE MOBILITY AMONG OLDER PEOPLE

by

Tsai L-T, Rantakokko M, Rantanen T , Viljanen A, Kauppinen M, Portegijs E.

Journals of Gerontology Series A: Medical Sciences 2016; 71(11):1466-1471.

III

ASSOCIATIONS BETWEEN REASONS TO GO OUTDOORS AND OBJECTIVELY MEASURED WALKING ACTIVITY IN VARIOUS LIFE-SPACE AREAS AMONG OLDER PEOPLE

by

Tsai L-T, Rantakokko M, Viljanen A, Saajanaho M, Eronen J, Rantanen T, Portegijs E.

Journal of Aging and Physical Activity, 2016, 24(1):85-91

IV

ENVIRONMENTAL MOBILITY BARRIERS AND WALKING FOR ERRANDS AMONG OLDER PEOPLE WHO LIVE ALONE VS. WITH OTHERS

by

Tsai L-T, Rantakokko M, Portegijs E, Viljanen A, Saajanaho M, Eronen J, Rantanen T.

BMC Public Health 2013; 13:1054

Open Access.

Tsai *et al. BMC Public Health* 2013, **13**:1054
http://www.biomedcentral.com/1471-2458/13/1054

BMC Public Health

RESEARCH ARTICLE Open Access

Environmental mobility barriers and walking for errands among older people who live alone vs. with others

Li-Tang Tsai*, Merja Rantakokko, Erja Portegijs, Anne Viljanen, Milla Saajanaho, Johanna Eronen and Taina Rantanen

Abstract

Background: Walking is the most popular form of physical activity among older people and for community-dwelling older people walking for errands is especially important. The aim of this study is to examine the association between self-reported environmental mobility barriers and amount of walking for errands among older people who live alone compared to those who live with others.

Methods: This observational study is based on cross-sectional data on 657 people aged 75–81 living in Jyväskylä, Central Finland. Self-reports of environmental mobility barriers were collected under four categories: Traffic, Terrain, Distances and Entrance. Persons who reported walking for errands ≤ 1.5 km/week or at most once a week were categorized as having low amount of walking for errands (LOWER). High walking for errands (HIGWER) was defined as the highest quartile of kilometers walked per week (cut-off 8.5 km, referent). The rest were defined as having moderate amount of walking for errands (MODWER). Multinominal regression analysis was used to compare the odds for LOWER vs. HIGWER and MODWER vs. HIGWER, which were formed for each environmental mobility barrier separately.

Results: Participants walked on average 6.5 km (SD 5.2) and 4.0 times (SD 2.2) per week and 14% reported LOWER. Persons living alone (57% of the participants) reported environmental mobility barriers more often than those living with others. LOWER was more common among those living with others. Among those living with others, all the environmental mobility barriers increased the odds for LOWER. In turn, among those living alone, only Distance- and Entrance- related environmental mobility barriers increased the odds for LOWER. People living alone typically run errands by themselves and become better aware of the barriers to environmental mobility, while those living with others have less exposure to environmental mobility barriers, as their walking for errands is more likely to be low.

Conclusions: These findings emphasize the need to take living arrangements into account when analyzing the association between environmental mobility barriers and walking for errands. Future longitudinal studies are warranted to better understand the temporal order of events and to find ways to enhance walking for errands among older people.

Keywords: Aging, Mobility, Environmental barriers, Living arrangements

* Correspondence: li-tang.tsai@jyu.fi
Gerontology Research Center and Department of Health Sciences, University of Jyväskylä, P.O.Box 35, Jyväskylä FI-40014, Finland

Background

Physical inactivity becomes more common with increasing age. Among older people, however, walking even short distances may help maintain health and functioning. In an American study, walking at least eight blocks per week helped maintain mobility in terms of walking speed [1]. For older people, walking is a feasible and popular form of physical activity [2] and ideal in the context of public health promotion [3]. Furthermore, engaging in community walking is an important contributory factor for social participation [4]. Walking for errands is a meaningful form of walking, which can be easily integrated into the daily routine of community-dwelling older people [5]. A German study found over eighty percent of community-dwelling older people run their errands on foot [6], and results from Finnish samples showed older women preferred walking to the use of cars or public transport for errands [7].

