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Minna Mänty

Early Signs of Mobility Decline and Physical Activity Counseling as a Preventive Intervention in Older People

JYVÄSKYLÄN YLIOPISTO

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ABSTRACT

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The purpose of this study was to examine the early signs of mobility decline and falls in older people. In addition, the effects of physical activity counseling on the development of mobility limitation in an older community-dwelling population were studied.

Data from two larger studies were used: Screening and Counseling for Physical activity and Mobility among Older People, SCAMOB, a 2-year single-blinded randomized controlled trial (n=632) with a 1.5-year post-intervention follow-up, focused on 75 to 81-year-old community-dwelling people and the FITSA study, a 3-year prospective observational study, on 63 to 75-year-old community-dwelling women (n=434). Data on mobility limitation, physical activity and health status were obtained in face-to-face interviews or with questionnaires. Muscle power and walking speed were measured during the research centre examinations and falls were followed-up for 1 year with daily fall calendars.

Self-reported preclinical mobility limitation and fall history increased the risk of manifest mobility limitation and future falls. A single individualized physical activity counseling session with a supportive phone contact every 4 months for 2 years had a positive effect on perceived mobility. However, the effects on muscle power and walking speed were significant only among women with no or only early signs of mobility limitation. No effects were observed among men or among women with more advanced mobility limitation at baseline.

The results of the present study indicate that self-reported preclinical mobility limitation and fall history should be considered as important early indicators of functional decline among community-dwelling older adults. In addition, the results suggest that physical activity counseling for older adults may provide an effective means to promote mobility, which is a crucial prerequisite for maintaining independence in the community in old age.

Keywords: Aging, mobility limitation, falls, risk assessment, physical activity, promotion, older people

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Jyväskylä, May 2010

Minna Mänty

LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the following original publications, which will be referred to by their Roman numerals.

I. Mänty M, Heinonen A, Leinonen R, Törmäkangas T, Sakari-Rantala R, Hirvensalo M, von Bonsdorff MB, Rantanen T. 2007. Construct and predictive validity of a self-reported measure of preclinical mobility limitation. Archives of Physical Medicine and Rehabilitation 88, 1108–1113.

II. Mänty M, Heinonen A, Viljanen A, Pajala S, Koskenvuo M, Kaprio J, Rantanen T. 2010. Self-reported preclinical mobility limitation and fall history as predictors of future falls in older women: prospective cohort study. Osteoporosis International 21, 689-693.

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

IV. Mänty M, Heinonen A, Leinonen R, Törmäkangas T, Hirvensalo M, von Bonsdorff MB, Heikkinen E, Rantanen T. Effect of physical activity counseling on leg extensor power and walking speed in older people. Submitted for publication.

V. Mänty M, Heinonen A, Leinonen R, Törmäkangas T, Hirvensalo M, Kallinen M, Sakari R, von Bonsdorff MB, Heikkinen E, Rantanen T. 2009. Long-term effect of physical activity counseling on mobility limitation among older people: a randomized controlled study. Journals of Gerontology Series A: Biological Sciences and Medical Sciences 64, 83-89.

ABBREVIATIONS

ADL	Activities of Daily Living
ANOVA	Analysis of Variance
BMI	Body Mass Index
cat	Categorized scale
CES-D	Center for Epidemiologic Studies Depression Scale
95% CI	95% Confidence Interval
cont	Continuous Scale
CV	Coefficient of Variation
dichot	Dichotomized scale
GEE	Generalized Estimating Equation
FITSA	Finnish Twin Study on Aging
HR	Hazard Ratio
IRR	Incidence Rate Ratio
MMSE	Mini-Mental State Examination
NNT	Number Needed to Treat
OR	Odds Ratio
RCT	Randomized Controlled Trial
RR	Risk Ratio
SCAMOB	Screening and Counseling for Physical Activity and Mobility in Older People -trial
SD	Standard Deviation
SE	Standard Error
W	Watt: expression of muscle power
WHO	World Health Organization

CONTENTS

1 INTRODUCTION

The ability to move independently and safely from one place to another is one of the most essential determinants of independent functioning in daily life. Despite improvements in the health and functional ability of older populations during recent decades (Aromaa & Koskinen 2004), the proportion of older people with mobility difficulties will remain high due to population aging (Nieminen & Koskinen 2006). Limitations in mobility are known to increase with advancing age (Aromaa & Koskinen 2004, Sainio et al. 2006), and are often the first noticeable signs of further functional decline. Loss of mobility hinders the ability to manage tasks of daily life and eventually leads to a need for help and an increased risk of institutionalization (Guralnik et al. 1994, Guralnik et al. 1995, Onder et al. 2005). In addition, falls, and especially serious injuries related to falls, are known to have a wide range of physical, psychological and economic consequences among older people (Tinetti & Williams 1997, Magaziner et al. 2000, Jorstad et al. 2005, Portegijs et al. 2008a). Consequently, with ever larger cohorts surviving to old age, the need to develop efficacious and acceptable ways to slow down the progression of functional decline with age is an important public health priority.

One of the major challenges in the prevention of functional decline and disability in old age is the identification of the optimal target population (Ferrucci et al. 2004). In particular, from the perspective of primary prevention, it is crucial to identify persons who are not yet disabled but who are at high risk (Fried et al. 1991, Fried & Guralnik 1997, Guralnik et al. 2003, Ferrucci et al. 2004). Poor physical performance, such as low muscle strength and poor balance, (Foldvari et al. 2000, Rantanen et al. 2001, Bean et al. 2002a, Tiedemann et al. 2005) and various medical conditions, such as musculoskeletal and cardiovascular diseases (Guralnik et al. 1993, Ettinger et al. 1994, Bootsma-van der Wiel et al. 2002, Ling et al. 2003), are among the most important risk factors for mobility decline among older people. However, despite the fact that the most common risk factors for mobility decline are nowadays widely recognized, further development of simple and easily administrable tools for use in identifying persons at risk in clinical work continue to be needed.

In the early stages of functional decline prior to the onset of task difficulty, older persons may be able to compensate for underlying impairments or physiological decrements by modifying their task performance, and thus maintain their everyday function without strong perception of difficulty. This early stage of functional decline has been conceptualized as preclinical mobility limitation, and refers to a stage between good mobility and manifest mobility limitation (Fried et al. 2000, Fried et al. 2001, Wolinsky et al. 2005). Self-reported preclinical mobility limitation may provide an inexpensive basis for screening and early intervention to prevent functional decline and disability among older people, and is thus an important topic for future studies.

Physical activity and exercise are widely promoted as effective means to enhance the health and physical functioning of older persons (Keysor & Jette 2001, Taylor et al. 2004, Manini & Pahor 2009). Multiple randomized controlled intervention trials (RCTs) have reported the beneficial effects of various exercise programs on mobility outcomes among healthy older adults as well as among frail and chronically ill older people (Keysor & Jette 2001, Lopopolo et al. 2006, Bartels et al. 2007, French et al. 2007, Lange et al. 2008, Watson et al. 2008, Fransen et al. 2009, Liu & Latham 2009). However, it is less certain how these promising results can be adapted to use in everyday clinical practice, where time constraints often limit the resources that can be used in preventive interventions (Pinto et al. 1998, Tinetti et al. 2006).

Physical activity counseling is an example of a low-cost educational intervention aiming to promote physical activity. So far, previous RCTs have shown that physical activity counseling increases physical activity among older people (Halbert et al. 2000, Stewart et al. 2001, Dubbert et al. 2002, Hillsdon et al. 2005a, Kerse et al. 2005, Pinto et al. 2005, Kolt et al. 2007, Dubbert et al. 2008, Morey et al. 2008). In addition, small beneficial effects of counseling on general health and hospitalization have been reported (Kerse et al. 2005). However, whether physical activity counseling, through increasing physical activity, prevents or slows down the age-related declines in mobility has been little studied (Dubbert et al. 2002).

The present study was conducted to obtain knowledge about early signs of mobility decline and falls in older people. In addition, the effects of physical activity counseling on the development of mobility limitation in an older community-dwelling population were studied.

2 REVIEW OF THE LITERATURE

2.1 Mobility in older people

2.1.1 Mobility limitation

Mobility refers to a person's ability to move him- or herself independently and safely from one place to another (Shumway-Cook & Woollacott 2001). In the present study, mobility is defined as the ability to walk from place to place and mobility limitation as difficulty in walking (United States National Library of Medicine 2009).

According to the widely used framework of the disablement process proposed by Nagi (1976) and further extended by Verbrugge and Jette (1994), functional limitations, such as difficulties in walking, are considered as important mediators of the pathway from disease to disability (Figure 1). Pathology, referring to physiological abnormalities, such as chronic diseases or injury, affects specific body systems and may result in impairments such as decreased muscle strength and balance. These impairments usually lead to functional limitation, which in turn may finally cause disability. In addition to pathology and impairment, different predisposing risk factors, such as certain demographic, social, lifestyle and behavioral characteristics of an individual, may have a direct or indirect effect on the development of functional limitation. Also, extra-individual factors, such as medical care, rehabilitation, external supports and the immediate environment, and intra-individual factors, such as lifestyle and behavioral changes, psychosocial attributes, and activity accommodations may either increase or reduce functional limitation or disability (Verbrugge & Jette 1994).

The Nagi´s disablement model has proven useful as a language used by researchers, and the model has been successfully utilized as a theoretical pathway and tested empirically in multiple data sets (Guralnik & Ferrucci 2009). The Nagi´s model is used as a theoretical frame also in this present study.

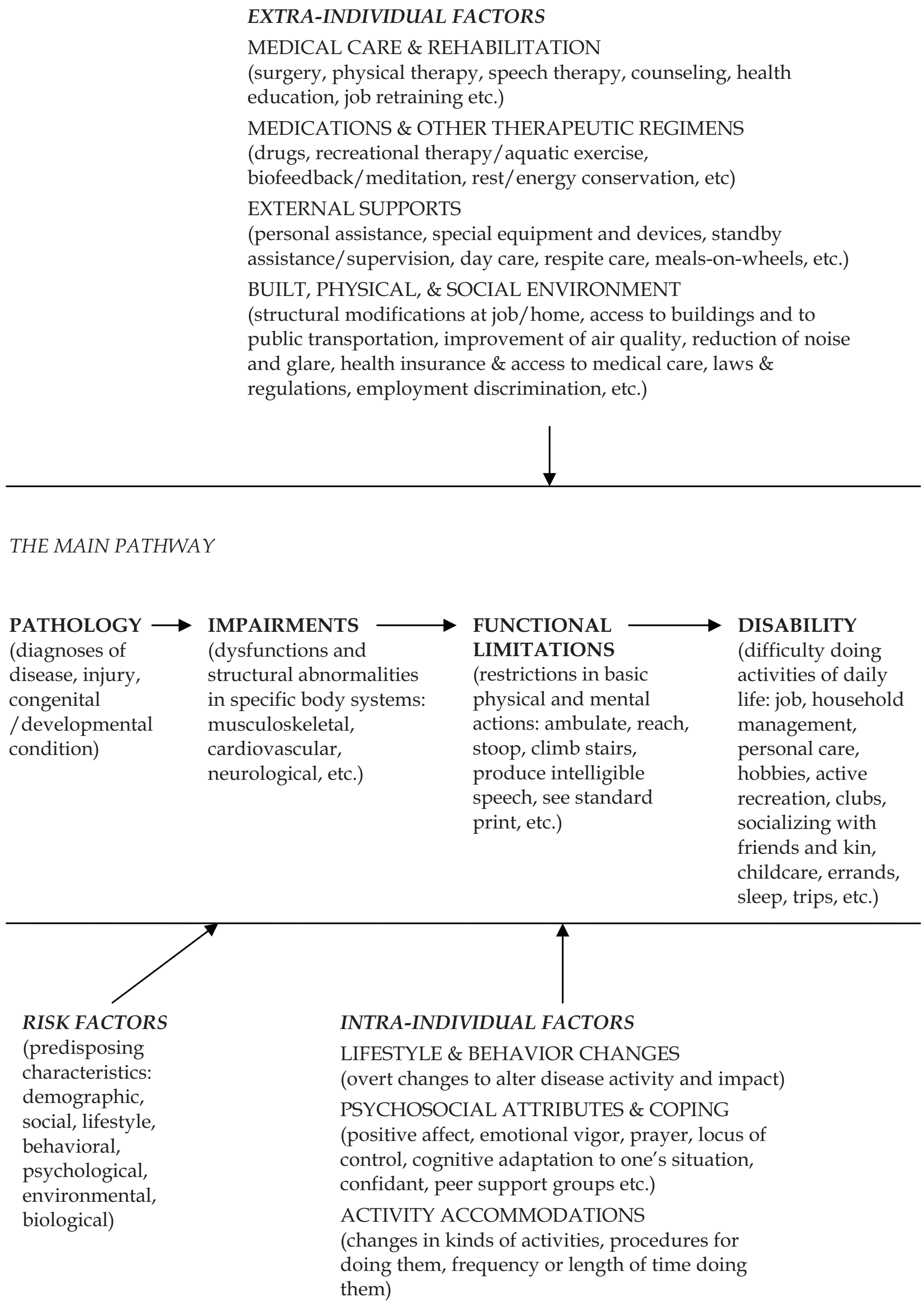

FIGURE 1 The disablement process (Verbrugge & Jette 1994).

In the past decade, the World Health Organization (WHO) has proposed the International Classification of Functioning, Disability and Health (ICF) (WHO 2001, WHO 2004). The framework identifies three levels of human functioning: functioning at the level of body or body part, the whole person, and the whole person in a social context. Functioning and disability are considered to be the result of complex interaction between health conditions and both environmental and personal contextual factors (WHO 2002). The ICF framework has been developed as a multipurpose classification intended for a wide range of uses in different sectors (WHO 2001, WHO 2002) and it has been proposed to serve as a helpful tool to support practical work and research by offering an internationally common language for different aspects of disability (Jette 2009). However, at the same time, the limitations and difficulties regarding the application of the ICF model in disability research have been discussed (Institute of Medicine 2007, Guralnik & Ferrucci 2009). Above all, it has been clearly highlighted that to be able to adapt the ICF framework fully in aging and disability research, more comprehensive interpretation and categorization of the concepts of the model are needed (Institute of Medicine 2007, Guralnik & Ferrucci 2009).

Assessing functional limitations can provide important information in both the research and clinical setting. In aging research, measures of functional limitation are often used as outcomes that indicate the impact of disease, impairments, and other risk factors on function. On the other hand, measures of functional limitation can be used to describe the functional status of individuals and populations, and as predictors of various adverse outcomes (Guralnik et al. 1996, Guralnik & Ferrucci 2003). For example, several previous studies have shown that functional limitations, such as difficulties in walking, are strong predictors of further disability (Guralnik et al. 1995, Guralnik et al. 2000, Shinkai et al. 2000, Cesari et al. 2005, Onder et al. 2005), development of dependency (Guralnik et al. 1994, Penninx et al. 2000, Cesari et al. 2005) and mortality (Guralnik et al. 1994, Markides et al. 2001, Melzer et al. 2003, Cesari et al. 2005). In addition, functional limitations are valuable endpoints in intervention studies aiming to improve functioning and they are suggested to represent an outcome that is relatively free of cultural and environmental influences (Guralnik et al. 1996, Guralnik & Ferrucci 2003).

Limitations in mobility have been shown to increase with higher age (Aromaa et al. 1989, Bohannon 1997, Freedman & Martin 1998, Aromaa & Koskinen 2004, Sainio et al. 2006), while the prevalence of difficulties in specific mobility tasks tends to be higher among older women than men (Bohannon 1997, Freedman & Martin 1998, Aromaa & Koskinen 2004, Sainio et al. 2006). For example, Bohannon (1997) found in their cross-sectional study that the average maximal walking speed among 30-year-old healthy women and men was 2.3 m/s and 2.5 m/s, respectively, while maximal walking speed among 60- to 70-year-old healthy women and men had decreased to 1.7 m/s and 2.0 m/s. In the Finnish nationally representative cross-sectional Health 2000 survey, 11% of women and 7% of men aged 55 to 64 years had a maximal walking speed of less than 1.2 m/s, whereas among 75- to 84–year-olds the corresponding proportions were already 67% and 49% (Aromaa & Koskinen 2004, Sainio et al. 2006). This was also reflected in perceived mobility. For instance, the proportion of 55- to 64-year-old Finnish men and women reporting difficulties in walking 0.5 km was 8% for both genders, while the corresponding proportion increased to 52% among women and to 41% among men aged 75 to 84 (Aromaa & Koskinen 2004, Sainio et al. 2006).

Cohort studies with representative samples of older people have shown that during the past three decades functional limitations have been gradually declining (Freedman & Martin 1998, Liao et al. 2001, Freedman et al. 2002, Aromaa & Koskinen 2004, Murabito et al. 2008). For example, Freedman & Martin (1998) showed that 33% of the US population aged 65 to 79 years reported difficulty in walking 400 meters (¼ mile) in the year 1984 whereas the corresponding percentage among those at the same age in 1993 was 27%. Among those aged 80 years and over, the corresponding numbers were 58% and 50% (Freedman & Martin 1998). In Finland, the Mini-Finland Health Survey (Aromaa et al. 1989) conducted during the years 1978 and 1980 and the Health 2000 survey (Aromaa & Koskinen 2004) carried out in 2000-2001 showed that among persons aged 65 and older the proportion reporting difficulties in walking 500 meters declined during these two decades from 44% to 28% among men and from 45% to 35% among women (Aromaa & Koskinen 2004). These declining trends in the prevalence of functional limitations may be partly explained by shifts in the demographic and socioeconomic composition of the older population (Freedman & Martin 1998). Education especially has been shown to be associated with these improvements (Freedman & Martin 1999). In addition, reductions in the debilitating effects of various chronic conditions are important in explaining declines in limitations experienced by older people (Freedman & Martin 2000). However, to date potential mediators for these improvements in the functional status of older people are not fully understood and clearly merit further investigation (Freedman et al. 2002).

Although much research has been done on the prevalence of and risk factors for mobility limitation, little work has focused on the pace of mobility limitation progression (Guralnik et al. 2001, Ayis et al. 2006). The results from a 7-year prospective cohort study by Guralnik et al. (2001) indicated that the onset of mobility disability can be sudden and catastrophic in some persons and slowly progressive in others. In addition, their results confirmed that both risk factors and mortality outcomes were different for progressive and catastrophic mobility disability, supporting the value of ascertaining the pace of disability development as a useful characterization of disability (Guralnik et al. 2001). Catastrophic disability is often a result of events such as hip fractures and strokes (Jarnlo 1991, Lamb et al. 1995, Kwakkel et al. 1996, Hendricks et al. 2002, Portegijs et al. 2008a), whereas worsening conditions, such as arthritis and peripheral artery disease, are examples of conditions that can cause progressive functional decline over many years (McDermott et al. 2002, Fautrel et al. 2005, van Dijk et al. 2006, McDermott et al. 2009a).

It has been also suggested that mobility disability among older persons is a dynamic process, with many older persons making multiple transitions between states of disability (Gill et al. 2006). Individuals who develop a limitation may recover from it, and possibly later on become disabled again (Beckett et al. 1996, Leveille et al. 2000, Gill et al. 2006, Jagger et al. 2007). Gill et al. (2006) showed in their 5-year prospective cohort study of community-living older persons that mobility disability, defined as the inability to walk a quarter of a mile and to climb a flight of stairs, is a highly dynamic process, characterized by frequent transitions between states of independence and disability. These results indicate that to enhance independent mobility requires a focus not only on the prevention of mobility disability but also on the restoration and maintenance of independent mobility in older persons who become disabled (Gill et al. 2006).

2.1.2 Self-reported preclinical mobility limitation

Early detection of the onset of the progressive disablement process is crucial from the perspective of primary prevention (Fried & Guralnik 1997, Guralnik et al. 2003). Poor performance in objective measures of physical performance is highly predictive of subsequent disability (Guralnik et al. 1995, Guralnik et al. 2000, Onder et al. 2005) and development of dependency (Guralnik et al. 1994, Penninx et al. 2000) among older adults. However, in some circumstances there is also a need for valid self-report measures as these do not require a specific location or equipment and they can be administered, for example, through phone interview, written questionnaire or in everyday clinical settings. Most existing self-report instruments primarily assess difficulty, inability or the degree of assistance required with respect to performing specific tasks of mobility, household management or personal care. Thus, these measures may not be sensitive enough to recognize early steps along the path to disability (Fried et al. 1991, Fried et al. 1996).

