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190

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Mobility and Its Decline in Old Age. Determinants and Associated Factors

JYVÄSKYLÄN YLIOPISTO

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ABSTRACT

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Mobility is an essential aspect of quality of life. Decline in mobility in old age restricts everyday activities and recreation and may have many unfavourable consequences in a person's life. The aim of this doctoral thesis was to examine mobility in older populations, deterioration in mobility over follow-up periods from five to sixteen years, and factors that are associated with this deterioration.

This study was part of an extensive research project focusing on health and functioning in the older population of the city of Jyväskylä, Central Finland, and also included samples from Glostrup, Denmark. The study consisted of a baseline interview and two eight-year follow-ups with subjects aged 65-84 (n=1224 at baseline) and interviews and laboratory tests with subjects aged 75 and 80 with two five-year follow-ups (n=617 at baseline). In Glostrup the same interviews and laboratory tests over a five-year follow-up were carried out among subjects aged 75 at baseline (n=481). Mobility was assessed through self-reports and performance-based tests.

The results of the study showed that mobility performance decreased and difficulties in mobility increased rapidly with age and particularly among women. It was common that people who did not report difficulties or who performed well in the performance tests at baseline, reported new difficulties after five years even when no essential decrease in mobility performance was found. Chronic musculoskeletal and cardiovascular conditions, along with the number of days spent in hospital care during the five-year follow-up, predicted the decline in mobility. Of the sensory, psychomotor and musculoskeletal functions, muscle strength, balance, visual acuity, reaction time and range of motion limitations of hips and knees were important determinants of mobility over the five years.

The results suggest that both self-assessments and performance-based measurements are needed to obtain a comprehensive picture of an older person's mobility functions. Actions to prevent mobility decline should be targeted more systemically at those older people who spend even rather short periods in hospital care. When developing preventive actions and rehabilitation, in addition to muscle strength and balance, attention should be paid to other determinants of mobility, such as visual acuity, reaction time and the flexibility of the lower extremity joints.

Keywords: mobility, aging, health status, dwelling environment, muscle strength, balance, visual acuity, reaction time, range-of-motion

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Jyväskylä, January 2013
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LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following articles, which will be referred to in the text by their Roman numbers. Additionally, some unpublished data are included in the thesis.

I Sakari-Rantala R, Avlund K, Frändin K, Era P: The incidence of mobility restrictions among elderly people in two Nordic localities. A five-year follow-up. Aging Clin Exp Res 2002; 14(Suppl. 3): 47-55.

II Sakari-Rantala R, Heikkinen E, Ruoppila I: Difficulties in mobility among elderly people and their association with socioeconomic factors, dwelling environment and use of services. Aging Clin Exp Res 1995; 7: 433-440.

III Sakari R, Rantanen T, Laukkanen P, Suutama T, Heikkinen E: Health status as predictor of mobility decline among older people: A five-year follow-up (submitted).

IV Sakari-Rantala R, Era P, Rantanen T, Heikkinen E: Associations of sensory-motor factors with poor mobility in 75- and 80-year-old people. Scand J Rehabil Med 1998; 30: 121-127.

V Sakari R, Era P, Rantanen T, Leskinen E, Laukkanen P, Heikkinen E: Mobility performance and its sensory, psychomotor and musculoskeletal determinants from age 75 to age 80. Aging Clin Exp Res 2010; 22:47-53.

ABBREVIATIONS

ADL	Activities of Daily Living
BMI	Body Mass Index
CES-D	Center for Epidemiological Studies Depression Scale
DST	Digit Symbol Test
ECG	Electrocadiogram
IADL	Instrumental Activities of Daily Living
ICD-9	International Classification of Diseases, version 9
ICF	International Classification of Functioning, Disability and Health
LISREL	Linear Structural Relations
MMSE	Mini-Mental State Examination
N	Newton
NORA study	Nordic Research on Aging
OR	Odds Ratio
ROM	Range of Motion
SEM	Structural Equation Modeling
SPMSQ	Short Portable Mental Status Questionnaire
SPPB	Short Physical Performance Battery
TIA	Transient Ischemic Attack
TUG	Timed Up and Go Test
VO_2	Oxygen Consumption, Oxygen Uptake
WHO	World Health Organization

CONTENTS

1 INTRODUCTION

Mobility is an essential aspect of quality of life (Netuveli et al. 2006). Decline in mobility in old age restricts everyday activities and recreation and often leads to disability. Here, by mobility is meant the ability to move physically unaided from one place or position to another using own muscular work. This includes tasks like rising from a chair, walking and climbing stairs.