For older people, the home environment and its immediate surroundings may be a decisive factor for engaging in outdoor physical activity, especially among people who report mobility limitations [8]. Environmental mobility barriers increase unmet physical activity need (the feeling that one's physical activity is inadequate) and fear of moving outdoors among older people [9,10]. Environmental facilitators for mobility such as having a park nearby decrease the risk for developing walking difficulty among older people [11]. Environmental features may be more closely associated with walking for errands than with walking for leisure among older people [12,13]. Walking for errands among older people is positively related to access to services and mixed land use [12,14]. Presence of multiple environmental mobility facilitators can motivate older people to walk for errands [15]. So far, there is limited information about the association between environmental mobility barriers and walking for errands. Further understanding of this topic is a crucial step towards promoting optimal mobility among older people, defined as being able to choose when, where, and how one wishes to go, safely and reliably [16].

A growing number of older people, mostly women, live alone in their own homes. Living alone may be associated with a higher likelihood of walking outside the home, as there is no other person to take care of the errands [17]. In another study, older people living with their families had better physical health status and more health-promoting behaviors than those living alone [18]. Understanding the dynamics between physical activity, environmental mobility barriers and living arrangements may help to detect need for support in physical activity participation among community-dwelling older people.

The aim of the present study was to examine the association between self-reported environmental mobility barriers and amount of walking for errands among older people with different living arrangements.

Methods

The present study is based on cross-sectional analyses of the baseline data of the Screening and Counseling for Physical Activity and Mobility (SCAMOB) project, which is a randomized controlled trial on physical activity counseling (ISRCTN 07330512). The participants were community-dwelling people aged 75–81 years living in Jyväskylä in Central Finland. The urban area where the study was conducted is characterized by small hills. Many streets are rather quiet with predominantly only residential traffic with some streets with more traffic intersecting. There are several small parks with seating areas. Most of the shops and other services are concentrated in the city center which is located also in the center of the current study perimeter.

In accordance with the SCAMOB main goal, the inclusion criteria were: (1) the ability to walk at least 0.5 km without assistance, (2) at most moderately physically active, (3) no memory impairment, (4) no medical contraindications for physical activity and (5) informed consent [19,20]. The present analysis comprises data on the 657 community-dwelling people who took part in a home-based face-to-face interview and functional tests in the study center at baseline.

The ethical committee of the Central Finland Central Hospital approved the SCAMOB project. Participants were informed about the research before signing a consent form.

Walking for errands was elicited with the question "How much do you walk outdoors in the course of your daily activities, such as shopping, walking to the bus stop, etc.?" Participants were asked to report the average distance and frequency of their walking for errands during one week. We categorized walking for errands into three levels (low, moderate, and high amount) based on the following criteria: Low amount of walking for errands (LOWER) was defined as walking no more than 1.5 km/week or at most once a week, and has been found to be associated with elevated mortality and functional capacity decline among older people [21,22]. High amount of walking for errands (HIGWER) was defined according to the amount walked by those in the highest quartile of distance walked/week, which in our study population corresponded to more than 8.5 km/week. Those who did not fall into the above two categories were defined as having moderate amount of walking for errands (MODWER). The reliability for the categorization as assessed with Kendall's tau-b was found to be good (r = 0.93) in a study among 29 older people interviewed two weeks apart [19]. Altogether 14 people (2% of the study population) had missing data on walking for errands.

Environmental mobility barriers were self-reported during an interview with standardized questions. Participants were asked whether a certain environmental mobility barrier hindered their possibility of moving outdoors independently (yes/no). Self-reported environmental mobility barriers to moving outdoors were categorized into four groups: Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places) [23] and Entrance (outdoor/indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting). For the data analysis, environmental mobility barriers were dichotomized according to presence.

Living arrangements were self-reported during an interview according to four alternatives: living alone, living with a spouse, living with own child/children, and living with relatives. Only 2% of the participants lived with somebody other than a spouse and these individuals were included in the same category for the data analysis (dichotomized into living alone and living with others).

Sociodemographic indicators included age, gender, perceived financial status (very bad, bad, or moderate vs. good or very good), and years of education. Number of chronic conditions were first self-reported (physician-diagnosed chronic conditions lasting more than 3 months), and then further confirmed by the study nurse in a clinical examination. Use of a cane was self-reported. Depressive symptoms were assessed on the Center for Epidemiologic Studies Depression Scale (CES-D) [24]. Maximal walking speed was measured with a stopwatch over a distance of 10 m in the study center corridor. Participants wore suitable footwear for walking and used a walking aid if needed.