In the early stages of functional decline prior to the onset of task difficulty, older persons may be able to compensate for underlying impairments or physiological decrements by modifying their task performance, and thus maintain their everyday function without strong perception of difficulty. For example, a person may have reduced his or her walking pace or uses a mobility aid in order to manage a certain walking distance without perceiving difficulty in doing so. This stage of functional decline, that is, change in the method, frequency, or time used in task performance have been conceptualized as *preclinical mobility limitation*, a stage between good mobility and manifest mobility limitation (Fried et al. 2000, Fried et al. 2001, Wolinsky et al. 2005) (Figure 2). In addition, increased tiredness in daily activities, as introduced by Avlund et al. (1998, 2001, 2003, 2004), can be considered as an early sign of functional decline. From the perspective of the theory of selective optimization with compensation by Baltes and Baltes (1990), preclinical disability encompasses a range of adaptations, including “selection” by performing the activity less often, “optimization” by planning activities to avoid problems and “compensation” by using assistive devices and receiving help (Baltes & Baltes 1990, Gignac et al. 2000, Gignac et al. 2002). In addition, Verbrugge and Jette (1994) have referred previously to related activity accommodations affecting the disablement process (Figure 1). At the conceptual level, preclinical disability can be considered as having a dual nature with compensation as both a risk marker associated with impairment or limitation and a mediating risk factor affecting the natural history of disability (Weiss et al. 2007).

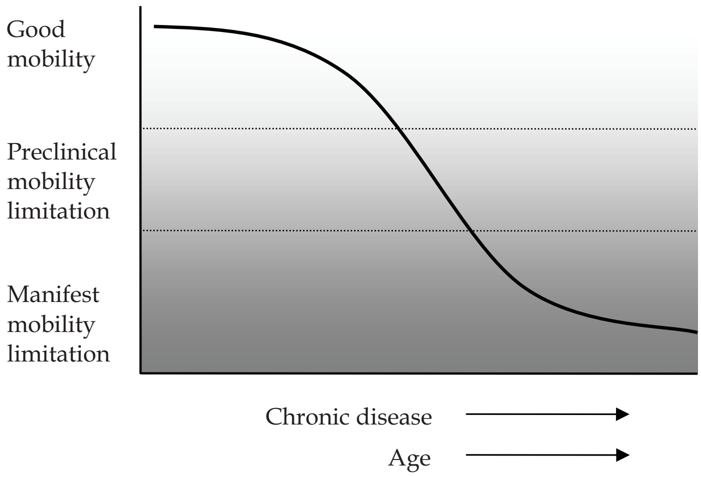

FIGURE 2 A conceptual representation of mobility decline illustrating the intermediate stage of preclinical mobility limitation through which the individual may pass during a chronic progression of manifest limitation. Modified from Fried et al. 2000.

There is some evidence that preclinical disability is an independent and strong predictor of risk for incident mobility disability (Fried et al. 2000, Wolinsky et al. 2005). Fried et al. (2000) showed in their prospective population-based cohort study that older women reporting no difficulty but who had modified their task performance had a three- to four fold higher risk of developing difficulties in mobility during an 18-month follow-up period compared to women who did not report difficulty or modification at baseline. In addition, they found that self-reported preclinical disability was associated with declines in objectively measured function, for example in walking speed, lower extremity strength and balance (Fried et al. 2001). Respectively, Avlund et al. (2002) showed among older non-disabled men and women that those who felt tired in their daily activities at baseline had around three times higher odds of developing mobility disability during a 5-year follow-up. The measure of preclinical disability may provide valuable information about the mobility limitation process by offering insight into a critical point of transition to risk for disability, and may help to define a subset of individuals at high risk of developing difficulties in mobility (Figure 2). However, at the time the present study was initiated, more prospective studies were still needed to further validate the preclinical mobility limitation concept with diverse samples of older people.

2.1.3 Determinants of mobility limitation

The essential requirements for successful and effective gait are progression, postural stability and adaptation to meet the goals of the individual and the demands of the environment (Shumway-Cook & Woollacott 2001). To meet these requirements controlled walking performance is dependent on close and continuous cooperation between multiple physiological and psychological characteristics (Sakari-Rantala et al. 1998, Shumway-Cook & Woollacott 2001). Thus, many age- and disease-related changes in these prerequisites challenge walking ability, potentially leading to subsequent mobility limitations and disabilities.

Lower extremity muscle strength is one of the most important physiological requirements for walking ability (Foldvari et al. 2000, Rantanen et al. 2001, Bean et al. 2002a, Tiedemann et al. 2005, Sakari et al. 2010). In addition, changing environmental and task demands often require the ability to generate force at high velocity, for example, when preventing a fall after a trip. Therefore, muscle power (power=force x velocity) is also considered an essential prerequisite for safe mobility (Skelton et al. 1994, Foldvari et al. 2000, Bean et al. 2002a, Bean et al. 2003). It has been suggested that the association between muscle strength and walking speed is curvilinear, and includes thresholds (Young 1986, Buchner et al. 1996a, Rantanen & Avela 1997, Rantanen et al. 1998). A certain minimum amount of muscle force and power is needed to be able to perform a variety of mobility tasks, such as walking, rising from a chair and ascending or descending stairs. Below this minimum threshold the amount of force is insufficient to perform a given functional task whereas above the threshold an increment in muscle force improves the performance of that task. However, at some point a plateau is reached after which performance do not further improve with higher muscle force. Above this threshold or reserve capacity, increments in muscle strength serve as a physiological reserve, providing a safety margin that absorbs age or disease-related changes without a loss in function. (Rantanen & Avela 1997, Rantanen et al. 1998).

In addition to sufficient muscle strength, adequate postural balance is crucial in maintaining upright position during walking (Rantanen et al. 1999, Rantanen et al. 2001, Shumway-Cook & Woollacott 2001, Tiedemann et al. 2005, Sakari et al. 2010). Rantanen et al. (2001) showed in their 3-year prospective study with older women that both poor strength and impaired balance were significant independent predictors of the onset of severe walking disability, with those having poorer baseline values at increased risk of severe walking disability. Most importantly, they observed that the combined effect of these impairments seems to be greater than the sum of the single impairments involved. The risk of developing severe walking disability was more than five times greater among older women with both strength and balance impairment compared with women with no impairments. In addition their results indicate that to some extent strength can compensate for poor balance and that the strength requirements for walking may be reduced by improving balance (Rantanen et al. 2001).

Other important physiological factors underlying mobility limitation in old age include low aerobic capacity (Buchner et al. 1996b, Morey et al. 1998, Alexander et al. 2003), reduced range of motion (Kerrigan et al. 1998, Sakari et al. 2010) and increased reaction time (Sakari-Rantala et al. 1998, Tiedemann et al. 2005, Sakari et al. 2010). In addition, age- and disease-related changes in sensory functions, such as pathologies within visual, proprioceptive, and vestibular systems reduce the availability of information from these senses for posture and gait, and may thus cause difficulties in maintaining stability and responding to environmental changes while walking (Sakari-Rantala et al. 1998, Shumway-Cook & Woollacott 2001, Cromwell et al. 2002, Tiedemann et al. 2005, Sakari et al. 2010).

The important psychological determinants of mobility include several perceptual and cognitive processes that are critical to successful interaction with the environment. Thus, impairments in perception, such as body image and spatial relation disorders as well as cognitive impairments, such as declines in attention, orientation and memory, affect the ability to move effectively and safely about the environment (Shumway-Cook & Woollacott 2001).

A variety of diseases and medical conditions may cause poor walking performance and mediate the impact of the physiological and psychological determinants of mobility. Cardiovascular and pulmonary diseases, such as hypertension, lower extremity peripheral arterial disease and chronic obstructive pulmonary disease, and related fatal events, such as angina pectoris, stroke and myocardial infarction are strong predictors of mobility limitation (Guralnik et al. 1993, Guccione et al. 1994, Bootsma-van der Wiel et al. 2002, Hendricks et al. 2002, McDermott et al. 2002, Shah et al. 2006, McDermott et al. 2009a). Multiple sclerosis and Parkinson’s disease are examples of neurological disorders causing progressive decline in everyday function and mobility due their debilitating effect on postural control and neuromuscular function (Bootsma-van der Wiel et al. 2002, Paltamaa et al. 2006, Snijders et al. 2007, Matinolli et al. 2009). Among musculoskeletal disorders, painful arthritis especially in the weight-bearing joints is one of the leading causes of mobility limitation (Ettinger et al. 1994, Ling et al. 2003, Fautrel et al. 2005). Diabetes is an example of a metabolic syndrome affecting mobility in old age because of its wide-ranging complications, including cardiovascular and peripheral arterial disease, vision loss, and peripheral neuropathy (Gregg et al. 2002, Volpato et al. 2002, Volpato et al. 2003, Al Snih et al. 2005). Obesity is a major health problem in the industrialized countries and a potential risk factor for many medical conditions, such as diabetes, hypertension and coronary artery disease (Zamboni et al. 2005). In addition, it has been considered as a major risk factor for mobility decline in old age (Zamboni et al. 2005, Mendes de Leon et al. 2006, Stenholm et al. 2007a). Also injurious accidents, such as falls resulting to hip fractures may have detrimental effects on functional ability among older people (Lamb et al. 1995, Portegijs et al. 2008a).

In addition to these direct consequences of pathology or impairment on mobility, prior predisposing risk factors, such as various demographic, lifestyle, and behavioral characteristics of an individual may contribute to the development of mobility limitation (Nagi 1976, Verbrugge & Jette 1994) (Figure 1). For example, low levels of physical activity and smoking have been shown to increase the risk of developing mobility limitation (LaCroix et al. 1993, Hirvensalo et al. 2000). In addition, fear of falling (Scheffer et al. 2008) and fear of moving outdoors (Rantakokko et al. 2009) may increase the risk of losing mobility due to fear-related avoidance of activities (Legters 2002, Jorstad et al. 2005, Deshpande et al. 2008a, Scheffer et al. 2008). Also, intra-individual factors such as psychosocial attributes and coping, and extra-individual factors such as medical care, rehabilitation, external supports and the immediate environment may either reduce or increase functional limitation (Verbrugge & Jette 1994) (Figure 1).

2.1.4 Measurement of mobility

Walking ability in older persons can be assessed either through self-report or through performance-based measures (Guralnik & Ferrucci 2003). Performance-based measures rely on a rater's assessment of a subject's performance of a specific mobility task, measured in a controlled environment. Self-report measures are those that are subject-completed, relying on self-perception of mobility status. They typically assess the subject's performance difficulties, restrictions, or need for assistance associated with functional activity (Guralnik et al. 1989, Guralnik & Ferrucci 2003, Latham et al. 2008). Because no standard procedure for evaluation exists, it is important to consider the relevance as well as sensitivity of a given assessment tool in relation to the specific purposes of the measurement. In addition, available equipment, personnel, room, time and financial resources determine the selection of the measurement tool (Guralnik et al. 1989, Guralnik & Ferrucci 2003).

Objective measures of physical performance have been found to be useful in the assessment of physical function (Guralnik et al. 1989, Guralnik & Ferrucci 2003). Of the available physical performance measures, walking speed has been widely recognized as a valid and reliable measure of mobility limitation for healthy and impaired older persons (Guralnik et al. 1995, Guralnik et al. 2000). Several versions of tests measuring walking speed are used, including different walking distances covered at either maximal or habitual walking speed. The most often used short-distance tests for walking speed include 2.4 meters (8 feet) (Guralnik et al. 1994, Markides et al. 2001), 4 meters (Rantanen et al. 1999, Studenski et al. 2003), 6.0 or 6.1 meters (20 feet) (Bassey et al. 1992, Fiatarone et al. 1994) and 10 meters (Aniansson et al. 1980, Sakari-Rantala et al. 1995, Kressig et al. 2001, Leinonen et al. 2007, Tiainen et al. 2007). While the habitual walking speed shows the normal performance level in everyday life, the maximal walking speed test captures the highest level of neuromuscular capacity, giving an idea of the individual´s potential to adapt to varying environmental and task demands, for example when crossing a street. Compared to these short-distance tests, long-distance walking tests offer more specific information about the aerobic capacity of older persons. The most commonly reported are the 6-minute walking test (Guyatt et al. 1985, Bean et al. 2002b, Lord & Menz 2002, Enright et al. 2003) and the long-distance corridor walk (400-meters) (Simonsick et al. 2001, Brach et al. 2004, Simonsick et al. 2008). Furthermore, walking has been used as part of a performance battery of physical function measures, such as the Short Physical Performance Battery (SPPB) (Guralnik et al. 1994), or combined with other mobility tasks, such as the Timed Up and Go (TUG) test (Podsiadlo & Richardson 1991) where the person is asked to stand up from sitting in a chair, walk 3 meters, turn around, walk back, and sit down.

In addition to walking time, velocity and distance, walking ability can be evaluated using various kinematic and kinetic measures. These assessments provide an objective description of the movement independent of the forces, such as linear and angular displacements, velocities and accelerations (kinematics), and internal and external forces, that cause the movement, such as joint moments, power and work of the lower limbs (kinetics) (Whittle 1999, Pearson et al. 2004, Winter 2004). These measurements may provide valuable information in evaluating the components of impaired walking. However, they often require complex and sophisticated technological devices operated by trained personnel and are thus costly and seldom used in large studies (Whittle 1999, Pearson et al. 2004, Winter 2004).

Mobility limitation can also be assessed with *self-report* using questionnaires or interviews regarding perceived walking ability. In general, structured questions are posed about perceived difficulties, or need for help in walking a certain distance indoors or outdoors. The distances used include e.g. 400 meters (¼ mile) (Rantanen et al. 1999, Sayers et al. 2004), 500 meters (Aromaa et al. 1989, Sainio et al. 2006, Leinonen et al. 2007), 800 meters (Guralnik et al. 1994, Reuben et al. 2004) and 2000 meters (Sainio et al. 2006, Leinonen et al. 2007). Subjects´ reports of their perceived degree of difficulty have been found to be reliable and valid measures to capture mobility limitation among older people (Guralnik et al. 1994, Fried et al. 2000, Fried et al. 2001).

Performance-based measures benefit from being objective and standardized, and having high sensitivity to change and low vulnerability to external influences such as cognition, culture, language, and education. However, self-report measures are often preferred to objective measures because they are less time- and money-consuming, do not require face-to-face contact, have good face validity, and are more practical for large-scale studies of older adults (Guralnik et al. 1996, Guralnik & Ferrucci 2003, Sayers et al. 2004). All in all, performance and self-report measures complement each other in providing useful information about functional status (Guralnik et al. 1994, Hoeymans et al. 1996, Kivinen et al. 1998, Latham et al. 2008).

2.1.5 Mobility and falls in old age

Several definitions of falls have been used in previous studies. The definition of falls originally proposed by the Kellogg International Work Group on Prevention of Falls by the Elderly (1987) has been widely applied in epidemiologic and intervention studies in this area. They defined a fall as "unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis such as stroke or an epileptic seizure". More recently, the collaborators in the Prevention of Falls Network Europe (ProFaNE) have adopted a simpler definition to include falls that occur from all causes, for example "an unexpected event in which the participant comes to rest on the ground, floor or lower level" (Lamb et al. 2005). This more simple definition may be the most appropriate, for instance, in situations where details of falls are unrecorded, or where a high proportion of subjects cannot provide reliable information about their falls.

According to the previous prospective studies, approximately 30% to 40% of community-dwelling individuals older than 65 years fall every year (Tinetti et al. 1988, Lord et al. 1993, O'Loughlin et al. 1993, Luukinen et al. 1994, Luukinen et al. 1995a, Stalenhoef et al. 2002, Ganz et al. 2007) and about half of those who fall do so repeatedly (Tinetti et al. 1988, Nevitt et al. 1989). Fall rates also increase beyond the age of 65 years, being highest among the oldest old (Tinetti et al. 1988, Lord et al. 1993, O'Loughlin et al. 1993, Luukinen et al. 1994). Furthermore, prospective studies have shown that the incidence of falls is considerably higher among older adults living in residential care facilities or nursing homes than among those living independently in the community (Lipsitz et al. 1991, Luukinen et al. 1995b, Thapa et al. 1996, Lord et al. 2003).

Consequences of falls on mobility. Although not all falls lead to injury, about 5% result in fracture and 5-10% in other serious injuries, such as severe head injuries, joint dislocations, and major soft tissue injuries (Tinetti et al. 1988, Tinetti & Speechley 1989, O'Loughlin et al. 1993, Thapa et al. 1996, Kannus et al. 1999, Gillespie et al. 2008). These injuries may further lead to institutionalization (Tinetti & Williams 1997) and even death (Kannus et al. 1999, Kannus et al. 2005, Piirtola et al. 2008). In terms of morbidity and mortality, hip fracture is one of the most serious fall-related injuries. Up to 30% of older hip fracture patients die within one year of their fracture (Magaziner et al. 1989, Farahmand et al. 2005, de Luise et al. 2008), and most surviving hip fracture patients experience reduced mobility and may lose their ability to function independently (Magaziner et al. 1990, Magaziner et al. 2000, Magaziner et al. 2003, Fredman et al. 2005, Portegijs 2008a, Sihvonen et al. 2009). However, whether falls irrespective of related serious injuries have a negative impact on mobility among older people has been little investigated with prospective studies (Tinetti & Williams 1998, Chu et al. 2006). In addition, it is not known whether indoor and outdoor falls have a different impact on mobility.

Tinetti & Williams (1998) found in their study with community-dwelling Americans over the age of 71 years, that falls and fall related injuries were associated with significant declines in basic and instrumental activities of daily living (BADL and IADL) over a three-year period. Using the same sample, they also observed that falls, and especially falls causing serious injury, such as fractures and head injuries, were strong predictors of placement in a nursing home (Tinetti & Williams 1997). For example, persons with one fall leading to a serious injury had a 10-fold adjusted risk of nursing home admission during the following year, as compared with persons with no falls. Respectively, one previous study with a one-year prospective follow-up showed that falls and fall injuries were associated with declines in balance and walking ability in community-dwelling older adults (Chu et al. 2006). However, in these studies it is not possible to determine for certain whether falls or fall injuries preceded the observed decline in functioning. For example, in the study by Tinetti & Williams (1998), falls were ascertained on a daily basis, while function was ascertained only yearly. Due to this methodological challenge, it is not possible to draw strong conclusions about the cause-effect relationship between falls or fall injuries and functional decline.

In addition to fall-related injuries, falls may have psychological consequences that result in functional decline. For example, fear of falling is common among older people irrespective of a previous fall history. Fear of falling has been reported to occur in up to 92% of older adults who have fallen and even up to 65% of older adults without a previous history of falling (Legters 2002, Jorstad et al. 2005, Scheffer et al. 2008). Fear of falling may increase the risk of losing mobility due to fear-related avoidance of activities (Legters 2002, Delbaere et al. 2004, Jorstad et al. 2005, Deshpande et al. 2008a, Scheffer et al. 2008). Depending on the characteristics of the study sample, 40 to 75% of older people reporting fear of falling also report fear-related restriction of activities (Tinetti et al. 1994, Murphy et al. 2002, Fletcher & Hirdes 2004, Wilson et al. 2005, Zijlstra et al. 2007, Deshpande et al. 2008a, Deshpande et al. 2008b, Curcio et al. 2009). For instance, in the prospective study by Deshpande et al. (2008a) 75% of community dwelling older adults reporting fear of falling also reported activity restriction due to fear. The restriction of activities was found to be a significant independent predictor of worsening ADL disability and accelerated decline in lower extremity performance over a 3-year follow-up (Deshpande et al. 2008a). In addition, fear of falling may be predictive of future falls (Cumming et al. 2000, Delbaere et al. 2004). Cross-sectional studies have also reported poorer measured physical performance, such as poorer balance, lower muscle strength and slower walking speed, in older persons who restrict their activities as a consequence of fear of falling than in those who do not (Kressig et al. 2001, Murphy et al. 2002, Delbaere et al. 2004).

Mobility limitation as a risk factor for falls. A number of studies have identified several risk factors for falling, of which impaired mobility, balance and history of falls have been recognized as among the most important (American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention 2001, Rubenstein & Josephsons 2002, The National Institute for Clinical Excellence 2004, Tinetti & Kumar 2010). In their review Rubenstein & Josephsons (2002) analyzed 16 studies reporting the relative risks (RR) or odds ratios (OR) for various fall risk factors. For a sample of older adults they summarized the mean relative risk of falls for each risk factor and ranked the 10 most important in descending order of RR/OR as follows: muscle weakness (RR/OR = 4.4), history of falls (3.0), gait deficit (2.9), balance deficit (2.9), use of assistive device (2.6), visual deficit (2.5), arthritis (2.4), impaired ADL (2.3), depression (2.2), cognitive impairment (1.8) and age > 80 years (1.7) (American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention 2001, Rubenstein & Josephsons 2002). A subsequent update conducted by the National Institute for Clinical Excellence (2004) and Tinetti & Kumar (2010) confirmed that impaired mobility and previous fall history are the two most important risk factors for falls among community-dwelling older people and those living in residential care facilities. Further, poor health and functional performance have been shown to be independent risk factors for indoor falls, whereas outdoor falls seem to be more common among healthy and active older people (Bath & Morgan 1999, Bergland et al. 2003, Pajala et al. 2008). At the time the present study started, no studies had yet been published on the association between preclinical mobility limitation and future falls.