Moving about requires the ability to move the body in the intended direction, the ability to maintain dynamic stability in relation to gravity and other acting forces, the ability to adjust movement to changes in the environment and to sustain the level of activity through the economical use of energy (Patla 1996). The ability to move about independently enables a variety of activities from self-care to household management and social and cultural activities as well as engagement in physical exercise. Consequently, losing independent mobility entails many kinds of restrictions in a person's life. It is usual that mobility deteriorates in old age, but the course, extent and speed of the deterioration can vary widely across individuals. This variation is due not only to the older person's specific physical, cognitive and emotional characteristics and personality, but also to the physical and social environment in which the person lives and moves about.

Older persons who have poor mobility appear to be a disadvantaged group. For example, in the study by Rasch et al. (2008a), persons who reported difficulties in everyday mobility had significantly more health problems than persons without difficulties, and were more often women and from the oldest age groups. Poor mobility also predicts several unfavourable events in the future. For example, limitations in mobility, measured by both self-assessments and performance-based tests, have been shown to predict future difficulties in mobility, general disability, falls, institutionalization and even death (Guralnik et al. 1994, Guralnik et al. 2000, Hämäläinen et al. 2006, Deandrea et al. 2010, Mänty et al. 2010). Self-reported difficulties in mobility tasks also seem to predict the incidence of other kinds of health conditions, such as musculoskeletal disorders, general symptoms, hypertension and respiratory diseases (Rasch et al. 2008b). In a study by Lampinen et al. (2006), self-rated mobility difficulties predicted poor mental health, e.g. depressive symptoms, anxiety and feelings of loneliness after 8 years.

Mobility and its deterioration can be described via the disablement process models developed by, for example, Nagi (1991), Verbrugge and Jette (1994), and the WHO (International Classification of Functioning, Disability and Health, ICF, WHO 2001). When applying these models, mobility can be described by three levels of functioning. The first is the organ level or body system level which represents the physiological and psychological functions that a person uses to move the body, such as the muscular, sensory and nervous systems. The second level represents the whole body level and describes a person's ability to move the body at a general level, in any basic movement task. This level is often measured as performance in standardized mobility tests, such as walking speed or chair-rising time. The third level represents the social aspects of mobility and describes a person's ability to move in relation to the demands of his or her own living circumstances and everyday life. Different kinds of mobility questionnaires are usually used to explore this aspect. Several factors inside the person, such as demographic factors and health, and outside the person, such as the physical and social environment and the health care system, affect the levels of mobility functions. The three levels of mobility functioning and the individual and environmental factors included in the models are in continuing interaction with each other.

The importance of mobility in the everyday life of older persons, along with the implications of poor mobility at the individual and population levels, underlines the need of examining how problems in mobility emerge, in whom and when, and what factors determine deterioration in mobility. Knowledge of this kind is needed for the development of prevention and of rehabilitation among older people. The aim of this study was to analyse mobility and its changes in different samples of older people, and to evaluate how different factors in the disablement process are associated with mobility and its decline.

2 MOBILITY IN OLD AGE

2.1 Basic characteristics of walking and stair climbing

The most common type of locomotion in humans is walking, where the body is moved horizontally. A more challenging task that is frequently performed in everyday life is to move the body vertically, for example when climbing stairs. The main focus here is in these two basic types of moving about.

The biomechanics of walking differ somewhat between young and older people. Self-selected walking speed in older persons, compared to younger ones, is characterized by lower speed and cadence, shorter stride length, a longer double-support phase and a shorter swing phase (Prince et al. 1997, Laufer 2005, Menant et al. 2009). However, in older people walking cadence does not necessarily differ from that of younger people, at least when walking at comfortable speed; in this case the lower speed is mostly caused by shorter step length (Winter et al. 1990, Kerrigan et al. 1998). Stride width and double-support time are related to the balance control of gait (Gabell & Nayak 1984). When asked to walk fast, healthy older people are able to increase cadence and stride length and to decrease the double-support phase so that the differences between younger and older persons may even disappear (Kerrigan et al. 1998, Laufer 2005).

The most important differences in joint kinematics among older walkers when compared to younger ones are probably reduced ankle plantarflexion and hip extension and greater anterior pelvic tilt (Judge et al. 1996, Kerrigan et al. 1998). These differences seem to be independent of walking speed (Kerrigan et al. 1998).

In level walking, the most important muscle group from the point of view of the forward propulsion of the body are the ankle plantarflexors, while the knee extensors are mainly responsible for the vertical stabilization of the body (Winter 1983b). Ankle power generation in the pre-swing is lower in older persons than in younger persons (Kerrigan et al. 1998, DeVita & Hortobagyi 2000). Younger persons increase walking speed by increasing ankle and hip power in late stance to generate more energy (Winter 1987). Older subjects do not seem to have the capability to increase ankle power sufficiently, and a great deal of the increase in speed is attained by increasing the hip flexion moment and work done by the knee (Judge et al. 1996, Kerrigan et al. 1998).