Participants' characteristics were described using means and standard deviations (SD) or percentages according to amount of walking for errands and living arrangements, and differences were tested with chi-square tests for categorical variables and *ANOVA* or *t-test* for continuous variables. *T-test* was also used for analyzing differences in distance and frequency in walking for errands according to environmental mobility barriers.

We observed a significant interaction between living arrangements and environmental mobility barriers for the odds of low walking activity ($p < 0.001$). Two sets of multinominal regression analyses were performed to identify the associations between environmental mobility barriers and walking for errands. In the first set of analysis, participants were stratified according to their living arrangements (living alone or living with others). For each environmental mobility barrier the odds for LOWER and MODWER were computed separately with HIGWER used as the reference value.

In the second set of multinominal regression analysis, we included all the participants in the same analysis by creating a combined distribution for the independent variables. For the living arrangements, and for each environmental mobility barrier, the following categorization was computed: lives alone and reports a barrier, lives with others and reports a barrier, lives alone and does not report a barrier, and lives with others and does not report a barrier. As the reference group, we used those who lived alone and did not report a barrier, as they had the lowest prevalence of LOWER. The odds for LOWER and MODWER vs. HIGWER were calculated separately for each environmental mobility barrier by living status categorization.

All multinominal regression analyses were adjusted for age and gender. Owing to the low number of people in some categories of the independent variables, we added walking speed, number of chronic conditions, and CES-D score into the models one at a time to control for health differences (models not shown but data available from the authors upon request). Men and women were included in the same models, as gender-stratified analyses produced practically identical results. Results are reported as odds ratios (OR) and 95% confidence intervals (CI). Differences were considered to be statistically significant when $p \leq 0.05$.

Statistical analyses were performed using the SPSS program (SPSS 19.0 for Windows/Mac, IBM).

Results

The average age of the participants (n = 657) was 77.6 ± SD 1.9 and 75% were women. The mean self-reported weekly walking distance was 6.4 ± 5.1 kilometers and walking frequency was 4.0 ± 2.2. Individual and environmental characteristics are shown in Table 1, categorized according to low, moderate, and high amount of walking for errands as well as living alone vs. living with others. Distances as an environmental mobility barrier was associated with LOWER while the other environmental mobility barriers did not show a clear association with walking for errands. People who lived alone reported more environmental mobility barriers and were less often in the LOWER category than those living with others. HIGWER did not clearly differ between those living alone vs. living with others. Terrain was the most common environmental mobility barrier (33%), followed by Traffic (21%), Entrance (20%) and Distances (18%). Mean walking distances and frequency according to the presence of each environmental mobility barrier is shown in Table 2. Participants who reported Distances as a barrier walked fewer kilometers and less frequently than those who did not report Distances as a barrier.

Table 3 presents the age and gender-adjusted odds for LOWER and MODWER with HIGWER as the reference. We observed a significant interaction between living arrangements and environmental mobility barriers for the odds of low walking activity ($p < 0.001$), and thus participants were stratified according to their living arrangements. Among people living alone, in general,

Table 1 Characteristics of the participants according to amount of walking for errands and living arrangements

	LOWER n = 96 Mean ± SD	MODWER n = 381 Mean ± SD	HIGWER n = 166 Mean ± SD	p-value*	Living alone n = 381 Mean ± SD	Living with others n = 276 Mean ± SD	p-value†
Age (years)	77.5 ± 2.0	77.6 ± 2.0	77.6 ± 1.9	0.875	77.8 ± 2.0	77.3 ± 1.9	0.002
Education (years)	8.9 ± 4.2	9.1 ± 4.0	9.3 ± 4.8	0.723	8.6 ± 4.1	9.8 ± 4.3	0.001
Chronic conditions (number)	3.8 ± 2.3	3.0 ± 1.9	2.7 ± 1.8	< 0.001	3.1 ± 2.0	2.9 ± 1.9	0.051
Walking speed (m/s)	1.2 ± 0.4	1.3 ± 0.4	1.5 ± 0.3	< 0.001	1.3 ± 0.3	1.4 ± 0.4	< 0.001
CES-D (score)	11.2 ± 8.2	10.5 ± 7.5	8.8 ± 7.2	0.020	10.4 ± 7.6	9.9 ± 7.6	0.375
Walking for errands							
Distance/week	1.2 ± 1.0	4.6 ± 1.8	13.5 ± 4.5	< 0.001	6.6 ± 4.5	6.2 ± 5.9	0.456
Frequency/week	1.4 ± 1.9	3.8 ± 1.7	5.9 ± 1.5	< 0.001	4.3 ± 2.0	3.6 ± 2.3	< 0.001
	%	%	%		%	%	
Female	56	83	69	< 0.001	90	54	< 0.001
Living alone	30	65	59	< 0.001			
Use of a cane (indoors or outdoors)	22	12	8	0.003	14	10	0.075
Perceived financial situation				0.604			< 0.001
Good or very good	40	41	45		35	50	
Very bad, bad or moderate	60	59	55		65	50	
Environmental mobility barriers							
Distances	31	18	8	< 0.001	21	15	0.049
Terrain	28	36	29	0.131	38	27	0.004
Traffic	19	22	19	0.542	22	20	0.534
Entrance	25	22	15	0.107	23	16	0.020
Amount of walking for errands							< 0.001
Low					8	24	
Moderate					85	66	
High					7	10	