2.2 Physical activity in the prevention of mobility limitation in old age

2.2.1 Physical activity guidelines

Physical activity is defined as any bodily movement produced by the contraction of skeletal muscles that results in a substantial increase over resting energy expenditure. *Exercise* is a type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness. *Physical fitness* is a set of attributes or characteristics that people have or acquire that relates to the ability to perform physical activity. These characteristics are usually separated into health-related, e.g. cardiovascular endurance, muscle strength and flexibility, or skill-related, e.g. balance, coordination and reaction time, components (Caspersen et al. 1985, WHO 2007, American College of Sports Medicine 2010).

Based on physiological, epidemiological, and clinical evidence, physical activity guidelines for health and principles of exercise prescription for older people have been established. The physical activity recommendations for older adults (Nelson et al. 2007a, Nelson et al. 2007b) resemble the recently updated recommendations for adults issued by the American College of Sports Medicine and American Heart Association (Haskell et al. 2007a, Haskell et al. 2007b) with some important additions and modifications appropriate for older persons

(American College of Sports Medicine 2010). According to these recommendations, to promote and maintain health, older adults need moderate-intensity *aerobic physical activity* producing noticeable increases in heart rate and breathing for a minimum of 30 minutes on five days each week or vigorous intensity aerobic activity producing large increases in heart rate and breathing for a minimum of 20 minutes on three days each week. This recommended amount of aerobic activity can be accumulated by performing bouts each lasting 10 or more minutes. Suitable forms of aerobic physical activity for older adults are, for example, walking, cycling, cross-country skiing and water sports. In addition, older adults should perform moderate to vigorous intensity *progressive muscle-strengthening activities* involving all the major muscle groups a minimum of two days each week. Because of the dose-response relation between physical activity and health, participation in aerobic and muscle-strengthening activities above these minimum recommended amounts may provide additional health benefits and results in higher levels of physical fitness. However, in all activities, the older adult's level of fitness should be taken into account and the intensity of the activities adjusted accordingly. *Flexibility activities* should be performed at least two days every week for at least 10 minutes each day to maintain the range of motion necessary for regular physical activity and daily life. In addition, to reduce the risk of falls and related injuries, older adults who are frequent fallers or have mobility problems should also perform *specific balance exercises*. These physical activity recommendations may be difficult to attain, especially among frail and chronically ill older adults. Thus the recommendations should be always tailored and defined relative to an individual´s abilities, fitness and health, especially among the above-mentioned population segments (Nelson et al. 2007a, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention 2008, American College of Sports Medicine 2010). The recommendations given by the WHO (2007) are in line with the American College of Sport Medicine recommendations described above. In Finland, the UKK Institute for Health Promotion Research has developed the "Physical Activity Pie" to combine and clarify the current physical activity recommendations for health and fitness for adults (Fogelholm et al. 2005, UKK institute 2009).

2.2.2 Physical activity in old age

Longitudinal (Armstrong & Morgan 1998, Bennett 1998, Bijnen et al. 1998, Hirvensalo et al. 1998) and cross-sectional (Caspersen et al. 2000, Fogelholm 2007, Ashe et al. 2008, Kruger et al. 2008, Troiano et al. 2008) studies indicate that physical activity decreases with increasing age among older people. For example, Bijnen et al. (1998) reported that among retired Dutch men aged 65 to 84 years in 1985, the total time spent on physical activity decreased by 33% during ten years of follow-up. Similarly, among Finnish women aged 75 to 84 years at baseline, the proportion of those reporting walking for fitness over three times per week declined from 47% to 25% during an 8-year follow-up. The corresponding numbers for men were 48% and 40% (Hirvensalo et al. 1998). In turn, the cross sectional study by Kruger et al. (2008) showed that in 2005 the proportion of the older U.S. population who did not engage in leisure-time physical activity was 29% among those aged 65 to 74 years, 37% among those aged 75 to 84 years and 46% among those aged ≥ 85 years. In addition, Matthews et al. (2008) showed in their cross sectional study that the most sedentary groups in the United States during the years 2003-2004 were older adolescents and adults aged ≥ 60 years, who spent about 60% of their waking time in sedentary pursuits.

On the other hand, some cohort studies have shown that leisure-time physical inactivity among older persons has somewhat declined during the past two decades (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention 2004a, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention 2005a, Hirvensalo et al. 2006). For example, among older urban Finnish adults, the proportion of 65- to 69-year old men who did not engage in leisure-time physical activity, decreased from 19% in the year 1988 to 14% in the year 1996, and further to 8% in the year 2004. For women, the corresponding proportions were 21%, 9% and 5% (Hirvensalo et al. 2006). At the same time, the frequency and intensity of physical activity increased. The proportion of 65- to 69-year-old adults reporting moderate intensity physical activity producing noticeable increases in heart rate and breathing ≥ 3 times a week was 16% among men and 13% among women in the year 1988. The corresponding percentages for those at the same age in the year 1996 were 26% and 20% and in the year 2004 31% and 38% (Hirvensalo et al. 2006). For comparison, a large survey study, the Behavioral Risk Factor Surveillance System (BRFSS), among a representative sample of the U.S. population showed that 33% of 60- to 69-year-old men and 37% of same-age women did not engage in leisure-time physical activity in the year 1988, whereas the corresponding percentages among those at the same age in 2002 were 26% and 31%. Among men and women aged ≥ 70 years, the proportions reporting no leisure-time physical activity in the year 1988 were 37% and 47%, respectively, and in the year 2002 31% and 39% (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention 2004a)

Although some decline in the prevalence of inactivity has been observed over the previous decades and despite the fact that the potential benefits of an active lifestyle are widely known, a substantial proportion of older adults do not participate in physical activity at the level recommended as beneficial to health (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention 2005b, Fogelholm 2007, Ashe et al. 2008). In Finland, the Health 2000 survey carried out in 2000-2001 showed that around 40% of older adults aged 65-74, around 30% of older adults aged 75-84 and only around 20% of those aged 85 or over reported participation in physical activity at the recommended minimal level (Fogelholm 2007). For comparison, Ashe et al. (2008) reported in their cross-sectional study, that around 30% of Canadian older adults over 65 years of age with no chronic diseases meet the guidelines of leisure-time physical activity, while only 23% met the recommendations if they had one or more chronic diseases. Respectively, a population-based survey of the U.S. population showed that around one fourth of 65- to 74-year-old men and women reported participation in regular moderate or vigorous intensity physical activity during the years 2001-2006. Among persons aged 75 years and over, the corresponding proportion was only around 15% (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention 2004b, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention 2005b). In the light of these observations, effective evidence-based strategies to encourage older adults to be physically active are indisputably needed.

Walking, gardening and home exercises are the most prevalent activities reported among older adults (Hirvensalo et al. 1998, Hirvensalo et al. 2006, Fogelholm et al. 2007, Rasinaho et al. 2007, Ashe et al. 2008). In addition, swimming, cross-country skiing, cycling and dancing are examples of exercise modes favored by the Finnish older population (Hirvensalo et al. 1998, Hirvensalo et al. 2006). An array of demographic (e.g. age and education), physiological (e.g. physical function, pain, obesity and chronic diseases), psychosocial (e.g. personality, self-efficacy and social support), behavioral (e.g. activity history), and environmental factors (e.g. safety and accessibility) may determine physical activity behavior in older age (DiPietro 2001, Trost et al. 2002). The most frequently reported important motives for physical activity among older people are health promotion and social life, whereas the main obstacles include poor health and lack of interest (Hirvensalo et al. 1998, Cohen-Mansfield et al. 2003, Schutzer & Graves 2004, Hirvensalo et al. 2006, Newson & Kemps 2007, Rasinaho et al. 2007). Many older people have also a fear of falling and injury, and feel insecure when exercising (Legters 2002, Jorstad et al. 2005, Scheffer et al. 2008, Sallinen et al. 2009).

2.2.3 Physical activity interventions to prevent mobility decline

Physical activity and exercise are widely promoted as effective means to enhance health and physical functioning among older adults (Keysor & Jette 2001, Keysor 2003, Bean et al. 2004a, Taylor et al. 2004, American College of Sports Medicine 2009, Manini & Pahor 2009). Several observational longitudinal studies have indicated that physical activity ameliorates the progression of mobility limitation in old age (e.g. LaCroix et al. 1993, Clark 1996, Schroll et al. 1997, Miller et al. 2000, Hillsdon et al. 2005b, Simonsick et al. 2005, Visser et al. 2005, Wannamethee et al. 2005, Christensen et al. 2006, Patel et al. 2006, Boyle et al. 2007, Manini et al. 2009) and multiple randomized controlled intervention trials (RCTs) have reported the beneficial effects of various exercise programs on mobility outcomes among healthy older adults as well as among frail and chronically ill older people (Fiatarone et al. 1994, Lord et al. 1996, Ettinger et al. 1997, Singh et al. 1997, Jette et al. 1999, Brandon et al. 2000, Schlicht et al. 2001, Tyni-Lenne et al. 2001, Timonen et al. 2002, Brandon et al. 2003, Hiroyuki et al. 2003, Bean et al. 2004b, Binder et al. 2004, Kongsgaard et al. 2004, Ouellette et al. 2004, LIFE Study Investigators et al. 2006, Tsourlou et al. 2006, Karinkanta et al. 2007, Henwood et al. 2008, Portegijs et al. 2008b, Sherrington et al. 2008, Bean et al. 2009, McDermott et al. 2009b). These intervention studies have included many different types of physical activity programs, ranging from simple home exercise programs to intense highly supervised hospital or center based programs. In addition, the frequency, intensity, duration and mode of the physical exercise have varied considerably between these different physical activity programs.

Several critical and systematic reviews and meta-analyses have been conducted in the last decade on the effects of randomized controlled physical activity trials on functional level outcomes among older adults with diverse health status. These reviews have shown interventions to have modest to strong beneficial effects on mobility outcomes (e.g. Keysor & Jette 2001, Latham et al. 2004, Bendermacher et al. 2006, Lopopolo et al. 2006, Bartels et al. 2007, French et al. 2007, Lange et al. 2008, Watson et al. 2008, Fransen & McConnell 2009, Fransen et al. 2009, Liu & Latham 2009, Saunders et al. 2009). For example, Liu and Latham (2009) showed in their recent systematic meta analysis on 121 randomized controlled trials involving a total of 6700 participants that progressive resistance strength training had a large positive effect on muscle strength, modest improvements in gait speed and moderate to large effect for getting out of a chair among older people with various health status. In the selected trials, the strength training was performed on average two to three times per week for eight to 12 weeks. Most of the programs included supervised high intensity training. Similar results were observed in two previous systematic reviews on progressive resistance strength training (Latham et al. 2004, Latham et al. 2007) Keysor and Jette (2001) summarized the exercise effects on walking in 31 experimental aerobic and resistance exercise interventions among older adults. Of the 21 studies in which walking were examined, 67% reported that walking ability improved significantly among those in the exercise group as compared with controls. Similarly, 5 out of 10 studies examining the effects of exercise on chair rise, reported improvements among exercise subjects as compared to controls. On average, the exercise training was performed two to three times per week with most interventions lasting 2 to 3 months (Keysor & Jette 2001). In addition, a meta-analysis of 24 intervention studies (Lopopolo et al. 2006) indicated that strength training and combination training, including aerobic and other exercise, had significant positive effects on habitual gait speed in community-dwelling older people. Their analysis also indicated that intensity and dosage of exercise are important contributory factors; high intensity exercise and high-dosage interventions had a significant effect on gait speed, whereas there was no effect for moderate- and low-intensity exercise or for low-dosage exercise (Lopopolo et al. 2006). In addition, several systematic reviews and meta analyses have shown the beneficial effects of exercise on differential mobility outcomes among specific groups of older people, such as older adults with intermittent claudication (Bendermacher et al. 2006, Watson et al. 2008), osteoarthritis (Bartels et al. 2007, Lange et al. 2008, Fransen & McConnell 2009, Fransen et al. 2009) or stroke (French et al. 2007, Saunders et al. 2009). However, the effects of exercise on functional outcomes among, for example, acutely hospitalized older medical patients (de Morton et al. 2007) or older people with dementia (Forbes et al. 2008) remains unclear.

2.2.4 Physical activity counseling

Randomized controlled trials (RCTs) are considered as the gold standard in evaluating the effects of interventions. The efficacy of a specific physical activity program can be evaluated in optimal and highly controlled conditions. Specific exercise trials, such as controlled and supervised strength training interventions are good examples of efficacy (explanatory) trials and they typically show the upper limit of the intervention effect. Effectiveness (pragmatic) studies instead measure the degree of beneficial effects of an intervention in real-world clinical settings (Gartlehner et al. 2006). In health promotion and education, effectiveness can be defined as "the extent to which the intended effect or benefits that could be achieved under optimal conditions are achieved in practice" (Green & Kreuter 1999). While explanatory studies have yielded important insights into the efficacy of exercise training in late life, effectiveness studies, which have more rarely been undertaken, can also offer insight into what makes for a feasible and effective approach to the promotion of physical activity among the older population (Jette et al. 1999). Physical activity counseling is an example of a low cost educational intervention to promote physical activity, where the participant is encouraged to exercise and is provided with advice about possibilities for exercise (Leinonen et al. 2007).

As many older adults use healthcare services regularly, educational physical activity counseling in primary health care settings could be an effective means of increasing physical activity and further slowing down the age-related deterioration in mobility (Hirvensalo et al. 2003). However, despite the known benefits of late-life exercise, many healthcare providers do not counsel their customers about physical activity and exercise (Damush et al. 1999, Hirvensalo et al. 2003, Hirvensalo et al. 2005, Dauenhauer et al. 2006, Schonberg et al. 2006). For example, among a sample of Finnish non-institutional 73 to 92-year-old people who reported at least one contact with health care during the previous 12 months, 34% did not recall exercise-related advice at all (Hirvensalo et al. 2005). Among an older community-dwelling U.S. sample, the prevalence of those who had ever received a recommendation by a physician to engage in exercise was 48% (Damush et al. 1999). Similarly, the 2000 National Health Interview Survey conducted in the United States showed that the prevalence of women who reported receiving recommendations for physical activity was 29% among those aged 65 to 74, 22% among those aged 75 to 84 and only 14% among those aged 85 and older (Schonberg et al. 2006).

The use of behavioral strategies such as the Social Cognitive Theory (Bandura 1998, Bandura 2000, Bandura 2004), the Transtheoretical Model (Prochaska & Velicer 1997, Prochaska et al. 2008) and motivational interviewing technique (Rollnick et al. 1999) have proven useful strategies in health promotion and highly applicable in physical activity counseling (Halbert et al. 2000, Stewart et al. 2001, Kerse et al. 2005, Pinto et al. 2005, Kolt et al. 2007). The social cognitive theory posits a complex causal structure in which self-efficacy beliefs operate together with goals, outcome expectations, and perceived environmental barriers and facilitators in the regulation of human motivation, behavior, and well-being (Bandura 1998, Bandura 2000, Bandura 2004). In this theory, belief in one's efficacy to exercise control is a common pathway through which psychosocial influences affect health functioning. This core belief, self-efficacy, affects each of the basic processes of personal change, that is, whether people even consider changing their health habits, whether they mobilize the motivation and perseverance needed to succeed should they do so, their ability to recover from setbacks and relapses, and how well they maintain the habit changes they have achieved. The Transtheoretical Model (Prochaska & Velicer 1997, Prochaska et al. 2008) describes the individual's motivational readiness to change his or her health behavior and posits that behavior change involves progress through six stages of change: precontemplation, contemplation, preparation, action, maintenance, and termination. The main idea of the model is that interventions targeting health behavior change should be tailored according to each person's level of readiness to change.

So far, previous RCTs have shown that physical activity counseling interventions have a moderate effect on self-reported (Halbert et al. 2000, Stewart et al. 2001, Dubbert et al. 2002, Hillsdon et al. 2005a, Kerse et al. 2005, Pinto et al. 2005, Kolt et al. 2007, Dubbert et al. 2008, Morey et al. 2008) and objectively measured (Dubbert et al. 2008) physical activity among older adults aged 60 and older. In addition to observed increments in physical activity level, small beneficial effects of counselling on general health and some decrements in hospitalization have been reported (Kerse et al. 2005). The effects on quality of life have been somewhat inconsistent, with small positive (Halbert et al. 2000, Kerse et al. 2005) and non-significant effects (Kolt et al. 2007). In these previous RCTs the duration of counseling interventions has varied between three (Kerse et al. 2005, Kolt et al. 2007) and 12 months (Stewart et al. 2001) with up to 12 months of follow-up (Halbert et al. 2000, Stewart et al. 2001, Kerse et al. 2005). The interventions have comprised individualized face-to-face counseling session reinforced with supportive phone calls (Halbert et al. 2000, Stewart et al. 2001, Dubbert et al. 2002, Kerse et al. 2005, Dubbert et al. 2008) or counseling over the telephone combined with mailed materials (Kolt et al. 2007, Morey et al. 2008).

At the time the Finnish randomized controlled trial "Screening and Counseling for Physical Activity and Mobility in Older People (SCAMOB)" was initiated in the spring 2003, the evidence on the effects of physical activity counseling on preventing or slowing down the age-related decline in mobility was very limited (Dubbert et al. 2002).

2.3 Summary of the literature

Mobility limitations are known to increase with higher age (Aromaa & Koskinen 2004, Sainio et al. 2006), and are often the first noticeable signs of further functional decline (Guralnik et al. 1994, Guralnik et al 1995., Onder et al. 2005). In addition, falls and, especially, serious injuries related to falls are known to have a wide range of physical, psychological and economic consequences among older people (Tinetti & Williams 1997, Magaziner 2000, Jorstad et al. 2005). Consequently, with ever larger cohorts surviving to old age, the need to develop efficacious and acceptable ways to slow down the progression of functional decline with age is an important public health priority.

One of the major challenges in the prevention of functional decline and disability in old age is identification of the optimal target population (Ferrucci et al. 2004). While the most common risk factors for mobility decline are nowadays widely recognized, there continues to be a need to the further development of simple and easily administrable tools for identifying at-risk persons in clinical work. Self-reported preclinical mobility limitation (Fried et al. 2000, Fried et al. 2001, Wolinsky et al. 2005) may provide an inexpensive basis for screening and early intervention to prevent functional decline and disability among older people, and is thus an important subject for future studies.

Physical activity and exercise are widely promoted as effective means to enhance health and physical functioning of older persons (Keysor & Jette 2001, Taylor et al. 2004, Manini & Pahor 2009, American College of Sports Medicine 2009). On the other hand, it is less certain how these promising results can be adapted for use in everyday clinical practice, where shortage of time often imposes limits on the resources that can be used in preventive interventions (Pinto et al. 1998, Tinetti et al. 2006). Physical activity counseling is an example of a low-cost educational intervention aiming to promote physical activity. However, whether physical activity counseling, through increasing physical activity, prevents or slows down the age-related decline in mobility has been little studied (Dubbert et al. 2002).

3 PURPOSE OF THE STUDY

The purpose of this study was to investigate early signs of mobility decline and falls in older people. In addition, the effects of physical activity counseling on the development of mobility limitation in an older community-dwelling population were studied. We hypothesized that self-reported preclinical mobility limitation and fall history would be early indicators of functional decline and future falls in old age (Studies I-III), and that physical activity counseling would ameliorate the age related declines in mobility among older community dwelling people (Studies IV and V).

The specific research questions were:

1. Does self-reported preclinical mobility limitation increase the risk for manifest mobility limitation? Is preclinical mobility limitation associated with declines in physical performance? (Study I)
2. Does preclinical mobility limitation increase the risk for falls? (Study II)
3. Do outdoor and indoor falls predict future mobility decline? (Study III)
4. Does counseling for physical activity have an effect on muscle power and maximal walking speed among older community-dwelling people? (Study IV)
5. Does counseling for physical activity have an effect on the development of perceived mobility limitation among older community-dwelling people? (Study V)

4 METHODS

4.1 Study design and participants

Data from two larger research projects were used in this study. Screening and Counseling for Physical Activity and Mobility in Older People, SCAMOB, is a randomized controlled trial on the effects of physical activity counseling. The study was conducted in the City of Jyväskylä between April 2003 and April 2005 and the post intervention follow-up lasted until November 2006. The Finnish Twin Study on Aging, FITSA, is an epidemiological prospective observational study conducted in the City of Jyväskylä, Finland between September 2000 and March 2004. The data used in the original publications are summarized in Table 1.

4.1.1 Screening and Counseling for Physical Activity and Mobility in Older People (SCAMOB; Studies I, IV and V)

SCAMOB, a 2-year single-blinded randomized controlled trial on the effects of customer-oriented physical activity counseling in older people, is registered as ISRCTN07330512. The target population consisted of all the 75- to 81-year-old residents of Jyväskylä, Central Finland who were living in the city centre area in March 2003 (N=1310). In 2003, when the study was launched, the City of Jyväskylä had about 85 000 inhabitants, of whom 6% were aged 75 years or older.