During the swing phase of the opposite leg, the vertical projection of the centre of mass is not above the base of support (the stance foot) but passes along the medial border of the stance foot (Shimba 1984, MacKinnon & Winter 1993). This phase challenges balance, which is why it is usually shortened in older compared to younger people (Laufer 2005). During the swing phase, the toes swing forward and are at their lowest about one centimetre above the ground in the middle of the swing, while their forward velocity is highest (Winter et al. 1990). In addition, at this moment the centre of gravity of the body is already in front of the stance foot (Winter 1992), which means that the position is very unstable. Thus even small objects, such as a pebble on the walkway, may threaten balance, if the swinging leg strikes in it.

Energy expenditure during walking at different speeds is about 20% higher in older than younger subjects (Ortega & Farley 2007). This is probably caused by mechanical factors such as the greater cost of stabilizing the body, greater amount of agonist-antagonist coactivation and poorer efficiency of the muscular system (Ortega & Farley 2007, Schmitz et al. 2009).

Stair climbing is a heavier task than level walking, and when functioning begins to deteriorate, problems in mobility usually appear early in stair climbing (Weiss et al. 2007). When climbing stairs, higher contact forces are present when the joints are at higher flexion angles, compared to level walking (Costigan et al 2002), which increases the loading of the joints. For example, it has been found that early in the stance phase of climbing, when the knee is flexed at about 60 degrees, the contact forces in the knee correspond to three times the force produced by body mass (Costigan et al. 2002). The knee extensors are needed to generate most of the energy for the vertical movement of the body in stair climbing (McFadyen & Winter 1988). When descending stairs, the knee extensors and ankle plantarflexors produce the highest bursts of eccentric muscle work so as to absorb energy (McFadyen & Winter 1988). The hip extends less at toe-off in stair walking than in level walking (Nadeau et al. 2003). In addition, the flexion in the knee is increased (Rowe et al. 2000) as also is the dorsiflexion in the ankle in both the stance and swing phases, which is partly due to the need to clear the step during swing phase (Nadeau et al. 2003). When descending stairs, old persons dorsiflex the ankle more than young persons, about 25 degrees compared to 20 degrees (Lark et al. 2004). Thus the dorsiflexion movement used by older persons in stair climbing is often at its maximum level.

When mounting a single high step, the subject needs to move the stepping leg high upward, without hitting the step, and at the same time control balance with the stance leg. After this the centre of mass will be shifted over the climbing foot. The step height that persons of different ages are able to climb without support has been analysed. Cesari et al. (2003) found that young adults were able to mount step heights similar to their leg length, whereas the older adults (aged 53 to 72 years) achieved only 74% of their leg length.

2.2 Epidemiology of problems in mobility

Changes in mobility in old age are common and usually mean deterioration. However, improvements are also possible (Jagger et al. 2007), even in the oldest age groups, but only in a minority of cases. Mobility changes usually follow a broad hierarchy, the most difficult or demanding tasks declining first. On the basis of the prevalence and onset of new difficulties, Weiss et al. (2007) showed this hierarchy in three mobility tasks. The most demanding task was walking half a mile, the second was climbing 10 steps, and the easiest was transferring from bed or chair (Weiss et al. 2007). Here the results of epidemiological studies are reported according to self-assessments of mobility tasks (reported difficulties or need of help) and to performance in standardized mobility tasks (performance-based tests).

<u>Cross-sectional comparisons</u>
Difficulties. An extensive Finnish cross-sectional cohort study, comprising about 8000 persons aged 30 and over, clearly showed the increasing prevalence of self- reported mobility difficulties across age groups (Sainio et al. 2006). In the easiest mobility task, moving about inside the home, 5% of men and 7% of women aged 65-74 reported some difficulties. In the age group 75-84 the proportions were about three times higher, peaking in the age group 85-99, where 39% of men and 56% of women reported difficulties. A somewhat higher proportion of men and women in each age group reported difficulties in walking 0,5 km, from 20% in the age group 65-74 to more than 80% in the oldest age group (Sainio et al. 2006). Very similar proportions for walking indoors and outdoors have been reported in the USA, even if comparison is somewhat difficult due to the different age group classification (Ervin 2006). In Finland, according to Sainio et al. (2006), more than half of a sample of subjects aged 65-74 reported difficulties in running 100 m, and in the oldest age group practically all the participants reported difficulties or inability. The proportions having difficulties in running 100 m were very similar to those found in a population study in Sweden (Ahacic et al. 2000).

Climbing stairs also is a difficult task. In a study from the Netherlands it was found that difficulties in climbing stairs were reported by 32% of men and 43% of women in the age group 65-74, while among those aged 85 or over 79% of men and 88% of women reported difficulties (Odding et al. 1995). Among a population aged 65 or over studied in England and Wales, the proportions were lower, difficulties or the inability to climb stairs being found in 26% of men and 38% of women (Jagger et al. 2007).