*one-way ANOVA & Chi-square.
† t-t est & Chi-square.
SD Standard Deviation.
CES-D Center for Epidemiologic Studies Depression Scale.
LOWER Low amount of walking for errands, *MODWER* Moderate amount of walking for errands, *HIGWER* High amount of walking for errands.
NOTE: Environmental mobility barriers studied were Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places), and Entrance (outdoor stairs present, indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting). LOWER: ≤ 1.5 km/week or at most once a week; HIGWER: ≥ 8.5 km/week (highest quartile); MODWER: those who did not fall into LOWER or HIGWER categories.

the presence of an environmental mobility barrier increased the odds for LOWER, although not all the associations reached statistical significance. For those living alone and those living with others, Distances consistently increased the odds for LOWER.

Table 4 reports the multinominal regression models showing the associations between each of the four mutually exclusive environmental mobility barriers and amount of walking for errands categories. For each model, people living alone and not reporting the environmental mobility barrier were assigned as the reference group. In general, the presence of environmental mobility barriers increased the odds for LOWER (vs. HIGWER), with the majority of associations reaching statistical significance. For Traffic and Terrain, living with others and not reporting mobility barriers in these categories resulted in the highest odds for LOWER. Reporting Distances as a mobility barrier increased the odds for LOWER almost eight-fold among those living alone and more than thirty-fold among those living with others compared with the reference group.

Adding the number of chronic conditions and CES-D score into the models one at a time had no material influence on the odds ratios. Adding walking speed into the models attenuated the odds to some extent, but the pattern of associations remained similar to those in the models adjusted for age and gender (data not shown).

Table 2 Average distance and frequency walked in a week by participants reporting environmental mobility barriers

Environmental mobility barriers	Distance (km) walked/week (n = 642) Mean ± SD	p-value*	Frequency of walking/week (n = 649) Mean ± SD	p-value*
Traffic		0.675		0.179
Yes	6.3 ± 5.0		4.2 ± 2.2	
No	6.5 ± 5.2		3.9 ± 2.2	
Terrain		0.173		0.685
Yes	6.0 ± 5.1		4.0 ± 2.1	
No	6.6 ± 5.2		4.0 ± 2.2	
Distances		< 0.001		< 0.001
Yes	4.5 ± 4.4		3.1 ± 1.9	
No	6.8 ± 5.2		4.2 ± 2.2	
Entrance		0.120		0.469
Yes	5.8 ± 5.1		3.9 ± 2.1	
No	6.6 ± 5.1		4.0 ± 2.2	

* *t*-test.
NOTE: Environmental mobility barriers studied were Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places), and Entrance (outdoor stairs present, indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting).

Discussion

We observed that the association between self-reported environmental barriers and amount of walking for errands differed by living arrangements. People who lived alone were less likely to report LOWER but more likely to report environmental mobility barriers than those living with others.

Our findings may be explained in several ways. First of all, we focused only on walking for errands. It is likely that the need to run daily errands personally is greater when living alone than when living with others, which reduces the odds for LOWER. For people who do not live alone, their companions may run their errands for them, which may increase the risk for LOWER. Our findings are in line with two earlier observations, i.e. older people most often receive help from their spouse when their functional capacity declines [25] and that walking outside the home was more common for older women who live alone than those living with another person [17]. We speculate that, owing to their greater walking activity, those who live alone are more exposed to and hence better aware of the existing environmental mobility barriers, and consequently also more likely to report them. As those living with others have less experience of negotiating their nearby environment, they are probably also less aware of the environmental mobility barriers, which results in less reporting of them [26]. Reporting Distances as a mobility barrier was consistently