The contact information for the target population was gathered from the Finnish population register. At baseline, a four-phase screening and data collection process was conducted, including a phone interview, an at-home face-to-face interview and a nurse's examination at the study center, supplemented with a physician's examination if needed. It was considered that cognitively intact old people who were able to move outdoors independently but were physically sedentary would be the group most likely to benefit from physical activity counseling. Thus, to be eligible for the study, persons had to be able to walk 500 meters without the help of another person, have a Mini-Mental State Examination (MMSE) (Folstein et al. 1975) score >21, be only moderately physically active or sedentary (at most 4 hours of walking or 2 hours of other exercise weekly) and have no severe medical contraindications for physical activity as assessed by the study nurse and, where necessary, further evaluated by a physician. The validity of the screening method was supported by the difference in self-rated health between those excluded from the study versus those included in the study. Of those included in the study, 18% reported good, 71% average and 12% poor self-rated health. The corresponding proportions of those excluded due to too high level of physical activity were 45%, 52% and 3%. For those excluded due to inability to walk 0.5 km without assistance, the corresponding proportions were 3%, 36% and 61% (P<0.001) (Leinonen et al. 2007).

The final study group consisted of 632 persons (75% women) who were randomly assigned to the intervention group (n=318) or control group (n=314). Each week after completion of the baseline assessments, participants were allocated to intervention and control groups using a randomization ratio of 1:1 by drawing lots. The randomization was performed by a trial administrator who was blinded to the study participants and their characteristics. After randomization, each participant in the intervention group received a two-year physical activity counseling intervention. The intervention is described in detail in page 47.

For the purposes of the present study, the data used were drawn from the structured interviews and physical performance tests of the trial. The structured face-to-face at-home interviews were conducted at baseline and at the end of the intervention two years later by trained interviewers. The interviews covered topics such as chronic conditions, medication, socio-economic status, cognitive functioning, falls, disability, mobility limitation, health-related lifestyle and physical activity. In addition to these face-to-face interviews, structured phone interviews regarding health, falls, mobility limitation and physical activity were conducted biannually during the 2-year intervention and 1.5-year post-intervention follow-up. Study center examinations, including physical performance measurements by three nurse examiners, were conducted at baseline and at the end of the two-year intervention. The study nurses and the interviewers who collected the data, as well as the assistants who recorded the data, were blinded to the group allocations. Flow charts describing Studies I, IV and V are presented in Figure 3 and Figure 4.

TABLE 1 Study designs, populations and outcomes

Study	Dataset	Design	Participants	Age (mean ± SD)	Primary outcomes
I	SCAMOB	**Observational** Cross-sectional Longitudinal 2-year follow-up	 632 women and men 314 women and men	75-81 (77.6 ± 1.9)	Muscle power Walking speed Mobility limitation
II	FITSA	**Observational** Longitudinal 1-year follow-up	428 women	63-75 (68.6 ± 3.4)	Falls
III	FITSA	**Observational** Longitudinal 3-year follow-up	376 women	63-75 (68.5 ± 3.2)	Mobility limitation
IV	SCAMOB	**Experimental** Randomized controlled trial 2-year intervention	632 women and men Intervention group n=318 Control group n=314	75-81 (77.6 ± 1.9)	Muscle power Walking speed
V	SCAMOB	**Experimental** Randomized controlled trial 2-year intervention with 1.5-year post-intervention follow-up	632 women and men Intervention group n=318 Control group n=314	75-81 (77.6 ± 1.9)	Mobility limitation

SD=Standard deviation

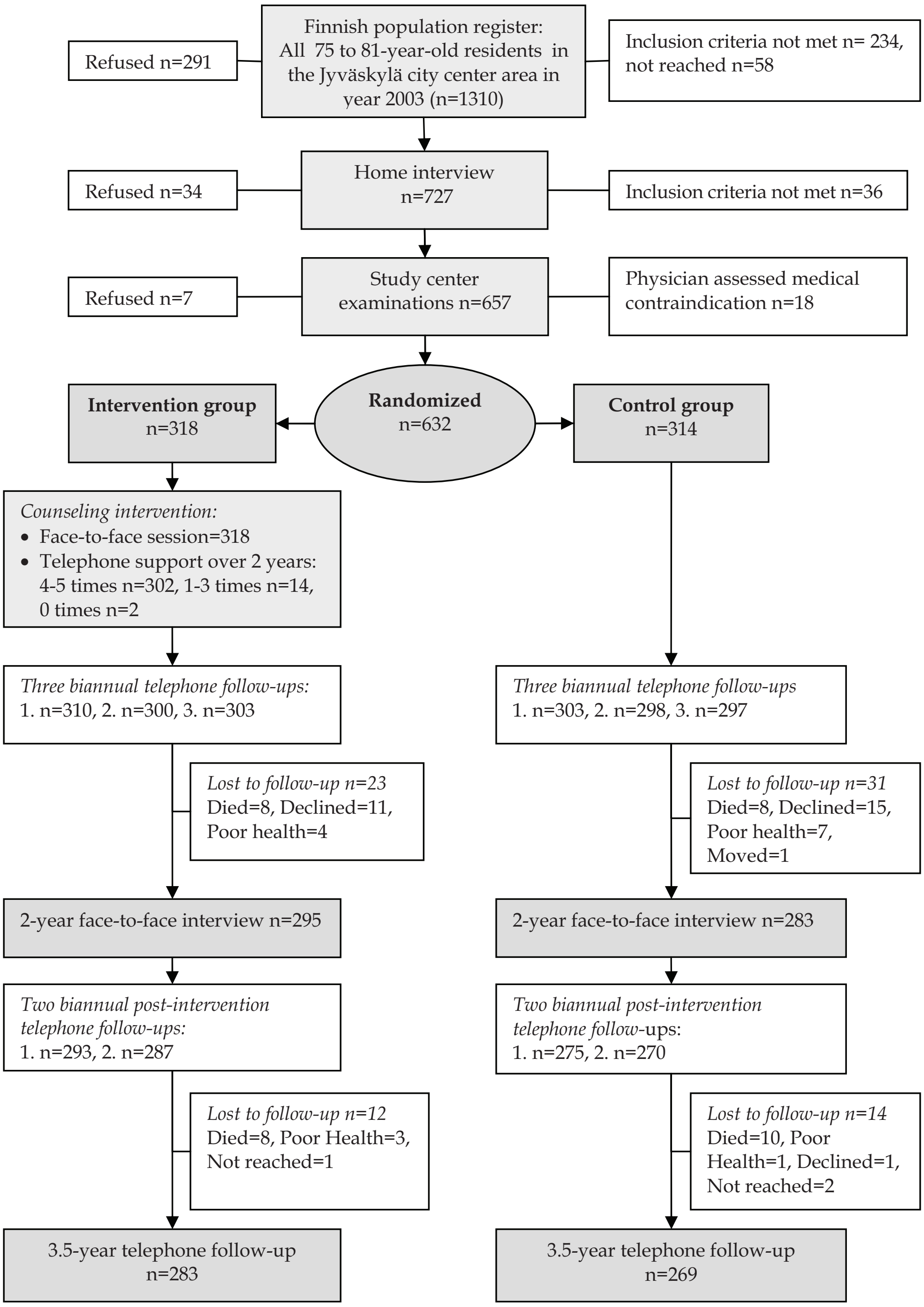

FIGURE 3 Flow chart of the SCAMOB trial according to the self-reported mobility outcomes used in Studies I and V.

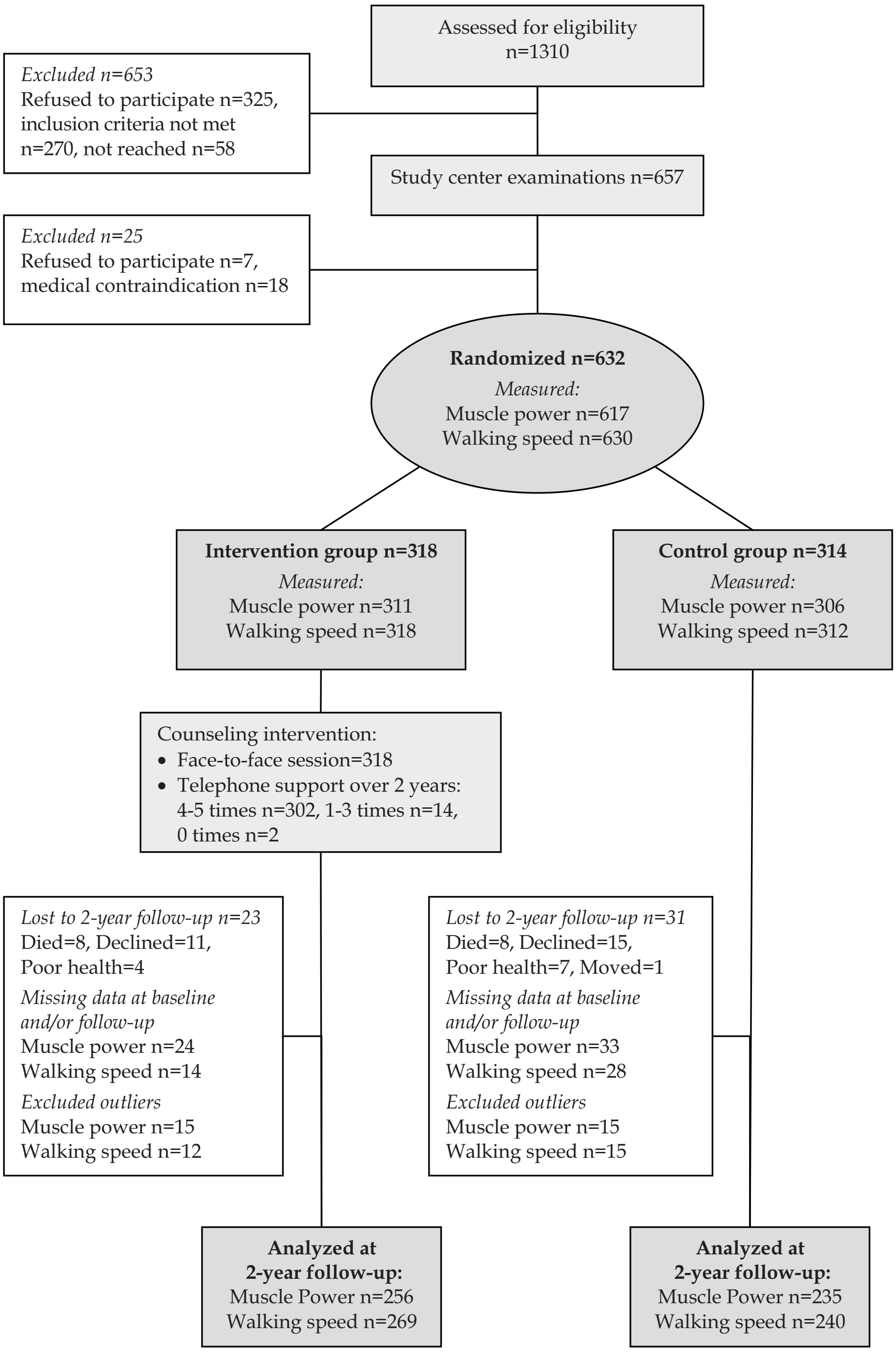

FIGURE 4 Flow chart of the SCAMOB trial according to muscle power and walking speed used in Studies I and IV.

4.1.2 Finnish Twin Study on Aging (FITSA; Studies II and III)

The FITSA study is a prospective observational study of genetic and environmental effects on the disablement process in older, 63 to 75-year-old, female twins (Rantanen et al. 2003, Tiainen et al. 2004, Pajala 2006, Tiainen 2006). The study population consists of monozygotic (n=103), and dizygotic (n=114) twin pairs recruited from the Finnish Twin Cohort (Kaprio et al. 1978, Kaprio et al. 2002). To be eligible for the study, both individuals in the pair had to agree to participate. In addition, they had to be able to walk 2 kilometers and be able to travel independently to the research centre situated in Jyväskylä, Central Finland. In view of these inclusion criteria and the fact that this was a non-clinical population of older women who were community-dwelling, we refer to this population as high-functioning older women.

In this study, baseline and follow-up data used were drawn from the structured questionnaires, fall surveillance and physical performance tests. The baseline laboratory examinations, including physical performance tests, were performed at the research center and followed-up by one-year prospective fall surveillance. The laboratory measurements were repeated 3 years later. Prior to each laboratory examination, participants received a structured health and functional ability questionnaire by mail. The questionnaires were returned when the participants attended the laboratory examinations, and were checked by study personnel.

In the analyses of the present study, the sample was treated as a set of individuals by taking into account the possible dependency between the sisters in each statistical analysis. Figure 5 shows the flow chart of the study according to the outcomes used in the Studies II and III.

4.2 Ethics

The SCAMOB trial and FITSA study were approved by the Ethics Committee of the Central Finland Health Care District. The studies were conducted according to the guidelines for good scientific and clinical practice laid down by the Declaration of Helsinki. Before the laboratory examinations, the participants were informed about the study and a signed informed consent was obtained. All the data were recorded, blinded, handled and registered according to the Finnish Personal Data Act.

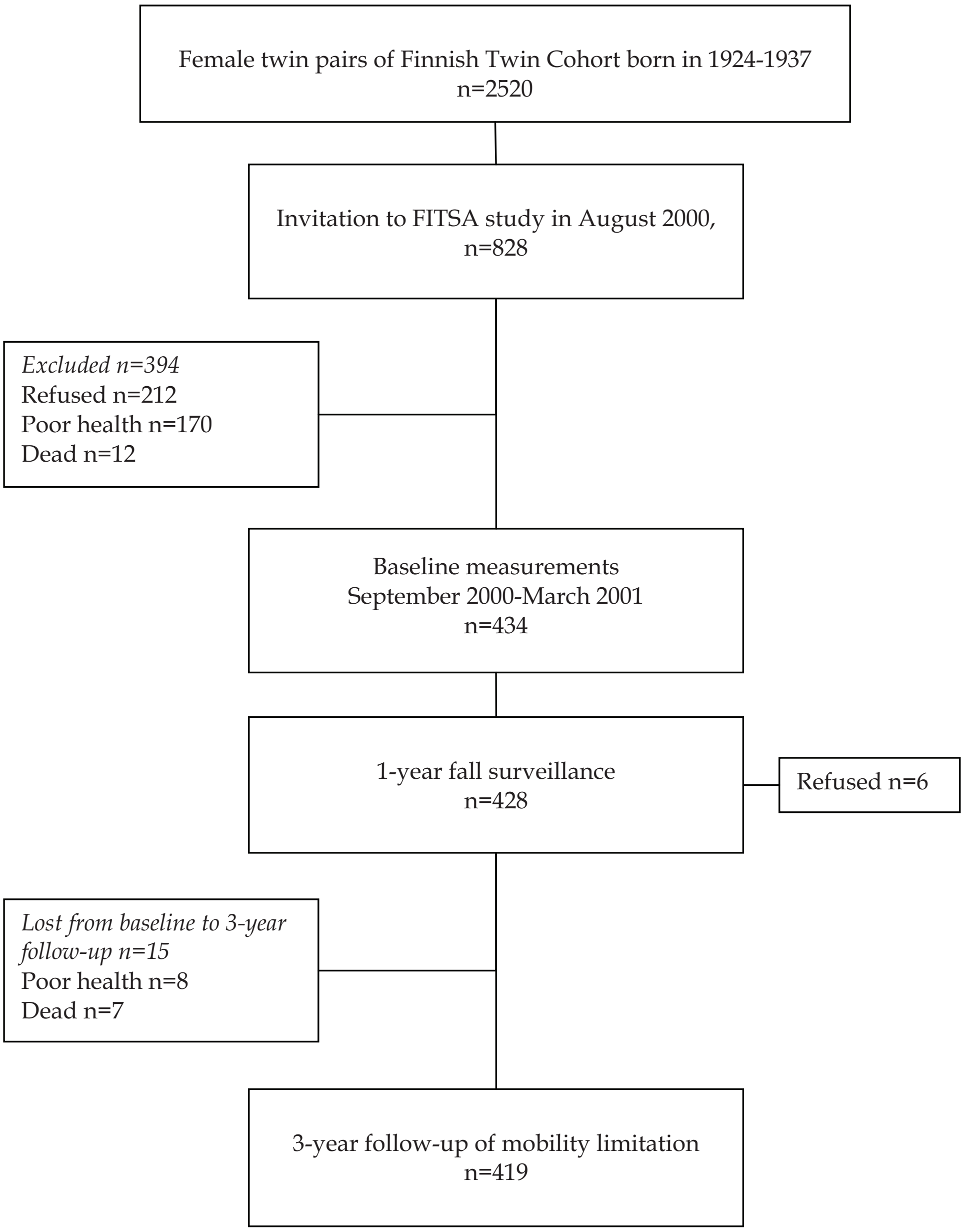

FIGURE 5 Flow chart of the FITSA study according to the fall and mobility limitation outcomes used in Studies II and III.

4.3 Measurements

A summary of the measurements and variables used in Studies I-V is given in Table 2.

4.3.1 Mobility

Baseline and follow-up information on *perceived difficulty in mobility* was available in both the SCAMOB and FITSA datasets. Interview data from the SCAMOB trial was used to determine the ability to walk 2 km (advanced mobility), 0.5 km (basic mobility) and climbing stairs (Studies I, IV and V), whereas, questionnaire-based data from the FITSA study was used to determine the ability to walk 2 km (Studies II and III). In the structured interviews and questionnaires the questions were formulated separately for each mobility task as follows: "Are you able to walk 2 km / 0.5 km /climb one flight of stairs?". The alternative response options given were: 1) able to manage without difficulty, 2) able to manage with minor difficulty, 3) able to manage with great deal of difficulty, 4) able to manage only with help from another person, and 5) unable to manage even with help (Figure 6).

In SCAMOB trial and FITSA study, the questions on the ability to perform each task included possible task modification, that is, *preclinical mobility limitation* (Figure 2, Figure 6). Participants who reported being able to do a given task without perceived difficulties were asked if they had reduced their frequency of doing the task or if their performance had slowed down compared to before (SCAMOB and FITSA; Studies I, II, IV and V). Further alternatives given included: resting in the middle of the performance, using an aid or support, experiencing tiredness when performing the task or some other negative change when carrying out the task (SCAMOB; Studies I, IV and V). The study population was divided into subgroups according to self-reported difficulties and modification of task performance in each mobility task: 1) no mobility limitation (no difficulty, no modification), 2) preclinical mobility limitation (no difficulty, ≥ 1 reported modification) and 3) minor or major manifest mobility limitation (difficulty) (Figure 6; Studies I, II, IV and V).

Maximal walking speed was assessed over a 10-meter distance timed with a stopwatch (SCAMOB, Studies I, IV and V) or photocells (FITSA; Studies II and III). Participants were allowed 2 to 3 meters for acceleration before the start line and they were encouraged to walk as fast as possible without risking their health. Participants wore walking shoes or sneakers, and use of a walking aid was allowed if needed.

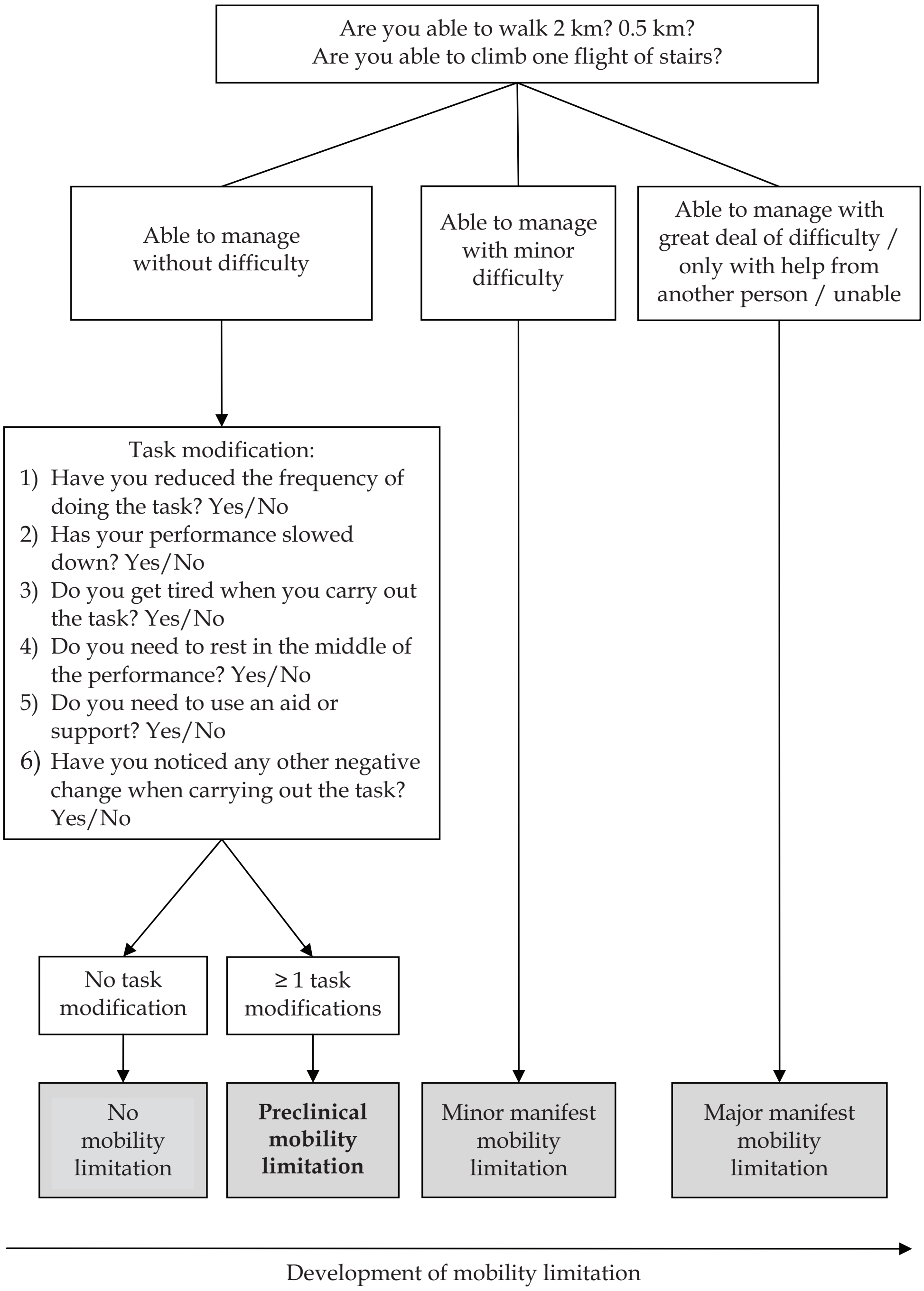

FIGURE 6 Subgroup divisions according to self-reported level of mobility limitation

4.3.2 Muscle power

Leg extensor muscle power was measured using the Nottingham Leg Extensor Power Rig (Bassey & Short 1990). The participant was seated in an upright sitting position with arms folded, one foot placed on the pedal in front of the seat, and the other foot resting on the floor. After 2 to 3 practice trials, participant was asked to push the pedal as hard and fast as possible. Five to nine maximal efforts per leg, separated by 30-second rests, were conducted. The best performance of the dominant leg (Studies I and III) or the best performance of either leg (Studies II and IV) was used as the measure of maximal power.

4.3.3 Prospective fall surveillance

In the FITSA study, the incidence of falls was followed up prospectively for 12 months using monthly fall calendars and telephone contact (Tinetti et al. 1993, Pajala et al. 2008). During the study center visit monthly fall calendars were given to each participant. Every day during the surveillance participants were asked to mark on the calendar whether she/he had fallen or not. At the end of each month the participant mailed the filled calendar page to the research center. The participant was contacted via phone if she/he had forgotten to send the calendar. In addition, if falls were reported, the participant was asked to state the occurrence, location, circumstances, causes and consequences of the fall. A fall was defined as unintentionally coming to rest on the ground, floor, or other lower level for reasons other than sudden onset of acute illness or overwhelming external force (Kellogg International Work Group on the Prevention of Falls by the Elderly 1987).

In this study, data on the incidence of falls (Study II), location of falls (Study III) and fall injuries (Study III) were used. For fall location, participants were categorized into those with no falls (non-fallers), those with ≥1 indoor falls (indoor fallers), and those with ≥1 outdoor falls but no indoor falls (outdoor fallers) (Study III). Severe fall injuries were defined as injuries which required medical attention, e.g. fractures, severe soft tissue injuries or joint dislocations/injuries (Study III).

4.3.4 Fall history

In the FITSA study, fall history was studied at baseline as recollection of falls over the previous 12 months. Participants reporting ≥1 falls were considered as having fall history (Studies II and III).

TABLE 2 Measurement methods and variables used in the original publications, including references and test-retest reliability

Variables	Study	Method and reference	Reliability and reference
Outcome and explanatory variables			
Difficulty in walking 2km, 500m (cat)	I, IV, V	Self-report, interview	Kendall´s tau-b=1.00 (Leinonen et al. 2007)
	II, III	Self-report, questionnaire	
Difficulty in climbing stairs (cat)	I	Self-report, interview	
Preclinical mobility limitation (cat)	I, IV, V	Self-report, interview (Fried et al. 1996, 2000)	κ coefficient 0.47-1.00 (Leinonen et al. 2007)
	II	Self-report, questionnaire	
Walking speed (cont)	I, IV, V	Stopwatch (Aniansson et al. 1980)	
	II, III	Photocells	CV 5% (Pajala et al. 2005)
Muscle power (cont)	I-III, IV	Nottingham power-rig (Bassey & Short 1990)	CV 8% (Tiainen et al. 2005)
Fall surveillance		Fall calendar (Tinetti et al. 1993)	
Falls (cont)	II		
Indoor/outdoor falls (cat)	III		
Fall history (dichot)	II, III	Self-report, questionnaire	
Descriptive, mediating and confounding variables			
Long-term diseases (cont)	I-V	Self-report, confirmed by physician	r=0.89 (Leinonen et al. 2007)
Prescribed medications (cont)	I-V	Self-report, confirmed by physician	r=0.94 (Leinonen et al. 2007)
Cognitive capacity (score 0-30, cont)	I-V	MMSE (Folstein et al. 1975)	
Depressive symptoms (cont)	I	CES-D (Radloff 1977)	Chronbach´s alpha 0.88
Depressive symptoms (dichot)	V		(Heikkinen et al. 1995)
Anthropometry			
Body height (m, cont)	II	Scale stadiometer	
Body weight (kg, cont)	II	Beam scale	
Body Mass Index (BMI, cont)	I, II, IV,V	Calculated: kg/m^2	
Obesity (dichot)	III	BMI ≥ 30	
Education (cont)	I, V	Self-report, interview	

(continues)

TABLE 2 (continues)

Variables	Study	Method and reference	Reliability and reference
Physical activity			
Habitual physical activity (cat)	IV, V	Self-report, interview (Grimby 1986)	Kendall's tau-b=0.87 (Leinonen et al. 2007)
Walking activity (dichot)	II, III	Self-report, questionnaire	
Balance			
Tandem stance ability (dichot)	II	Force plate, the Good Balance System	
Semi-tandem stance ability (cont)	III	(Metitur Ltd., Jyväskylä, Finland)	
Vision (dichot)	II, III	Illuminated Landolt ring chart (Oculus 4512)	
Hearing (dichot)	II, III	Clinical audiometer Madsen OB 822 with THD 39 headphones (Madsen Electronics, Denmark)	
Fear of falling (dichot)	III	Self-report, questionnaire	

CV=coefficient of variation, cat=categorized scale, cont=continuous scale, dichot=dichotomized scale, MMSE=Mini Mental State Examination, CES-D=Center for Epidemiological Studies Depression Scale, BMI=Body Mass Index (kg/m^2)

4.3.5 Descriptive, mediating and confounding variables

Baseline information on the number of *long-term diseases and prescribed medications* was collected during the face-to-face interviews and clinical examinations. In the SCAMOB trial, the information was first elicited during the home interview and then double checked during the study center visit by the study nurse. In the FITSA study, information on the presence of chronic conditions and use of medication was collected using a standardized questionnaire and confirmed by a physician in the clinical examination. *Cognitive capacity* was assessed with the Mini-Mental State Examination (MMSE) (Folstein et al. 1975) (Studies I-V). In the SCAMOB trial, the MMSE score was used as one of the eligibility criteria and persons with a MMSE score under 21 were excluded from the trial. *Depression* was measured with the Center for Epidemiological Studies Depression Scale (CES-D) (Study I) and the cut-off point of 16 was used to distinguish individuals considered to be depressed from those classified as non-depressed (Radloff 1977) (Study V). *Body Mass Index* (BMI, kg/m2) was calculated from body weight and height measured at the laboratory (Studies I-V). Women with BMI ≥ 30 were considered as obese (Study III). *Education* was assessed as total formal education in years (Studies I and V).

In the SCAMOB trial, habitual *physical activity* was assessed with the previously validated seven-point scale by Grimby (1986) (Studies IV and V). The habitual physical activity level was assessed during the face-to-face home interview at baseline and at the end of the 2-year intervention. Participants were asked to evaluate their average physical activity level during the previous 12 months according to seven response options: 1) mainly resting, 2) most activities performed sitting down, 3) light physical activity 1–2 h/wk, 4) moderate physical activity 3 h/wk, 5) moderate physical activity 4 h/wk, 6) strenuous physical exercise several times a week, and 7) competitive sports several times a week. Persons who belonged to the two highest categories were excluded from the SCAMOB trial before the baseline randomization as they would not have benefitted from our physical activity counseling intervention. To study the effects of the intervention on the changes in habitual physical activity from baseline to the 2-year follow-up, we categorized participants into 1) those whose activity level remained moderate or above, or who increased their activity level from sedentary (light physical activity 1–2 h/wk at the most) to at least moderate during the 2-year intervention, and into 2) those who remained sedentary or who reduced their physical activity from at least moderate to sedentary. In the FITSA study, information on weekly walking activity was collected with a questionnaire and then averaged to daily activity by dividing it with seven (Study II). Women whose average walking distance per day was less than 1.6 km (1 mile) were considered as having low walking activity (Hakim et al. 1998).

Balance was measured using the Good Balance force platform (Metitur Ltd, Jyväskylä, Finland) (Studies II and III). Movement of the centre of pressure

(COP) was recorded during a semitandem standing position with eyes open, and the mean moment of velocity (VEL, mm^2/s) calculated as the mean of the areas covered by the movement of COP during each second of the 20 s test (Study III). Lower scores represent better balance. The absolute COP measures were adjusted for the subject's height [(COP variable/ participant height (cm)) × 180]. Balance impairment was assessed as inability to perform the balance test in a tandem standing position in an acceptable manner (Study II). *Visual acuity* (VA) was measured with the illuminated Landolt ring chart (Oculus 4512). Participants were defined as having visual loss if their best distance visual acuity was <1.0 (Kulmala et al. 2009). Audiometric measures were performed using a clinical audiometer Madsen OB 822, equipped with THD 39 headphones (Madsen Electronics, Denmark). A person was defined as having *hearing impairment* if the hearing threshold level (HTL) of the better ear was ≥21 dB (Stephens 2001, Viljanen et al. 2009). *Fear of falling* was self-reported using a structured questionnaire (Study III). In the SCAMOB trial, *adverse effects* which might have resulted from the physical activity counseling intervention were assessed by asking the participants whether they had sustained any injuries in the previous year, and if so, whether these injuries had required medical treatment (Studies IV and V).

4.4 Physical activity counseling intervention

In the SCAMOB trial, each participant in the intervention group received a single individualized motivational face-to-face physical activity counseling session by a physiotherapist who was specifically trained for the task and who did not take part in the data collection process (Leinonen et al. 2007). The average duration of this face-to-face session was 50 minutes. The face-to-face counseling session was followed up with telephone contacts by the same physiotherapist to support compliance and behavior change. Telephone contact took place on average every 4 months during the 2-year intervention (Figure 3, Figure 4). In addition to personal counseling, the intervention group was invited to participate in two voluntary lectures on topics such as home calisthenics and disability prevention. The no-intervention control group continued to receive advice on healthy living habits as usual when visiting health and social service providers and had access to the same public exercise facilities as the intervention group (Leinonen et al. 2007).

The theoretical background of the physical activity counseling was based on the Transtheoretical Model (Prochaska & Velicer 1997, Prochaska et al. 2008), the Social Cognitive Theory of Health Behavior (Bandura 1997), and motivational interviewing technique (Rollnick et al. 1999). In the SCAMOB trial, at the beginning of the face-to-face counseling intervention, the physiotherapist evaluated each participant's readiness to change and tailored the physical activity counseling accordingly (Pelo-Arkko 2009). An important component of the motivational counseling was to promote self-efficacy for more active physical behavior (Leinonen et al. 2007, Pelo-Arkko 2009). The physiotherapist reinforced the ideas for increasing their physical activity presented by the participants themselves. The aim was to motivate change by making the participant notice the discrepancy between the present and the desired level of physical activity. From this point of view, the physiotherapist helped the participant to use problem-solving approaches to address the barriers to change and develop a plan for more active physical behavior. The topics covered during the counseling sessions included the participants´ present level of physical activity and interest in beginning or maintaining physical activity or exercise, that is, willingness to be active in performing everyday chores, to exercise on their own, or to participate in exercise classes. In addition, potential barriers to exercise and strategies to overcome these were considered. The physiotherapist and the participant together designed a personal physical activity plan that could be carried out by the person alone after the counseling session, for example, in an exercise center (Leinonen et al. 2007, Pelo-Arkko 2009).

4.5 Statistical methods

The descriptive statistics were analyzed using SPSS (SPSS Inc., version 14.0 and 15.0) (Studies I, IV and V) and STATA (Stata Corp., version 10) (Studies II and III) software. The baseline comparisons of the discrete characteristics of the study groups were performed using Pearson's χ^2 –test and comparisons for continuous variables were done using independent sample Student's t-test and one-way analysis of variance (ANOVA). In this study, the original FITSA twin sample was treated as a set of individuals by taking into account the possible dependency between the sisters in each analysis (Studies II and III). Consequently, the baseline comparisons in the FITSA data was performed using an adjusted Wald test (Studies II and III). In all the analyses, the level of statistical significance was set at $p<0.05$.

In the SCAMOB trial, the calculation of sample size was based on the pilot sample. It was estimated that about 60% of the target population were experiencing, or were at increased risk for, mobility limitation. The significance level was set at 5% and power at 80%. A within-person correlation of 0.4 was assumed. To allow for 10% attrition, the total sample size needed was about 630.

Analysis of covariance
Analysis of covariance was used to validate the self-reported preclinical mobility concept against measured lower extremity muscle power and walking speed (Study I). The mean differences in muscle power and maximal walking speed among those at different stages of the mobility limitation process were estimated using Mplus software (Muthén & Muthén, version 4.2). Age, gender,

and number of long-term diseases and prescription medication were used as covariates.

Generalized estimating equations modeling

To analyze the biannual changes in perceived mobility limitation in the SCAMOB data, Generalized Estimating Equation (GEE) models (Liang & Zeger 1986) were constructed using SAS software (SAS Institute Inc., version 9.1) the GENMOD procedure (Studies I and V). With GEE modeling both the incidence of difficulty and the recovery from a difficulty, are taken into account. Accordingly, the group*time interaction term represents the difference between groups over time in the proportion of participants reporting mobility limitation. The predictive value of self-reported preclinical mobility limitation for developing major manifest mobility limitation was assessed using the control group of the SCAMOB trial (n=314) (Study I). The risk for manifest mobility limitation was assessed using the biannual 2-year follow-up data on perceived difficulties in walking 2 km, walking 0.5 km and climbing stairs. Only participants without major manifest mobility limitation at baseline were included in further analyses of each activity (n=266-295). Three separate models were constructed for each mobility task using age, gender, presence of chronic diseases known to affect mobility (osteoarthritis, rheumatoid arthritis, diabetes, chronic obstructive pulmonary disease, ischemic heart disease, myocardial insufficiency, sciatica), depressive symptoms, weight, height, walking speed, and muscle power as covariates to gain an idea about the factors underlying the mobility limitation process (Study I).

The effects of the physical activity counseling on the development of mobility limitation were analyzed using the SCAMOB data on basic (walking 0.5 km) and advanced (walking 2 km) mobility (Study V). The information on these outcomes was gathered biannually during the 2-year counseling intervention and 1.5-year post-intervention follow-up. Separate models were constructed for both outcome measures. For cases with missing values at any point following the baseline measurements, data were imputed with the multiple imputation procedure implemented in SAS by using information on the other mobility tasks and baseline information on age, gender, long-term diseases, prescription medications, muscle power, walking speed, BMI, MMSE, and CES-D scores. We did not impute values for persons who died during the intervention or post-intervention follow-up. The number of imputed observations at different measurement points during the 2-year intervention ranged from 17 to 41 (3% – 7%) and during the 1.5-year follow-up after the intervention from 46 to 63 (7% – 10%). The sensitivity analyses performed suggested no substantial differences in effects due to imputation. Number needed to treat (NNT) (Cook & Sackett 1995) was calculated to evaluate the efficacy of the trial at the 2-year follow-up point.

Negative binomial regression model

The predictive value of self-reported preclinical mobility limitation and fall history for future falls was analyzed using negative binomial regression model to compute the incidence rate ratios (IRR) (Study II). This method considers falls as recurrent and non-independent observations and allows the analysis of incomplete follow-up data. Altogether eight participants had missing data for one or more months during the 12-month fall surveillance, and three people died during the follow-up. All the available fall data on these 11 participants were included in the analysis. The analyses were performed using STATA software (Stata Corp., version 10).

Logistic regression model

The association of outdoor and indoor falls with the incidence of mobility limitation was studied using logistic regression models (Study III). Incident mobility limitation was defined as the onset of major difficulty or inability in walking 2 km among those without difficulties at the baseline. The base model was adjusted with age, and further, known and postulated determinants of falls and mobility limitation were added individually to the regression model to examine in more detail the possible factors on the pathway from falls to mobility limitation. We tested the significance of the difference of the regression coefficient for the fall variable in the age-adjusted model with the corresponding coefficient in the model with the potential confounder using an appropriate Wald test. A significant difference between the coefficients suggests that the potential confounder may partially explain the association between falls and future mobility limitation. The potential confounders tested included number of chronic conditions, number of prescribed medications, muscle power, walking speed, balance, education, walking activity, memory, obesity, visual loss, hearing impairment, fall history, fear of falling and serious fall injuries. The analyses were performed using STATA software (Stata Corp., version 10).

Repeated measures analysis of variance

The effects of the physical activity counseling on leg extensor power and walking speed were estimated with repeated measures analysis of variance using Mplus (Muthén & Muthén, version 5.2) software (Study IV). Participants with missing values at baseline and /or follow-up were excluded from the final analysis of muscle power (n=57) and walking speed (n=42). In addition, participants who were unable to complete the muscle power (n=30) or walking speed test (n=29) in an acceptable manner at baseline and/or follow-up were excluded. We used box plots with 95% confidence intervals (CI) for the percentage mean change variable to identify extremes and outliers in the intervention and control groups. The sensitivity analyses performed suggested no substantial differences in effects due to missing data or exclusion of outliers. The approximate power calculations for these analyses were computed as described in Bollen (1989).

5 RESULTS

The result section includes the main findings of this study. More detailed information is given in the original publications I-V.

5.1 Sample characteristics

The total study population consisted of 1066 community-dwelling people aged 63 years or older. Table 3 shows the baseline characteristics of the participants in the SCAMOB and FITSA datasets.

TABLE 3 Participant characteristics of the SCAMOB and FITSA datasets.

	SCAMOB n=632	FITSA n=434
Variables	Mean ± SD	Mean ± SD
Age (years)	77.6 ± 1.9	68.6 ± 3.4
Education (years)	9.2 ± 4.2	8.6 ± 3.1
Number of long-term diseases	3.0 ± 2.0	2.0 ± 1.5
Number of prescribed medications	4.0 ± 2.8	2.0 ± 2.0
Body Mass Index (kg/m^2)	28.4 ± 4.5	28.0 ± 4.7
Mini Mental State Examination score	27.1 ± 2.1	27.0 ± 2.3
Maximal walking speed (m/s)	1.4 ± 0.4	1.7 ± 0.3
	%	%
Women	74.8	100

5.2 Early signs of mobility decline

5.2.1 Preclinical mobility limitation as predictor of manifest mobility limitation and falls (Studies I and II)

In order to study if self-reported preclinical mobility limitation is a valid measure to identify older persons at high risk for future disability and falls, we divided the participants into subgroups according to self-reported baseline difficulties and modification of task performance in walking 2 km (Studies I and II), walking 0.5 km (Study I) and climbing stairs (Study I) (Figure 6). The subgroup division was done separately for each task. A substantial number of the participants who reported no difficulty in walking 2 km, 0.5 km, or climbing stairs reported task modification or increased tiredness in performing the task. Depending on the task being assessed, 31% to 55% of the participants in total were categorized into the preclinical mobility limitation subgroup (Table 4), forming an intermediate group between those with manifest and those with no mobility limitation in terms of their health and physical function outcomes (Studies I and II).