Table 3 Odds ratios* for low and moderate amount of walking for errands with perceived environmental mobility barriers among those living alone and living with others

	Living alone		Living with others	
	LOWER (n = 29)	MODWER (n = 248)	LOWER (n = 67)	MODWER (n = 133)
Environmental mobility barrier	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Traffic	1.95 (0.76-5.01)	1.32 (0.72-2.40)	0.64 (0.25-1.64)	1.25 (0.59-2.62)
Terrain	1.83 (0.78-4.31)	1.38 (0.83-2.29)	0.75 (0.34-1.66)	1.12 (0.58-2.17)
Distances	7.77 (2.94-20.56)	1.93 (0.96-3.91)	7.35 (2.00-26.99)	2.86 (0.80-10.22)
Entrance	8.76 (3.37-22.80)	2.13 (1.09-4.20)	0.59 (0.22-1.57)	0.75 (0.34-1.64)

OR Odds Ratio, *CI* Confidence Interval.
LOWER Low amount of walking for errands, *MODWER* Moderate amount of walking for errands, *HIGWER* High amount of walking for errands.
* Adjusted for age and gender from multinominal logistic regression: LOWER and MODWER each compared to HIGWER. Models are computed separately for those living alone and those living with others.
Environmental mobility barriers studied were Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places), and Entrance (outdoor stairs present, indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting). LOWER: ≤ 1.5 km/week or at most once a week; HIGWER: ≥ 8.5 km/week (highest quartile); MODWER: those who did not fall into LOWER or HIGWER categories.

Table 4 Odds rations* for low and moderate amount of walking for errands among older people with different living arrangements and perceived environmental mobility barriers

Environmental mobility barrier	LOWER vs. HIGWER			
	Living alone (n = 29)		Living with others (n = 67)	
	n	OR (95% CI)	n	OR (95% CI)
Traffic				
Yes	9	2.00 (0.78-5.10)	9	2.76 (1.00-7.59)
No	20	1.00	58	4.18 (2.16-8.08)
Terrain				
Yes	13	1.85 (0.79-4.33)	14	3.27 (1.33-8.07)
No	16	1.00	53	4.45 (2.19-9.03)
Distances				
Yes	14	7.55 (2.88-19.78)	16	30.45 (7.83-118.44)
No	15	1.00	51	4.18 (2.06-8.47)
Entrance				
Yes	16	8.82 (3.41-22.82)	8	3.98 (1.37-11.57)
No	13	1.00	59	6.97 (3.34-14.54)
	MODWER vs. HIGWER			
	Living alone (n = 248)		Living with others (n = 133)	
Traffic				
Yes	55	1.30 (0.71-2.35)	30	1.22 (0.59-2.54)
No	193	1.00	103	1.04 (0.66-1.64)
Terrain				
Yes	98	1.41 (0.85-2.33)	40	1.23 (0.64-2.34)
No	150	1.00	93	1.10 (0.68-1.79)
Distances				
Yes	51	1.98 (0.98-3.98)	17	2.78 (0.79-9.84)
No	197	1.00	116	1.03 (0.67-1.59)
Entrance				
Yes	59	2.15 (1.10-4.23)	23	0.94 (0.45-1.97)
No	189	1.00	110	1.21 (0.77-1.91)

OR Odds Ratio, *CI* Confidence Interval.
LOWER Low amount of walking for errands, *MODWER* Moderate amount of walking for errands, *HIGWER* High amount of walking for errands.
*Odds ratios adjusted for age and gender, calculated using multinomial logistic regression analyses comparing the odds of LOWER vs. HIGWER (upper panel) and MODWER vs. HIGWER (lower panel). Each environmental mobility barrier forms a separate model. Environmental mobility barriers studied were Traffic (noisy traffic and dangerous crossroads), Terrain (hilly terrain and poor street condition), Distances (long distance to services and lack of resting places), and Entrance (outdoor stairs present, indoor stairs present, no elevator, heavy doors, slippery floor and inadequate lighting). LOWER: ≤ 1.5 km/week or at most once a week; HIGWER: ≥ 8.5 km/week (highest quartile); MODWER: those who did not fall into LOWER or HIGWER categories.

associated with LOWER regardless of whether the person lived alone or with others. Distances as a mobility barrier increased the odds for LOWER to almost eight-fold for those living alone and more than thirty-fold for those living with others compared with the reference group. It is possible that people reporting Distances as a mobility barrier live in places where their destinations of interest are too far away to be reached on foot. Earlier studies have reported that older people who live close to particular destinations of interest to them walk more for transportation [12,27,28]. It is also possible that perceiving Distances as a mobility barrier reflects poorer health and physical functioning. This is supported by the fact that walking speed – an objective measure of physical functioning – attenuated the odds ratios to some extent. However, the odds ratios remained significant, and consequently we concluded that the association was not completely explained by poorer physical functioning among those reporting Distances as a mobility barrier.

Another interesting finding of our study was that Entrance as a mobility barrier was a stronger correlate of LOWER for people living alone than for those living with others. Entrance barriers may be easily overcome by the help of another person when exiting or entering the home. It is a reasonable assumption that people living alone more often need to negotiate Entrance barriers by themselves. Consequently, for people living alone, Entrance barriers may literally prevent them from going out.

Very low walking activity is a risk factor for further functional decline [1]. As people living alone had a lower prevalence of LOWER in our study, we suspect that older people living alone may be at a lower risk for functional decline in the future compared to those living with others. However, this needs to be confirmed in future studies. The present topic has not been widely studied previously. An earlier study showed comparable physical activity levels for those living with a spouse and those living alone [29]. Prospective studies showed that older women living alone had less functional decline and comparable risk for poor health outcomes than those living with a spouse [30,31]. However, we have not found earlier studies that have addressed the simultaneous associations of environmental mobility barriers and living arrangements with physical activity.

The main strength of this study is use of a large population-based sample to explore an increasingly topical issue [32-34]. Most of the participants were living in condominiums and some in detached houses within a radius of approximately 5 km in the same urban area. Hence the results are unlikely to be explained by differences in living environments. The age range is rather narrow, and consequently residual confounding due to age is not likely to explain the results either.

The study has some limitations. We studied only walking in the context of running errands. It is possible that some people were engaging in other important forms of walking, such as recreation or fitness, that were not included in the analysis. However, it is unlikely that a meaningful proportion of people would have been wrongly assigned to the LOWER category. Even if people have given up walking for fitness or leisure, walking for errands is maintained for as long as possible, as it allows people to maintain independent community living. Consequently, if people do not report walking for errands, it is highly likely that they are not active in other forms of walking either. An earlier longitudinal study found walking to be one of the most popular forms of customary physical activity among older people [35]. The present results are based on cross-sectional analyses, and consequently we cannot make inferences as to the temporal order of occurrence. It should also be noted that, stemming from the design of the original study, both the most active and the most disabled individuals were excluded. Therefore, the distribution of functioning and walking in the current study is located around the population average, but is likely to be somewhat truncated. Consequently, the present results are likely to underestimate the actual strength of the associations. However, we believe that similar associations would be found in any Western country.

Conclusions

Among older people, the associations of environmental mobility barriers with walking for errands differ for those living alone vs. living with another person. Older people living with others had higher odds for low amount of walking for errands. This topic warrants further study to better understand the behavioral patterns that underlie the lower walking activity of these individuals and how they could be encouraged to be more physically active. Perceiving long distances to services as a mobility barrier was consistently associated with increased odds for low amount of walking for errands regardless of whether people lived alone or with others. Consequently, living in areas where there are local services and attractive walking destinations in the near vicinity of home may promote physical activity. The present results may be generalized to older people who are able to walk independently outdoors and who live in regular housing in urban areas. It is possible that some of the associations reported here may be due to poorer health among those who report environmental barriers and low amount of walking for errands. The present results may serve as a justification for future studies. Prospective studies would help to gain an idea of future trajectories of walking for errands, thereby clarifying the temporal order of the variables studied here, while qualitative studies would help us better understand the relevance of the studied associations in older people's lives.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

The authors are justifiably credited with authorship, according to the authorship criteria. LT: conception, design, analysis and interpretation of the data, writing the article; MR: conception, design, critical revision of the article; EP: conception, design, critical revision of the article; AV: conception, design, critical revision of the article. MS: conception, design, critical revision of the article; JE: conception, design, critical revision of the article; TR: conception, design, data collection, critical revision of the article, PI for the SCAMOB project. All the authors approved the final manuscript.

Acknowledgements

This study was financially supported by the Ministry of Education, Finland; the Ministry of Social Affairs and Health, Finland; the City of Jyväskylä and University of Jyväskylä, Finland and the Juho Vainio Foundation, Finland. The Academy of Finland (future of living and housing program ASU-LIVE; grant number 255403). Anne Viljanen is funded by a personal grant from the Academy of Finland (Grant number 251723). The Gerontology Research Center is a joint effort between the University of Jyväskylä and the University of Tampere.