TABLE 4 Frequency of self-reported levels of mobility limitation at baseline for walking 2 km, walking 0.5 km and climbing stairs (Studies I, II and V)

	SCAMOB n=632	FITSA n=434
Mobility task	n (%)	n (%)
2 km walk		
No limitation	167 (26.4)	142 (33.2)
Preclinical limitation	257 (40.7)	152 (35.0)
Minor or major manifest limitation	208 (32.9)	138 (31.8)
0.5 km walk		
No limitation	347 (54.9)	-
Preclinical limitation	194 (30.7)	-
Minor or major manifest limitation	91 (14.4)	-
Climbing stairs		
No limitation	132 (20.9)	-
Preclinical limitation	346 (54.7)	-
Minor or major manifest limitation	154 (24.4)	-

Preclinical mobility limitation as a predictor of manifest mobility limitation (Study I)

The cross-sectional analyses showed that the objective measures of maximal walking speed and muscle power were associated in a stepwise relationship with the level of reported mobility limitation, that is, participants with preclinical mobility limitation showed intermediate levels of walking speed and muscle power compared with those with no limitation or manifest mobility limitation (Figure 7). In addition, the risk for developing major manifest mobility limitation during the 2-year prospective follow-up was intermediate among participants with preclinical mobility limitation compared with those with no limitation or minor manifest limitation (Figure 8). Table 5 shows the risk ratios for the onset of task-specific major manifest limitation in each mobility task compared with the subjects with no limitation. Participants reporting baseline preclinical mobility limitation in walking 2 km or 0.5 km had 3- to 6-fold higher age- and gender-adjusted risk of progressing to major manifest mobility limitation during the 2-year follow-up compared with participants with no limitation at baseline. In turn, the risk among those with minor manifest limitation at baseline was 13-to 18-fold higher compared with those with no limitation. Further adjustments with potential cofounders, and with lower extremity muscle power and maximal walking speed, attenuated the risk ratios in all three mobility tasks (Table 5).

TABLE 5 Risk Ratios (RR) and their 95% Confidence Intervals (CI) for the onset of major manifest limitation for the 2-km walk, 0.5-km walk, and climbing stairs among participants with preclinical or minor manifest mobility limitation compared with participants with no limitation at baseline (Study I)

	Risk for developing major manifest limitation					
	Model I*		Model II†		Model III‡	
Mobility at baseline	RR	95% CI	RR	95% CI	RR	95% CI
2 km walk						
Preclinical limitation	5.8	2.6 - 12.9	5.0	2.2 - 11.2	2.9	1.2 - 6.6
Minor manifest limitation	17.8	7.6 - 41.9	17.1	7.0 - 41.5	8.9	3.6 - 21.6
0.5 km walk						
Preclinical limitation	2.5	1.2 - 5.1	2.3	1.1 - 4.6	1.4	0.7 - 2.9
Minor manifest limitation	13.2	6.1 - 28.4	10.3	4.8 - 22.0	5.4	2.3 - 12.2
Climbing stairs						
Preclinical limitation	2.3	0.7 - 7.4	1.8	0.5 - 6.1	1.2	0.4 - 3.9
Minor manifest limitation	13.9	4.2 - 45.7	10.2	2.8 - 37.5	5.4	1.6 - 19.1

* Model adjusted for gender and age.

† Model adjusted for gender and age and osteoarthritis, rheumatoid arthritis, diabetes, chronic obstructive pulmonary disease, ischemic heart disease, myocardial insufficiency, sciatica, and depressive symptoms.

‡ Model adjusted for gender and age and osteoarthritis, rheumatoid arthritis, diabetes, chronic obstructive pulmonary disease, ischemic heart disease, myocardial insufficiency, sciatica, and depressive symptoms as well as weight, height, walking speed, and muscle power.

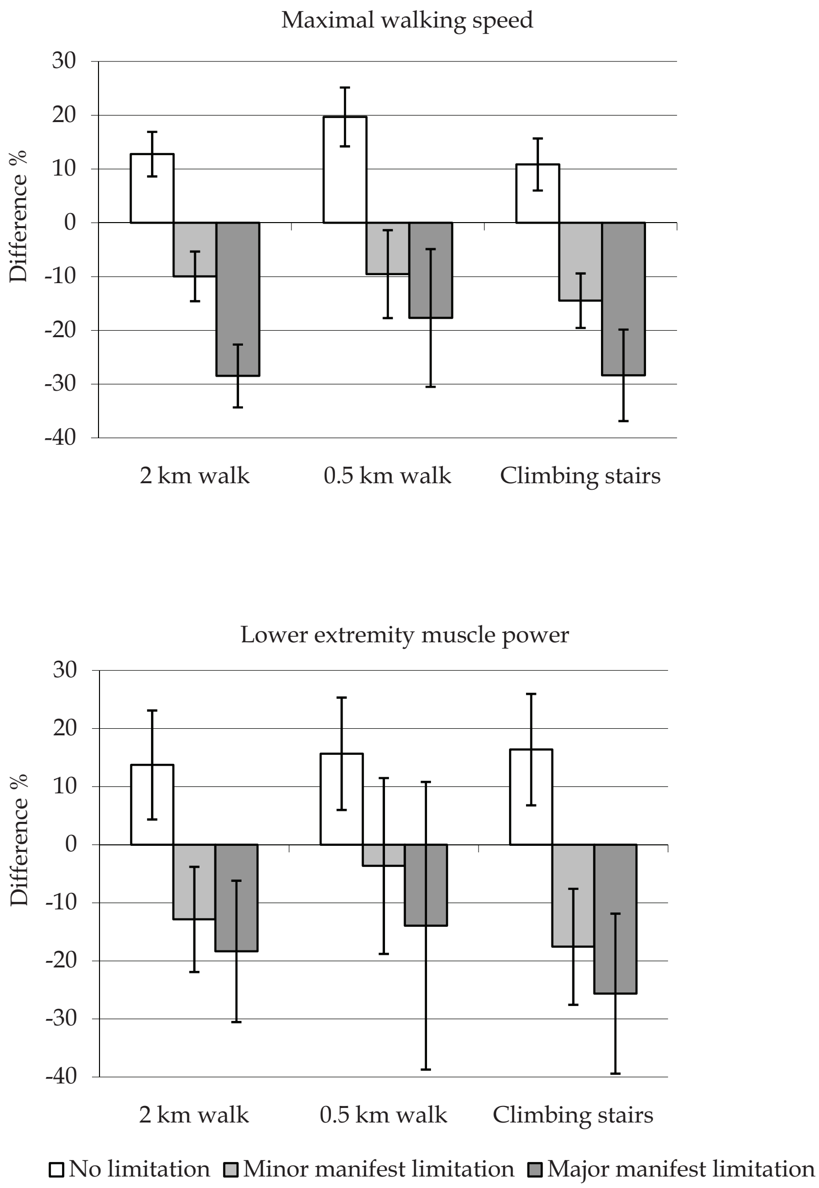

FIGURE 7 Adjusted mean differences (%) and their 95% CI in maximal walking speed and lower-extremity muscle power compared with people with preclinical mobility limitation (0 level) (Study I).

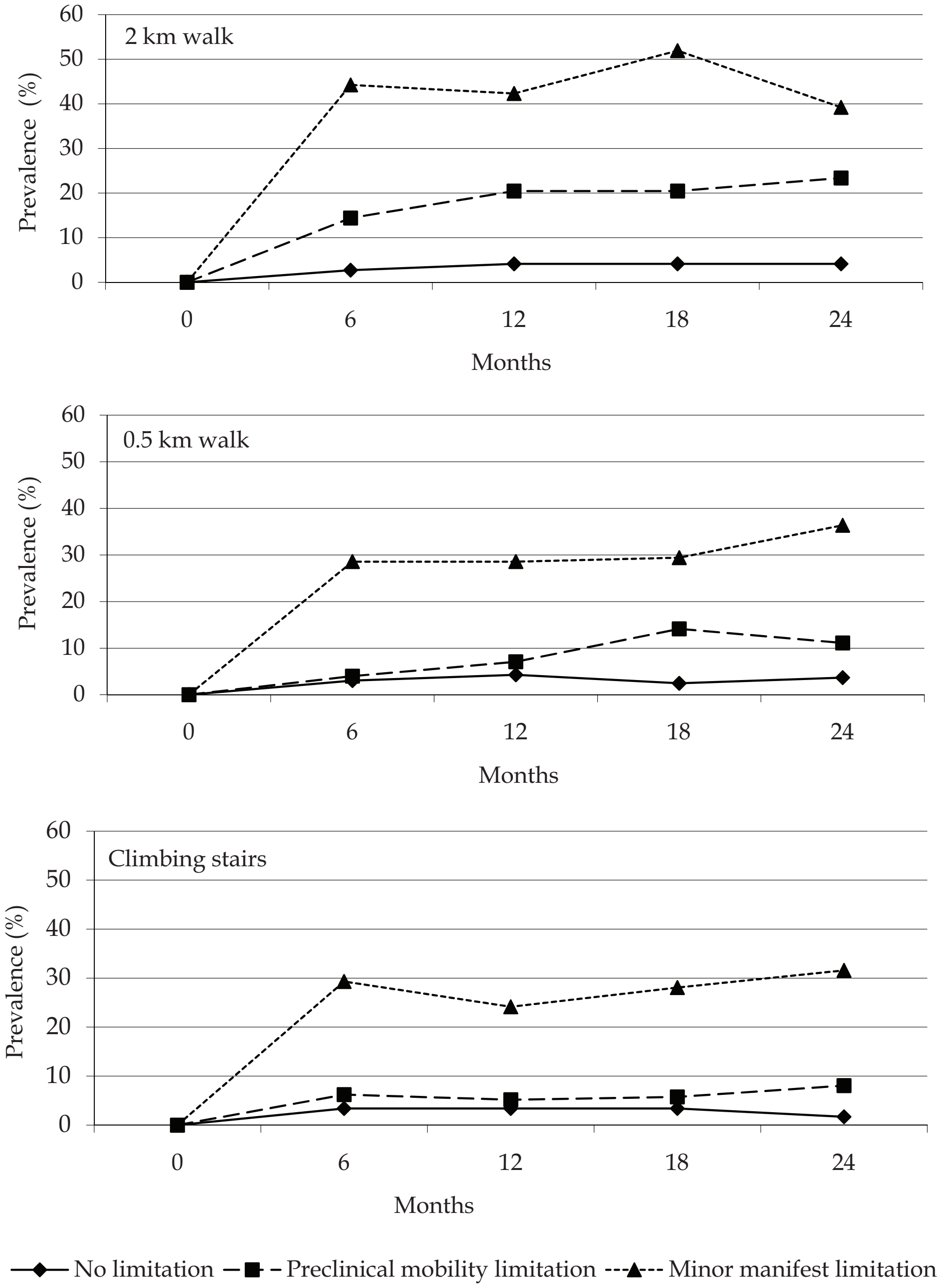

FIGURE 8 Unadjusted prevalence (%) of major manifest limitation for the 2 km walk, 0.5 km walk, and climbing stairs during 24-month follow-up (Study I).

Preclinical mobility limitation and fall history as predictors of future falls (Study II)
During the 12-month prospective fall surveillance, 227 participants reported no falls, 201 participants experienced at least one fall, and the total number of falls was 440. Figure 9 shows the combined effect of mobility limitation and fall history on future falls after adjusting for age, number of chronic conditions, and medications. The association of mobility limitation with risk for future falls depended on fall history. Women who had fallen during the past year and had preclinical mobility limitation had almost 4-fold (IRR 3.77, 95% CI 1.02-13.92) and those with manifest mobility limitation almost 15-fold (IRR 14.66, 95% CI 2.72-79.00) adjusted risk for future falls compared to those with no mobility limitation and no previous falls. Among women without a fall history, preclinical or manifest mobility limitation did not predict future falls. Fall history without mobility limitation did not predict future falls either (Figure 9).

To gain further insight into how people with preclinical and manifest mobility limitation and a history of falls differ from their counterparts without a fall history, we compared known fall-risk factors between them. Among women who had preclinical mobility limitation and who had fallen during the past year, the prevalence of low walking activity and visual loss was significantly higher (70% vs. 60%, p=0.04 and 59% vs. 38%, p=0.03, respectively) compared to women with preclinical limitation but no previous fall history. Respectively, among women who had manifest mobility limitation and a history of falls, the prevalence of balance impairment was significantly higher compared to women with manifest limitation but no previous fall history (60% vs. 29%, p=0.01). No other significant baseline differences were observed between these groups. Adjusting the negative binomial model one at a time for daily walking activity, visual loss and balance impairment attenuated the risks, indicating that the differences in these factors partially explained the increased risk for falls among people with preclinical and manifest mobility limitation and a fall history compared to those without fall history.

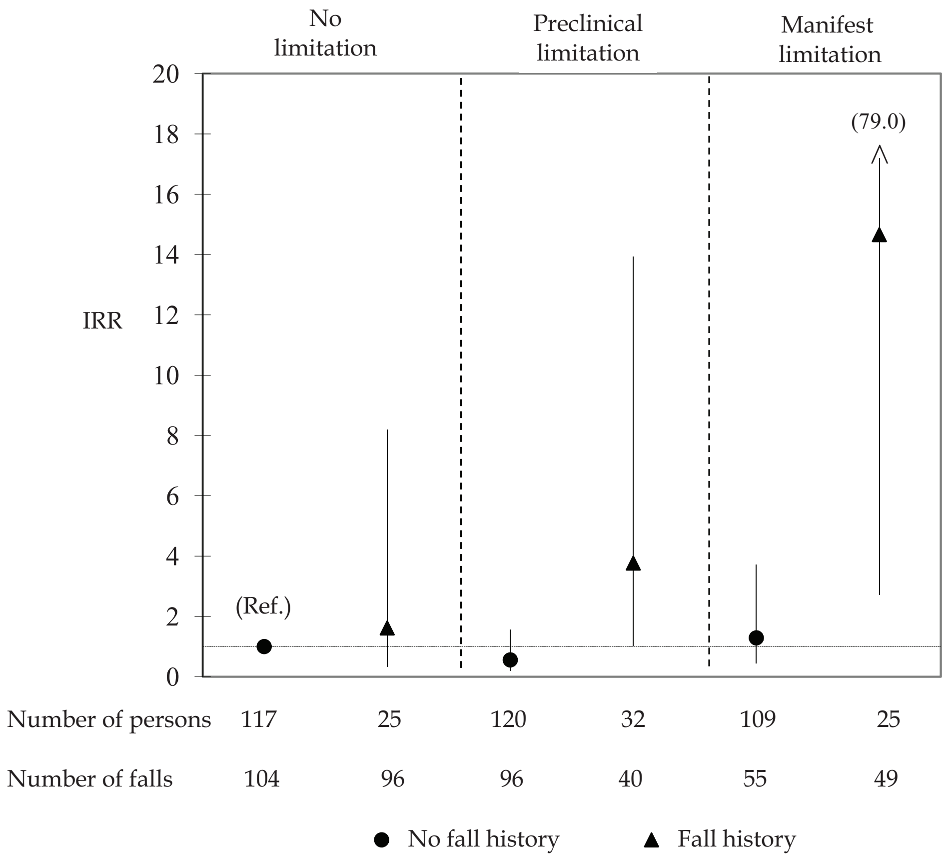

FIGURE 9 Incidence rate ratios (IRR) and 95% confidence intervals for future falls in groups according to the baseline mobility limitation and fall history. Model adjusted for age, number of chronic conditions, and prescription medication. Women with no mobility limitation and no previous falls were used as a reference group (Study II).

5.2.2 Outdoor and indoor falls as predictors of mobility limitation (Study III)

Among women without baseline mobility limitation (n=376), 173 experienced at least one fall during the 12-month prospective fall surveillance (III). The total number of falls was 357, of which 17% occurred indoors. Compared to outdoor fallers and non fallers, indoor fallers had approximately 20% poorer standing balance and reported approximately 30% less outdoor walking activity at baseline. In addition, compared to outdoor fallers and non fallers, a bigger proportion of indoor fallers were obese (24% vs. 26% vs. 51%, respectively), had visual loss (41% vs. 41% vs. 57%) and a previous fall history (22% vs. 13% vs. 38%) (Study III).

The incidence of mobility limitation during the follow-up was 7% among those with no falls, 7% among those with outdoor falls only and 19% among those with indoor falls. Table 6 shows the association between indoor and outdoor falls, and future mobility limitation after adjusting for age. Compared to those with no falls, women with indoor falls were over three times (OR 3.2; 95% CI 1.3-8.1, p=.01) more likely to develop difficulties in walking 2 km by the end of the 3-year follow-up. Outdoor falls (OR 1.1; 95% CI 0.4-2.6, p=.89) did not increase the risk for future mobility limitation (Table 6).

To explore further the nature of the increased risk for future mobility limitation among those with indoor falls, important determinants of falls and mobility limitation were added one at the time to the age-adjusted regression model. Baseline obesity, low walking activity and chronic conditions attenuated significantly the risk among women with indoor falls (Wald test p<.05), suggesting that these factors may partially explain the increased risk for future mobility limitation among indoor fallers (Table 6).

In addition, the effect of the accumulation of the most important risk factors, i.e., indoor falls, obesity and low walking activity, on the development of future mobility limitation (n=372) was analyzed. Compared to women with none of the three risk factors (n=122), women with one (n=153) or two (n=74) risk factors had a four-fold increased risk for developing future mobility limitation (OR 3.8; 95% CI 1.1-13.8, p=.04 and OR 4.0; 95% CI 0.9-17.2, p=.06, respectively). Importantly, women who had all three risk factors (n=23), had a 17-fold (OR 17.1, 95% CI 4.00-73.3, p<.001) risk for developing mobility limitation as compared to women with none of the risk factors.

TABLE 6 Logistic regression models for future mobility limitation among those with indoor or outdoor falls as compared to women with no falls. The Odds Ratios (OR) indicate the association between falls and future mobility limitation. A marked change in OR indicates that the respective covariate underlies the association (Study III).

	Indoor fallers	Outdoor fallers
	OR (95% CI)	OR (95% CI)
Base model*	3.20 (1.27-8.06)	1.07 (0.43-2.63)
Base model adjusted for†		
Number of chronic conditions	2.97 (1.14-7.73)	1.10 (0.44-2.74)
Number of prescribed medications	2.94 (1.13-7.65)	1.04 (0.42-2.57)
Muscle power (W/kg)	3.52 (1.41-8.81)	1.20 (0.48-3.00)
Maximal walking speed (m/s)	3.34 (1.30-8.58)	1.33 (0.51-3.43)
Balance (Velocity moment, mm^2/s)	3.10 (1.28-7.52)	1.07 (0.43-2.64)
Education (years)	3.05 (1.20-7.76)	1.07 (0.43-2.63)
Low walking activity‡	2.63 (1.04-6.64)	1.12 (0.44-2.85)
MMSE‖	3.25 (1.28-8.27)	0.97 (0.38-2.47)
Obesity¶	2.66 (1.05-6.73)	1.08 (0.43-2.69)
Visual loss**	3.08 (1.22-7.76)	1.07 (0.43-2.64)
Hearing impairment††	3.08 (1.19-7.93)	1.01 (0.40-2.53)
Fall history	3.08 (1.22-7.82)	1.05 (0.43-2.57)
Fear of falling	3.34 (1.32-8.44)	1.10 (0.45-2.72)
Serious fall injuries	3.39 (1.32-8.70)	1.14 (0.45-2.76)

* Adjusted for age

† The base model was adjusted one at a time for known and suspected fall risk factors.
‡ Walking activity < 1.6 km (one mile) per day
‖ Mini Mental State Examination score
¶ Body Mass Index (kg/m2) ≥30
** Visual acuity <1.0
†† Hearing threshold level of the better ear > 21 dB.

5.3 Effects of physical activity counseling on mobility

In the SCAMOB data, the baseline characteristics of the intervention and control groups were comparable (Studies IV and V). The mean age of the study sample was 78 years and the majority were women (75%). The participants in both groups had on average three chronic diseases and four prescribed medications in use. The mean score for the Mini Mental State Examination (MMSE) was 27, indicating intact cognitive function, while around 20% of the study sample suffered from depressive symptoms (CES-D ≥ 16). The participants had on average nine years of formal education (Studies IV and V).

Physical activity counseling increased habitual physical activity and reduced the decline in physical activity significantly in the intervention group compared with the control group. The proportion of participants who increased their activity level from sedentary to at least moderate or remained at least moderately active during the 2-year intervention was significantly higher in the intervention compared with the control group (83% versus 72%, OR 2.0, 95% CI 1.3 – 3.0). Similarly, the proportion of those who reduced their physical activity level from at least moderate to sedentary or who remained sedentary was lower in the intervention than in the control group (17% versus 28%, OR 0.51, 95% CI 0.3 – 0.8).

At baseline, approximately 30% of those in the intervention group and 28% of those in the control group reported having had some form of injury during the previous year. There were no statistically significant changes in the number of injuries sustained during the 2-year intervention period. This indicates that the intervention did not cause excessive adverse effects.

5.3.1 Walking speed and muscle power (Study IV)

Altogether 78% (n=491) of the participants completed the baseline and follow-up measurements on muscle power and 81% (n=509) on walking speed (Figure 4). Participants who did not complete the measurements or who were excluded from the analysis of muscle power (n=141) and walking speed (n=123) had significantly more chronic conditions and medications, higher BMI, poorer lower extremity performance and a lower physical activity level, and a bigger proportion of them reported difficulties in walking at baseline as compared to those who were included in the follow-up analysis (Study IV).

The mean difference in change in walking speed was 0.03 m/s (95% CI 0.00-0.07, p=.07) and in muscle power 2.30 W (95% CI: -2.67-7.47, p=.38) in favor of the intervention group (Table 7, Figure 10, Figure 11). Our ancillary analyses indicated that among women the decrements in muscle power were significantly smaller (Δ 5.8 W, 95% CI 0.89-10.66, p=.02) (Figure 10) and the increase in walking speed significantly greater (Δ 0.06 m/s, 95% CI 0.02-0.10, p=.001) (Figure 11) in the intervention group compared to the control group, while in men the intervention had no effect. For new hypotheses building, we carried out further analyses on the effects of the intervention among participants at different stages of the mobility limitation process. These analyses showed that the beneficial effects took place, in particular, among women with no or only early signs of mobility limitation, while no effects were observed in men or women with more severe mobility limitation (Figure 10, Figure 11).

5.3.2 Perceived mobility (Study V)

During the 2-year counseling intervention at least 90% percent of the study sample completed the mobility interview at every semiannual follow-up point (Figure 3). The proportion of participants reporting difficulties in advanced (walking 2 km) and basic mobility (walking 0.5 km) increased in both groups during the intervention (Figure 12). In advanced mobility, the proportions of participants with difficulty in the intervention group were 34% in the beginning and 38% at the end of the intervention, whereas in the control group, the corresponding proportions were 32% and 45%. The treatment effect was significant (OR 0.84, 95% CI 0.70 – 0.99) (Table 8). The positive effect of the intervention at the 2-year follow-up was mainly due to prevention of difficulty among those without difficulty at baseline and to a lesser extent due to recovery from baseline difficulty. About 52% of those without difficulty at baseline remained so in the intervention group versus 47% of those in the control group, whereas 9% of those with difficulty at baseline recovered in the intervention group versus 8% in the control group. The effect on basic mobility was parallel but non-significant at the end of the 2-year intervention (OR 0.87, 95% CI 0.69 – 1.09).

In advanced mobility, the treatment effect remained significant (OR 0.82, 95% CI 0.68 – 0.99) after the post-intervention 1.5-year follow-up, whereas in basic mobility, the effect gradually disappeared (OR 1.09, 95% CI 0.87 – 1.37) (Figure 12; Table 8). At the 2-year follow-up point, the NNT for advanced mobility was 15. This indicates that to prevent one person from developing difficulty or to recover from baseline difficulty, 15 persons had to receive counseling.

TABLE 7 Walking speed and muscle power at baseline and after the intervention (Study IV).

	Intervention			Control				
Variable	Mean	(SE)	n	Mean	(SE)	n	p	Power*
Walking speed (m/s)								
Baseline	1.43	0.02	269	1.40	0.02	240		
2-year follow-up	1.51	0.02	269	1.45	0.03	240		
Group effect							0.22	0.22
Time effect							< 0.001	1.00
Group-by-time effect							0.07	0.47
Leg extensor power (W)								
Baseline	110.1	3.4	256	109.3	3.3	235		
2-year follow-up	104.8	2.9	256	101.7	3.2	235		
Group effect							0.64	0.07
Time effect							< 0.001	1.00
Group-by-time effect							0.38	0.15

SE=Standard Error
* Approximate power calculations were computed as described in Bollen (1989)

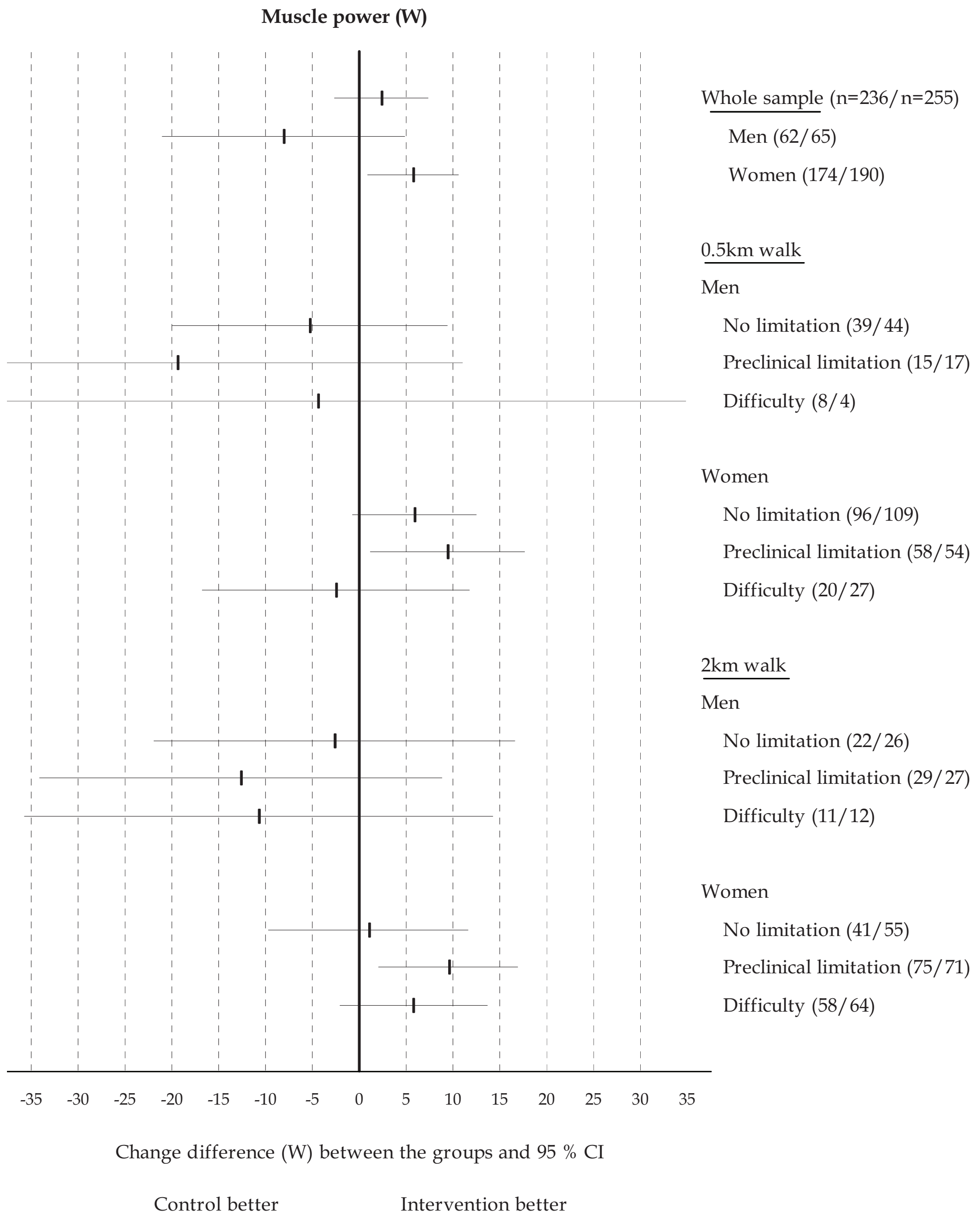

FIGURE 10 Estimated treatment effects of the intervention on muscle power expressed as mean change in the physical activity group minus mean change in the control group from baseline to two-year follow-up. Mean changes and their 95% confidence intervals (CI) are illustrated by bars (Study IV).

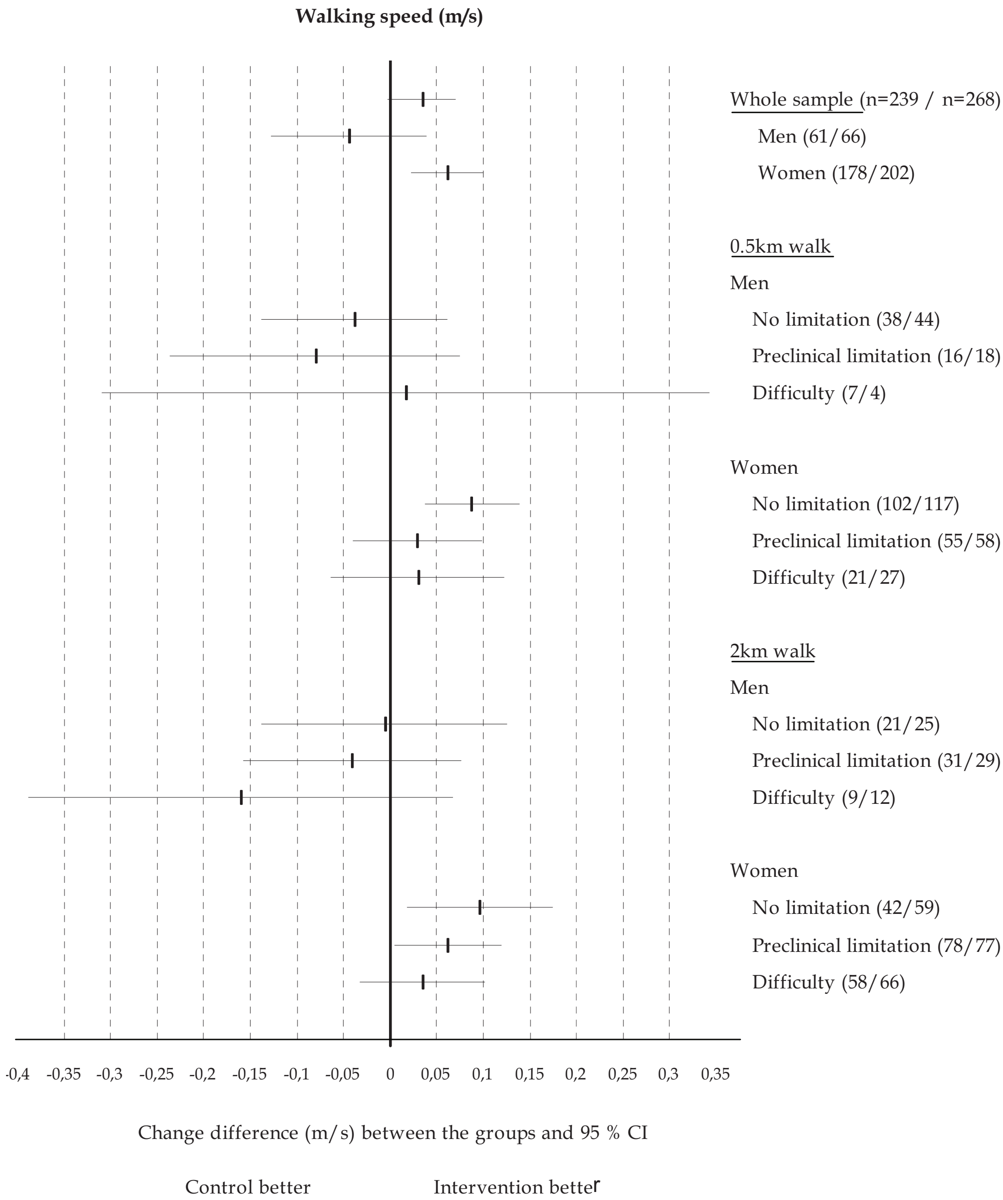

FIGURE 11 Estimated treatment effects of the intervention on walking speed expressed as mean change in the physical activity group minus mean change in the control group from baseline to two-year follow-up. Mean changes and their 95% confidence intervals (CI) are illustrated by bars (Study IV).

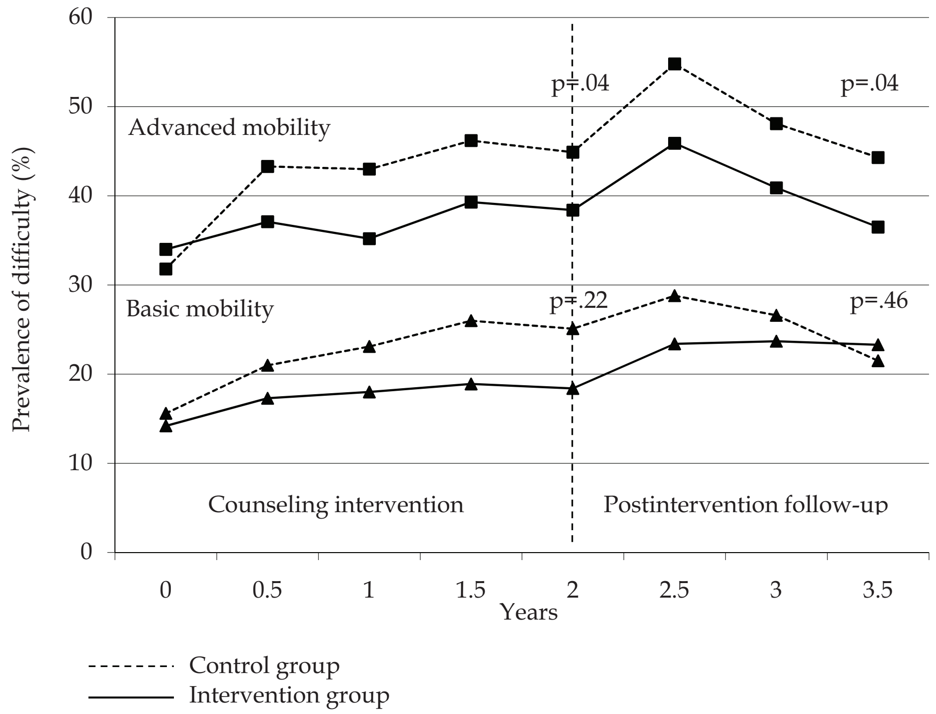

FIGURE 12 Proportion of participants with difficulty in advanced and basic mobility at semiannual follow-up points during the counseling intervention and 1.5-year postintervention follow-up. The p-values indicate the statistical significance of the treatment effects (groupxtime interaction) observed in the generalized estimating equation models (Study V).

TABLE 8 Treatment effects of physical activity counseling intervention on advanced and basic mobility after the 2-year counseling intervention (2-year follow-up) and 1.5-year post-intervention follow-up (3.5-year follow-up). Odd Ratios (OR) represent the extent of the treatment effects (group x time interaction) (Study V).

	2-year follow-up			3.5-year follow-up		
	OR	95% CI	p	OR	95% CI	p
Advanced mobility*	0.84	0.70 - 0.99	.04	0.82	0.68 - 0.99	.04
Basic mobility†	0.87	0.69 - 1.09	.22	1.09	0.87 - 1.37	.46

* Difficulties in walking 2 km
† Difficulties in walking 0.5 km
CI = Confidence Interval

6 DISCUSSION

The purpose of this study was to investigate early signs of mobility decline and falls in older people. In addition, the effects of physical activity counseling on the development of mobility limitation in an older community-dwelling population were studied.

In this study, older people's self-reported modification of task performance, that is, preclinical mobility limitation, proved to be a valid measure to capture early signs of mobility decline. Participants with preclinical mobility limitation showed intermediate levels of lower extremity performance as compared with those with no limitation or manifest mobility limitation. Preclinical mobility limitation was also found to predict future manifest mobility limitation and, combined with a previous fall history, also predicted future falls. Additionally, indoor falls were found to be early markers of mobility decline among older high functioning women. The present study also showed that the 2-year physical activity counseling intervention had a positive effect on self-reported mobility among older community dwelling people. In addition, physical activity counseling improved leg extension power and walking speed among women with no or only early signs of mobility decline. No effects were observed among men or among women with more advanced mobility limitation at baseline.

6.1 Self-reported preclinical mobility limitation, fall history and indoor falls as early indicators of functional decline

Self-reported preclinical mobility limitation and fall history

Early identification of at-risk populations is crucial from the perspective of primary prevention (Guralnik et al. 1996, Guralnik et al. 2003, Ferrucci et al. 2004). Despite the fact that the most common risk factors for mobility decline are widely recognized, there remains a clear need to the further development of simple and easily administrable tools for identifying persons at risk. The results of this study indicate that using a self-reported measure of preclinical mobility limitation and fall history may help identify at-risk persons among the still high-functioning older population.

The cross-sectional findings of our study on self-reported preclinical mobility limitation are in accordance with the previous findings of Fried et al. (2001), providing further criterion validity for the preclinical mobility limitation concept. Objectively measured physical performance was found to decrease and disease frequency increase in association with decreasing mobility function across the three self-report categories: no limitation, preclinical mobility limitation and manifest limitation. The results of this study showed that the levels of maximal walking speed and muscle power of the participants with preclinical mobility limitation lay between the levels of the participants with no limitation and those with manifest limitation. These results confirm that self-reported preclinical mobility limitation is also reflected as declines in objectively measured physical performance.

In two previous studies, preclinical mobility limitation was shown to be highly predictive of the development of manifest mobility limitation among 70- to 80-year-old high-functioning American women (Fried et al. 2000) and late-middle-aged African Americans (Wolinsky et al. 2005). The results of the present study corroborated these earlier findings among 75- to 81-year-old to Finnish community-dwelling men and women by showing that older people who reported preclinical mobility limitation had a 3- to 6-fold higher task-specific adjusted risk for progressing to major manifest mobility limitation during the 2-year prospective follow-up compared with those with no limitation at baseline. In the two previous studies the corresponding task specific odds ratios varied between 2 and 5 (Fried et al. 2000, Wolinsky et al. 2005). In the present study, adjustment for long-term diseases and depressive symptoms somewhat attenuated the increased risk for manifest limitation among the participants with preclinical mobility limitation or minor manifest limitation, while a further reduction was observed when walking speed, muscle power, height and weight were added into the models. This indicates that these covariates may lie on the pathway to mobility limitation, as suggested by the theoretical model (Verbrugge & Jette 1994).

Preclinical mobility limitation combined with a fall history was found to be predictive of future falls. Only one earlier study has investigated the association between preclinical mobility limitation and future falls (Clough-Gorr et al. 2008). In that study, self-reported preclinical mobility limitation predicted falls among older people irrespective of fall history. In our somewhat younger and healthier sample of older adults, preclinical mobility limitation without a fall history or a fall history alone did not predict future falls. It is possible that we failed to observe the independent effect of mobility limitation in predicting future falls as there was not enough variability in our truncated sample of high-functioning older women. In addition, methodological differences in the follow-up of falls and statistical analyses may partially explain the differences between the results. All in all, the results indicate that early signs of mobility decline combined with a history of falls increases the risk of further falls and should be considered as an indicator for fall prevention interventions. It is possible that people with preclinical mobility limitation and a history of falls are at a more advanced stage of mobility decline, which thus places them at an increased risk of future complication in mobility, such as falls.

The results of this study together with those of previous research confirm the construct and predictive validity of the concept of preclinical mobility limitation among older populations (Fried et al. 2000, Fried et al. 2001, Clough-Gorr et al. 2008). Self-reported preclinical mobility limitation together with previous fall history may serve as an inexpensive tool for identifying a vulnerable subset of non-disabled persons at high risk for future disability (Weiss et al. 2007). These high risk persons with early signs of mobility limitation may be a potential target group for primary prevention, given that they do not have existing disability, which would hinder, for example, independent participation in physical activity, whereas persons with more advanced mobility difficulties often need more support in physical activity and rehabilitation.

There are still some aspects of the preclinical mobility limitation concept that needs to be clarified with future studies. Preclinical mobility limitation can be regarded as a complex concept with modification of task performance operating both, as a risk marker associated with manifest limitation and as a mediating risk factor affecting the natural pathway of disability (Weiss et al. 2007). This dual role of preclinical limitation in the disability process remains to be clarified. Further development of the measurement tool also needs to be done by exploring how the different previously examined indicators of preclinical mobility limitation relate to each other and whether the same indicators apply to different groups of older people. Additionally, natural recovery from preclinical disability merits investigation in future studies.

Indoor falls

In addition to self-reported preclinical mobility limitation and fall history, the results of this study showed that indoor falls may signal functional decline among older community-dwelling high-functioning women. The present study is the first observational study to report on the association of outdoor and indoor falls with the incidence of mobility limitation in older people. Falls in old age often cause physical injuries, which may lead to hospitalization and institutionalization (Tinetti & Williams 1997). However, whether falls in general have an impact on mobility decline has been little studied (Tinetti & Williams 1998, Chu et al. 2006). It has been suggested that outdoor falls are more common among healthy and active older people, whereas indoor falls are often related to intrinsic risk factors, such as poor health and impaired balance (Bath & Morgan 1999, Bergland et al. 2003, Pajala et al. 2008). As poor health and low functional ability are known to be risk factors for both indoor falls (Bath & Morgan 1999, Bergland et al. 2003) and mobility disability (Guralnik et al. 1995), the most likely hypotheses for our results would be that indoor fallers may have been more vulnerable to the adverse effects of falls or that they may have had risk factors common to both falls and mobility limitation. Our baseline comparisons and multivariate analyses suggested that low walking activity, obesity and chronic conditions were important factors explaining the association between indoor falls and future mobility limitation, whereas serious injuries resulting from falls did not explain the association. Thus, our results support the latter hypothesis, indicating that high body mass (Stenholm et al. 2007a, Stenholm et al. 2007b), low walking activity (Hirvensalo et al. 2000, Miller et al. 2000, Boyle et al. 2007) and chronic conditions (Guralnik et al. 1993) decrease women's functional ability, rendering them more vulnerable to both indoor falls and mobility limitation. We found that, in particular, women who had fallen indoors and who were obese and had low walking activity were in at extremely high risk for future mobility limitation. Women in this group thus constitute an important and challenging target for preventive interventions.