Received: 28 May 2013 Accepted: 4 November 2013
Published: 8 November 2013

References

1. Simonsick EM, Guralnik JM, Volpato S, Balfour J, Fried LP: **Just get out the door! Importance of walking outside the home for maintaining mobility: findings from the women's health and aging study.** *J Am Geriatr Soc* 2005, **53**(2):198–203.
2. Wong CH, Wong SF, Pang WS, Azizah MY, Dass MJ: **Habitual walking and its correlation to better physical function: implications for prevention of physical disability in older persons.** *J Gerontol A Biol Sci Med Sci* 2003, **58**(6):M555–M560.
3. Owen N, Humpel N, Leslie E, Bauman A, Sallis JF: **Understanding environmental influences on walking: review and research agenda.** *Am J Prev Med* 2004, **27**(1):67–76.
4. Leyden KM: **Social capital and the built environment: the importance of walkable neighborhoods.** *Am J Public Health* 2003, **93**(9):1546–1551.
5. Murtagh EM, Murphy MH, Boone-Heinonen J: **Walking–the first steps in cardiovascular disease prevention.** *Curr Opin Cardiol* 2010, **25**(5):490–496.
6. Hinrichs T, Trampisch U, Burghaus I, Endres HG, Klaaßen-Mielke R, Moschny A, Platen P: **Correlates of sport participation among community-dwelling elderly people in Germany: a cross-sectional study.** *Eur Rev Aging Phy Activ* 2010, **7**(2):105–115.
7. Siren A, Hakamies-Blomqvist L: **Does gendered driving create gendered mobility? Community-related mobility in Finnish women and men aged 65.** *Transport Res Part F: Traffic Psychol Behav* 2006, **9**(5):374–382.
8. Rasinaho M, Hirvensalo M, Leinonen R, Lintunen T, Rantanen T: **Motives for and barriers to physical activity among older adults with mobility limitations.** *J Aging Phys Act* 2007, **15**(1):90–102.
9. Rantakokko M, Mänty M, Iwarsson S, Törmäkangas T, Leinonen R, Heikkinen E, Rantanen T: **Fear of moving outdoors and development of outdoor walking difficulty in older people.** *J Am Geriatr Soc* 2009, **57**(4):634–640.
10. Rantakokko M, Iwarsson S, Hirvensalo M, Leinonen R, Heikkinen E, Rantanen T: **Unmet physical activity need in old age.** *J Am Geriatr Soc* 2010, **58**(4):707–712.
11. Eronen J, von Bonsdorff M, Rantakokko M, Rantanen T: **Environmental facilitators for outdoor walking and development of walking difficulty in community-dwelling older adults.** *Eur J Ageing* 2013. doi:10.1007/s10433-013-0283-7.
12. Shigematsu R, Sallis J, Conway T, Saelens B, Frank L, Cain K, Chapman J, King A: **Age differences in the relation of perceived neighborhood environment to walking.** *Med Sci Sports Exerc* 2009, **41**(2):314–321.
13. Shimura H, Sugiyama T, Winkler E, Owen N: **High neighborhood walkability mitigates declines in middle-to-older aged adults' walking for transport.** *J Phys Act Health* 2012, **9**(7):1004–1008.
14. Frank L, Kerr J, Rosenberg D, King A: **Healthy aging and where you live: community design relationships with physical activity and body weight in older Americans.** *J Phys Act Health* 2010, **7**(1):S82–S90.
15. Van Cauwenberg J, Clarys P, De Bourdeaudhuij I, Van Holle V, Verté D, De Witte N, De Donder L, Buffel T, Dury S, Deforche B: **Older adults' transportation walking: a cross-sectional study on the cumulative influence of physical environmental factors.** *Int J Health Geographics* 2013, **12**(1):37. doi:10.1186/1476-072X-12-37.
16. Satariano WA, Guralnik JM, Jackson RJ, Marottoli RA, Phelan EA, Prohaska TR: **Mobility and aging: new directions for public health action.** *Am J Public Health* 2012, **102**(8):1508–1515.
17. Simonsick EM, Guralnik JM, Fried LP: **Who walks? Factors associated with walking behavior in disabled older women with and without self-reported walking difficulty.** *J Am Geriatr Soc* 1999, **47**(6):672–680.
18. Sok SR, Yun EK: **A comparison of physical health status, self-esteem, family support and health-promoting behaviours between aged living alone and living with family in Korea.** *J Clin Nurs* 2011, **20**(11–12):1606–1612.