It is evident that there are also other factors on the pathway from indoor falls to mobility limitation that need to be considered in future studies. For example, as our outcome measure was based on self-report, it can be hypothesized that compared to outdoor falls indoor falls may have had a more detrimental effect on mobility-related self-efficacy, which may have been reflected as perceived difficulty in walking. However, our data did not allow us to study this possibility. In addition, our results need to be confirmed with more frail populations and with samples including men.

6.2 Effects of physical activity counseling on mobility

Mobility is a critical component for the maintenance of independence in old age (Guralnik et al. 2000). Physical activity and exercise are widely promoted as effective means to enhance health and physical functioning among older populations (Keysor & Jette 2001, Keysor 2003, Bean et al. 2004a, Taylor et al. 2004, Manini & Pahor 2009). However, a need remains for the further development of low-cost interventions to promote physical activity and mobility in less controlled clinical settings.

Little research has been conducted on the effects of physical activity counseling on mobility among older adults (Dubbert et al. 2002, Dubbert et al. 2008, Morey et al. 2008). Dubbert et al. (2002) reported that the change in physical activity after a 10-month phone-based nurse counseling intervention to promote exercise among 60- to 80-year-old primary care patients had some positive effects on gait and balance. In a later study, Dubbert et al. (2008) observed with a sample consisting of 60- to 85-year-old male veterans, that a 10 month counseling intervention to promote home-based walking and strength exercise improved measured and perceived physical performance especially among those who engaged in strength exercise during the intervention. Additionally, pooling the data from two randomized controlled trials, Morey et al. (2008) found that older sedentary adults with multiple chronic conditions can improve physical function by meeting the recommended physical activity levels after a telephone-based six-month physical activity counseling program. Compared to these previously reported studies, the present study included considerably longer and more intense follow-ups of mobility outcomes. In the SCAMOB trial, mobility was followed-up biannually for a total of 3.5 years.

Our results supported the previous research findings by showing that a single individualized physical activity counseling session with a supportive phone contact every 4 months for 2 years had a positive effect on perceived mobility among community-dwelling older adults. However, the effects on muscle power and walking speed were significant only among women with no or only early signs of mobility limitation. No effects were observed among men or among women with more advanced mobility limitation at baseline. In addition to perceived mobility, the physical activity counseling reduced incident disability (von Bonsdorff et al. 2008) and need for home care (von Bonsdorff et al. 2009). Thus, it was expected that the physical activity counseling, through increasing physical activity, would also improve or maintain leg extension power and walking speed, both of which are important prerequisites for mobility and independent living. However, the results indicate that there are also other factors besides lower extremity performance that mediate the intervention effect on perceived mobility and disability. Our intervention was motivational with a specific emphasis on self-efficacy (Leinonen et al. 2007). Therefore, mood benefits (Pakkala et al. 2007) and possible effects on mobility related self-efficacy (McAuley et al. 2006, McAuley et al. 2007) may partly explain why the positive effects on perceived mobility were more evident than the effects on muscle power and walking speed. These mediating factors clearly merit further investigation.

After our primary care-based 2-year counseling program, we found a significant 19% reduction in the risk for perceived difficulty in advanced mobility with a NNT of 15. By comparison, it has been estimated recently that 254 women aged 70 to 74 years, need to be screened with bone densitometry and treated, 51 of them by bisphosphonates for 5 years, to avert one hip fracture (Järvinen et al. 2008). As the outcome was perceived difficulty, a subjective evaluation of mobility in the participant´s everyday environment, and the study was population-based, the results can be considered clinically relevant and significant. The Working Group on Functional Outcome Measures (Bhasin et al. 2008) has argued recently that conducting a clinical trial in older individuals may lead to disease-specific improvements that have only little impact on the day-to-day function of the individual. Particularly among older people, it is crucial to include an assessment of functional outcomes, reflecting the overall health status of the individual, in RCTs (Bhasin et al. 2008).

We performed ancillary analyses on the effects of the intervention with the aim of constructing hypotheses for future studies. The subgroup analysis according to gender indicated a positive intervention effect on leg extensor power and walking speed among women but not among men. Our preliminary analysis indicated that in the intervention group the proportion of participants who increased their activity level from sedentary to at least moderate, or remained at least moderately active, during the 2-year intervention did not differ significantly between women and men (82% vs. 87%, p=0.25). In the control group, the corresponding numbers were 70% vs. 77% (p=0.24). However, women are known to be more frail and closer to disability compared to men at the same age (Winblad et al. 2001, Dunlopp et al. 2002, Sainio et al. 2006, Hardy et al. 2008), and thus similar increments in physical activity level may lead to greater improvements among women. For example, the study by Fiatarone et al. (1994) suggested that older subjects who were initially the weakest showed the greatest benefit from weight-lifting exercise due to improved neural recruitment of existing but underused skeletal muscle. In our study, a bigger proportion of women than men were sedentary at baseline (27% vs. 18%, p=.017), and they had poorer functional performance, for example, lower muscle power (88 W vs. 171 W, p<.001) and slower walking speed (1.4 m/s vs. 1.6 m/s, p<.001), compared to men. A similar gender difference in the intervention effect was found in the study by Avlund and colleagues (Avlund et al. 2007) where preventive home visits reduced functional decline in community-living older women but not in men. The mechanisms underlying these gender differences need to be clarified in future studies as they may have implications for determining what could be the best way to prevent disability in older men and women.

Further ancillary analyses were carried out on the effects of the intervention among participants at different stages of the mobility limitation process in order to generate new hypotheses for future studies. We found that the beneficial effects of physical activity counseling on walking speed and muscle power were apparent only among women with no or only early signs of mobility limitation. No effects were observed among women with more advanced mobility limitation at baseline. It is possible that the intervention may have had a different impact on the physical activity behavior of women at different stages of mobility decline. However, the underlying mechanisms need to be considered in detail in future research. Overall, these observations suggest that older people with severe walking difficulties need more intense and rehabilitative interventions than counseling alone to improve their mobility. More studies are needed to determine what interventions would be efficacious for women and what for men, and for women and men at different stages of mobility decline.

6.3 Methodological considerations

This study is based on two research projects, a randomized controlled trial (SCAMOB) and a prospective observational study (FITSA), each consisting of a rather large sample of well-functioning community-dwelling older people. The data and study designs of these two projects were highly appropriate for investigating the research questions of the present PhD study.

The randomized controlled design allowed the true effects of physical activity counseling on mobility to be studied (Studies IV and V). The randomization process was successful and the baseline characteristics of the intervention and control groups were comparable. The intervention was single-blinded, that is, both the study nurses who performed the baseline and follow-up examinations and the interviewers were unaware of the study group assignment of the participants. Compared to previous physical activity counseling programs targeted at older population, the intervention and follow-up in the present study were considerably longer. The participation rate in the trial was high, with attrition less than 10% during the 2-year intervention and less than 15% during the entire 3.5-year follow-up. This strengthens the reliability of the results derived from the study. In addition, the sample size calculations assured that the study sample was large enough to observe the possible intervention effects on the primary outcome of this study, that is, perceived limitations in mobility. In addition, the control group of the trial provided a good possibility to study naturally occurring changes in mobility during the follow-up (Study I).

The participants recruited for the physical activity counseling trial represented a group of older people who were expected to benefit the most from preventive actions, i.e., the physically very active and those who were not able to move independently were excluded from the study. Based on the inclusion criteria of the study, the reported results of the trial can be generalized to sedentary or moderately active and relatively well-functioning older community dwelling people. In addition, local circumstances, such as community resources and differences in the attitudes toward physical activity, should be taken into account. In the City of Jyväskylä, where the trial was conducted, the opportunities for supervised as well as independent exercise for older people are very versatile and easily accessible. All in all, it should be emphasized that the physical activity counseling intervention was acceptable, inexpensive, efficacious, and could easily be adapted to various settings in other countries as well.

The meticulous prospective follow-up of falls and mobility limitation in the FITSA study offered an excellent possibility to investigate the predictive validity of preclinical mobility limitation on future falls (Study II) as well as the consequences of falls on the development of mobility limitation (Study III). The participation rate in the study was high. Over 95% of the baseline sample completed the 12-month fall surveillance and 3-year follow-up of mobility limitation. To be recruited for the study, the participants had to be female, be able to walk 2 kilometers and travel independently to the research laboratory from their town of residence. Consequently, the results can be considered generalizable to older high-functioning community-dwelling women.

Some *limitations* of the present study should be emphasized. It is possible that the physical activity-related interviews or personal interaction between the intervention and control group members in the physical activity counseling trial may have motivated physical activity on the part of the control group, causing some underestimation of the results. In addition, reporting bias due to social desirability may have affected the results on perceived mobility, although the physiotherapist who carried out the counseling did not participate in the data collection process. The inclusion and exclusion criteria set for the eligibility to the trial were highly relevant with regard to the aims of the trial as a whole. However, the use of this truncated distribution may have caused some underestimation in the cross-sectional and follow-up results of Study I, where the control group of the trial was utilized to study the validity of the preclinical mobility limitation concept. It is possible that with a more diverse sample of older people we would have seen even stronger associations between preclinical mobility limitation and manifest mobility limitation. A potential weakness in Study IV was that around 20% of the participants had missing data or outlier results in the tests of walking speed or muscle power. However, despite this, the baseline characteristics of the intervention and control groups remained comparable after these people were excluded. It is possible that the intervention effects on muscle power and walking speed were underestimated because the attrition rate was somewhat higher in the control group. Among older people, attrition in studies typically is not random but instead, those with more functional limitations tend to drop out. It is also possible that having three nurse examiners in the study may have increased the random examiner effect in the data, thereby reducing the intervention effect. In addition, the subgroup analyses were performed for the purpose of hypothesis building for future studies and subsequently the conclusions are indicative only.

The participants of this study were relatively well-functioning older people. This imposed some limitations on what measures of perceived mobility were relevant to use in the analyses. For example, in the FITSA study, walking 2 kilometers was the only task that showed reasonable variation among our high functioning participants and consequently was the only one that could be used in the analyses. Thus, the predictive value of preclinical mobility limitation and indoor falls needs to be further confirmed with more diverse populations of older people using a wider variety of mobility tasks. However, from the stand point of primary prevention, the results of this study are highly relevant as self-reported early signs of mobility decline as well as indoor falls already signaled functional decline among these independently living high-functioning samples of older adults.

The *strengths* of this study include the strong and relatively large datasets, including a randomized controlled trial and prospective follow-up study, with meticulous follow-up of previously validated mobility outcomes and intensive prospective fall surveillance. In addition, this study adds new and significant information to the previous research literature on physical activity counseling and early signs of functional decline among older people.

6.4 Implications and future directions

Although health and functional ability among the older populations have gradually improved over the past few decades, the number of persons suffering from mobility decline is expected to increase in the future as this population increases in numbers. Thus, the development of effective interventions to prevent or delay progression of mobility limitation and further disability in older persons is an important public health priority (Guralnik et al. 1996, Ferrucci et al. 2004).

One of the major challenges in the prevention of functional decline and disability is identification of the optimal target population (Ferrucci et al. 2004). In particular, with respect to primary prevention, it is of paramount to identify persons who are not yet disabled but who are at high risk for disability progression in the near future (Fried et al. 1991, Fried & Guralnik 1997, Ferrucci et al. 2004). Although the most common risk factors for mobility decline are nowadays widely recognized, there remains a need for the further development of simple and easily administrable tools for indentifying at risk persons in clinical work. The results of this study together with previous evidence indicate that combining self-reported preclinical mobility limitation and fall history offers a possible measure for the identification of high-risk persons among the older, still high-functioning population. Thus, the approach offers an excellent preventive framework and opportunity for early intervention. In the light of this knowledge, it can be argued that it is time to move forward to translational research and clinical applications, using the concept of preclinical mobility limitation.

The evidence on the efficacy of physical activity and exercise on health and physical functioning among older persons is highly encouraging. However, further research is needed on the extent to which the beneficial effects of physical activity observed in optimal and highly controlled research conditions can also be achieved in everyday clinical practice (Jette et al. 1999). This is highly relevant especially in today´s health care context where lack of time often restricts the resources available for use in primary prevention (Pinto et al. 1998, Tinetti et al. 2006). Thus, there is a growing need for the development of easily adaptable, acceptable and low-cost interventions that can be implemented in practice. The present study indicates that an educational intervention to promote physical activity in older adults may also be an effective means to promote mobility, an important factor for maintaining independence in the community in old age. However, further confirmatory research in the area is required before firm conclusions can be drawn. The findings suggest that much research remains to be done, exploring the most efficacious interventions for women and for men, and for people at different stages of mobility decline. Further, the cost-effectiveness of interventions as well as the mechanisms through which physical activity counseling effects mobility should also be further investigated.

7 MAIN FINDINGS AND CONCLUSIONS

The main findings of the present study can be summarized as follows:

1. Among community-dwelling older people, self-reported preclinical mobility limitation was associated with early declines in physical performance and increased risk for manifest mobility limitation.
2. Self-reported preclinical mobility limitation together with history of falls increased the risk for future falls among older high-functioning women.
3. Indoor falls were associated with increased risk of developing limitations in mobility among older high-functioning women.
4. A single individualized physical activity counseling session with a supportive phone contact every 4 months for 2 years improved leg extension power and walking speed among women with no or only early signs of mobility decline. No effects were observed among men or among women with more advanced mobility limitation at baseline.
5. Physical activity counseling had a positive effect on perceived mobility among older community-dwelling people.

In conclusion, the results of the present study indicate that self-reported preclinical mobility limitation and fall history should be considered as important early indicators of functional decline among community-dwelling older adults. In addition, the results suggest that physical activity counseling for sedentary or moderately active older adults may offer an effective means to promote mobility, which is a crucial prerequisite for maintaining independence in the community in old age. The observations of the present study can be applied in planning and targeting efficient interventions to prevent and alleviate mobility limitation in older people.

YHTEENVETO (FINNISH SUMMARY)

Liikkumiskyvyn heikkenemistä ennakoivat merkit ja liikuntaneuvonta liikkumisvaikeuksien ehkäisyssä iäkkäillä henkilöillä

Riittävä liikkumiskyky on yksi tärkeimmistä itsenäisen toimintakyvyn perusedellytyksistä. Liikkumiskyvyssä ilmenevät vaikeudet lisääntyvät iän myötä ja ovat usein ensimmäinen merkki siitä, että toimintakyky on alkanut heikentyä. Myös kaatumistapaturmat, kuten vakavaan vammaan johtavat kaatumiset, lisääntyvät iän myötä ja saattavat heikentää iäkkään henkilön liikkumis- ja toimintakykyä. Vaikka iäkkäiden henkilöiden terveys on parantunut viimeisten vuosikymmenten aikana, kasvaa liikkumisvaikeuksista ja kaatumistapaturmista kärsivien määrä eliniän pidentyessä.

Riskihenkilöiden tunnistaminen riittävän aikaisessa vaiheessa on tärkeää ennaltaehkäisevien toimenpiteiden kohdentamisen ja onnistumisen kannalta. Liikkumiskyvyn heikkenemisen tärkeimmistä riskitekijöistä, kuten heikentyneestä lihasvoimasta ja tasapainosta, on nykypäivänä jo paljon tietoa. Edelleen kuitenkin tarvitaan lisätietoa luotettavien haastattelumenetelmien kehittämiseen, sillä nykyisin käytössä olevat menetelmät eivät ole riittävän herkkiä liikkumiskyvyn heikkenemisen alkuvaiheessa olevien ikäihmisten tunnistamiseen. On viitteitä siitä, että iäkkäiden henkilöiden havaitsemat liikkumiskyvyn heikkenemistä ennakoivat muutokset, kuten kävelyn hidastuminen, vähentäminen ja väsyminen, edeltävät varsinaisten liikkumisvaikeuksien kehittymistä. Nämä prekliiniset liikkumisongelmat saattavat tarjota hyvän mahdollisuuden liikkumiskyvyn heikkenemisen alkuvaiheessa olevien ikäihmisten tunnistamiseen ja haastattelumenetelmien kehittämiseen.

Pitkittäistutkimukset ja satunnaistetut kontrolloidut kokeet ovat osoittaneet, että intensiivisellä ja säännöllisellä liikuntaharjoittelulla voidaan ylläpitää ja parantaa iäkkäiden henkilöiden liikkumiskykyä. Edelleen tarvitaan kuitenkin lisätietoa käytännön työelämään soveltuvista helposti toteutettavista liikuntainterventioista. Perusterveydenhuollossa toteutetulla liikuntaneuvonnalla tiedetään olevan positiivisia vaikutuksia iäkkäiden henkilöiden liikunta-aktiivisuuteen, mutta neuvonnan vaikuttavuudesta liikkumiskykyyn tiedetään vasta hyvin vähän.

Tässä tutkimuksessa selvitettiin iäkkäiden henkilöiden liikkumiskyvyn heikkenemistä ja kaatumisia ennakoivia merkkejä. Lisäksi tutkittiin liikuntaneuvonnan vaikuttavuutta iäkkäiden henkilöiden liikkumiskykyyn. Tutkimuksessa käytettiin kahta tutkimusaineistoa. Screening and Counseling for Physical Activity and Mobility among Older People (SCAMOB) -tutkimukseen osallistui 632 Jyväskylän kaupungin keskusta-alueella itsenäisesti asuvaa 75-81-vuotiasta miestä ja naista. Tutkittavat satunnaistettiin koe- (n=318) tai kontrolliryhmään (n=314). Koeryhmä osallistui yhteen henkilökohtaiseen liikuntaneuvontakertaan, jonka jälkeen fyysisen aktiivisuuden lisäämistä tuettiin puhelinkeskusteluin neljän kuukauden välein kahden vuoden ajan. Tutkittavien liikkumiskyvyssä tapahtuvia muutoksia seurattiin puolen vuoden välein koko intervention ajan sekä 1,5 vuotta intervention päättymisen jälkeen. Finnish Twin Study on Aging (FITSA) on prospektiivinen seurantatutkimus, johon osallistui 419 tervettä 63–75 -vuotiasta naista. Tutkimuksessa seurattiin liikkumiskyvyssä tapahtuvia muutoksia kolmen vuoden ajan. Lisäksi toteutettiin intensiivinen 12 kuukauden kaatumisten seuranta.

Tutkimuksen tulokset osoittivat, että prekliinisiä liikkumisongelmia hyväkuntoisilta ikäihmisiltä tiedustelemalla voidaan luotettavasti tunnistaa liikkumiskyvyn heikkenemisen alkuvaiheessa olevat henkilöt. Prekliiniset liikkumisongelmat ennustivat kahden vuoden seurannan aikana varsinaisten liikkumisongelmien kehittymistä hyväkuntoisilla itsenäisesti asuvilla iäkkäillä henkilöillä ja yhdessä aiempien kaatumisten kanssa lisäsivät riskiä myös tulevan vuoden kaatumisille. Lisäksi havaittiin, että iäkkäiden henkilöiden raportoimat prekliiniset liikkumisongelmat olivat yhteydessä heikentyneeseen suorituskykyyn, kuten alentuneeseen voimantuottotehoon ja hidastuneeseen kävelynopeuteen. Prekliinisten liikkumisongelmien lisäksi sisällä tapahtuneet kaatumiset olivat yhteydessä itsenäisesti asuvien ikäihmisten liikkumisongelmien kehittymiseen.

Kokeellinen tutkimus osoitti, että yksilöllisellä liikuntaneuvonnalla voidaan ylläpitää iäkkäiden henkilöiden liikkumiskykyä. Liikuntaneuvonta ehkäisi merkitsevästi koettujen kävelyvaikeuksien kehittymistä kahden vuoden intervention aikana ja saavutetut tulokset säilyivät osittain puolentoista vuoden intervention jälkeisen seurannan ajan. Liikuntaneuvonnalla oli positiivisia vaikutuksia myös iäkkäiden hyväkuntoisten naisten alaraajojen voimantuottotehoon ja kävelynopeuteen. Vaikutuksia ei havaittu miehillä, eikä naisilla, joilla oli liikkumisvaikeuksia tutkimuksen alussa. Lisätutkimuksia tarvitaan selvittämään, millaiset interventiot ovat tehokkaimpia iäkkäiden henkilöiden liikkumisongelmien ehkäisyssä miehillä ja naisilla sekä eri liikkumiskyvyn heikentymisen vaiheessa olevilla ikäihmisillä.

Yhteenvetona voidaan todeta, että prekliiniset liikkumisongelmat ja kaatumiset ovat tärkeitä liikkumiskyvyn heikkenemistä ennakoivia merkkejä hyväkuntoisilla itsenäisesti asuvilla iäkkäillä henkilöillä. Lisäksi havaittiin, että liikuntaneuvonnalla voidaan ylläpitää iäkkäiden henkilöiden liikkumiskykyä. Tämän tutkimuksen tuloksia voidaan hyödyntää iäkkäiden ihmisten liikkumisvaikeuksien ennaltaehkäisyyn suunnattujen interventioiden suunnittelussa ja kohdentamisessa.

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