19. Leinonen R, Heikkinen E, Hirvensalo M, Lintunen T, Rasinaho M, Sakari-Rantala R, Kallinen M, Koski J, Möttönen S, Kannas S, Huovinen P, Rantanen T: **Customer-oriented counseling for physical activity in older people: study protocol and selected baseline results of a randomized-controlled trial (ISRCTN 07330512).** *Scand J Med Sci Sports* 2007, **17**(2):156–164.
20. Mänty M, Heinonen A, Leinonen R, Törmäkangas T, Hirvensalo M, Kallinen M, Sakari R, von Bonsdorff MB, Heikkinen E, Rantanen T: **Long-term effect of physical activity counseling on mobility limitation among older people: a randomized controlled study.** *J Gerontol A Biol Sci Med Sci* 2009, **64**(1):83–89.
21. Shimada H, Ishizaki T, Kato M, Morimoto A, Tamate A, Uchiyama Y, Yasumura S: **How often and how far do frail elderly people need to go outdoors to maintain functional capacity?** *Arch Gerontol Geriatr* 2010, **50**(2):140–146.
22. Hakim AA, Petrovitch H, Burchfiel CM, Ross GW, Rodriguez BL, White LR, Yano K, Curb JD, Abbott RD: **Effects of walking on mortality among nonsmoking retired men.** *N Engl J Med* 1998, **338**(2):94–99.
23. Rantakokko M, Iwarsson S, Mänty M, Leinonen R, Rantanen T: **Perceived barriers in the outdoor environment and development of walking difficulties in older people.** *Age Ageing* 2012, **41**(1):118–121.
24. Radloff LS: **The CES-D scale: a self-reported scale for research in the general population.** *Applied Psychol Measurement* 1977, **1**:385–401.
25. Stoller EP, Earl LL: **Help with activities of everyday life: Sources of support for the noninstitutionalized elderly.** *Gerontologist* 1983, **23**(1):64–70.
26. Fänge A, Iwarsson S: **Accessibility and usability in housing: Construct validity and implications for research and practice.** *Disabil Rehabil* 2003, **25**(23):1316–1325.
27. Nagel CL, Carlson NE, Bosworth M, Michael YL: **The relation between neighborhood built environment and walking activity among older adults.** *Am J Epidemiol* 2008, **168**(4):461–468.
28. Michael Y, Beard T, Choi D, Farquhar S, Carlson N: **Measuring the influence of built neighborhood environments on walking in older adults.** *J Aging Phys Act* 2006, **14**(3):302–312.
29. Satariano WA, Haight TJ, Tager IB: **Living arrangements and participation in leisure-time physical activities in an older population.** *J Aging Health* 2002, **14**(4):427–451.
30. Sarwari A, Fredman L, Langenberg P, Magaziner J: **Prospective study on the relation between living arrangement and change in functional health status of elderly women.** *Am J Epidemiol* 1998, **147**(4):370–378.
31. Michael YL, Berkman LF, Colditz GA, Kawachi I: **Living arrangements, social integration, and change in functional health status.** *Am J Epidemiol* 2001, **153**(2):123–131.
32. Gómez LF, Parra DC, Buchner D, Brownson RC, Sarmiento OL, Pinzón JD, Ardila M, Moreno J, Serrato M, Lobelo F: **Built environment attributes and walking patterns among the elderly population in Bogotá.** *Am J Prev Med* 2010, **38**(6):592–599.
33. Kemperman A, Timmerman H: **Influences of built environment on walking and cycling by latent segments of aging population.** *Transport Res Record: J Transport Res Board* 2009, **2134**:1–9.
34. Ståhl A, Carlsson G, Hovbrandt P, Iwarsson S: **"Let's go for a walk!": identification and prioritisation of accessibility and safety measures involving elderly people in a residential area.** *Eur J Ageing* 2008, **5**(3):265–273.
35. Armstrong GK, Morgan K: **Stability and change in levels of habitual physical activity in later life.** *Age Ageing* 1998, **27**(suppl 3):17–23.

doi:10.1186/1471-2458-13-1054
Cite this article as: Tsai *et al.*: Environmental mobility barriers and walking for errands among older people who live alone vs. with others. *BMC Public Health* 2013 **13**:1054.