Cohort comparisons of self-reported mobility have often shown decreasing trends, but earlier studies have also shown no cohort differences or increasing trends. Difficulties in walking and climbing stairs have decreased according to several cohort studies in Sweden (Ahacic et al. 2000), the Netherlands (Puts et al. 2008) and the USA (Freedman & Martin 1998, Liao et al. 2001, Seeman et al. 2010). Most often this has been seen in the oldest age groups, those aged 70 and over (Liao et al. 2001) or 80 and over (Seeman et al. 2010). In Finland, however, a decreasing trend has been seen most often in younger groups of old people (Malmberg et al. 2002, Martelin et al. 2002, Leinonen et al. 2006). An exception to this was the study by Malmberg et al (2002), where no cohort differences were found among subjects aged 59-63 years, between the study years 1981 and 1996. In addition, no cohort differences were found among men aged 65-84 between the years 1993 and 2003 in another Finnish study by Sulander et al. (2006).

The increasing trend towards mobility difficulties between cohorts has been shown in the USA (among subjects aged 60-69 in the study by Seeman et al. 2010) and in Sweden (Parker et al. 2005, Fors et al. 2008). In Finland, Sulander et al (2006) showed that difficulties in using stairs or walking outdoors increased among women aged 65-84 years between the years 1993 and 2003. Future studies will show how far the differences found in the trends are caused by differences in the tasks assessed, age groups studied, years of measurement or large variation in functioning in general in old age.

Need of help. Reporting need of help in performing mobility tasks is less common than reporting difficulties. For example, less than 10% of those aged 65 or over report need of help in walking or stair climbing (Guccione et al. 1994, Shumway-Cook et al. 2005). However, the proportions are higher in more strenuous tasks; for example, Guccione et al. (1994) found that 18% of persons aged 64-95 reported need of help in walking one mile.

According to the cohort comparisons of the Framingham Heart Study, the prevalence of needing help in climbing stairs, walking half a mile and doing heavy housework declined substantially in men and women aged 55 to 70 years, when two birth cohorts separated by a 17-year interval were compared (Allaire et al. 1999). In the same study, the cohort comparison of older subjects (aged 79-88), with a 20-year interval between assessments, showed that need of help in mobility had declined only in the cohorts of women (Murabito et al. 2008).

Performance-based tests. Performance-based mobility tests also show that older age groups get poorer results and usually perform more slowly in timed tests than younger groups. For example in the study by Sainio et al. (2006), maximal walking speed over 6.1 m was 1.6 m/s in men and 1.4 m/s in women among those aged 65-74, 1.3 m/s in men and 1.1 m/s in women in the next 10-year age group and 0.9 m/s in men and 0.7 m/s in women aged 85-99. A similar trend was shown in the time for 5 chair stands, which took 4-5 s more time in the oldest age groups compared to those aged 65-74 (Sainio et al. 2006). The ability to mount high steps was measured as the highest box the subject could mount in a single step without support among Norwegian women aged 75 and over by Bergland et al. (2008). The boxes were of height 10, 20, 30, 40, 50, 60 and 70 cm. The mean age of the participants was 81 years, and 22% of them were able to mount the 50 cm or higher step (Bergland et al. 2008).

Longitudinal studies

Difficulties. In a 16-year follow-up, the proportions of men (aged 59-63 at baseline) reporting difficulties in walking increased from 28% to 62% (Malmberg et al. 2002). Among women, the corresponding figures were 32% and 78%. In stair climbing, the proportions were higher at baseline, 45% in men and 65% in women, but the rate of increase was lower and the proportions of those reporting difficulties 16 years later were 68% in men and 82% in women (Malmberg et al. 2002).

The incidence of mobility difficulties has been reported in a few studies. In an 18-month follow-up among community-dwelling women aged 79-80 years, 24% of the participants who were free of mobility difficulties at baseline developed difficulties in the mobility tasks of walking 0.8 km, climbing 10 steps and transferring into a car or bus (Chaves et al. 2000). Over longer follow-up times the proposition of incident difficulties is higher. For example, in the study by Brach et al. (2007), more than a half (59%) of the community-dwelling men and women (mean age 79.1 ± 4.2) developed new difficulties in walking half a mile over 4.5 years. In the Health, Aging and Body Composition study, in which the follow-up time was also 4.5 years but the subjects somewhat younger, 70-79 years, new difficulties in walking half a mile or climbing 10 steps occurred in 34% of men and 47% of women (Visser et al. 2005).

In follow-up studies with several measurement phases it has been possible to analyse the pattern of change in mobility functions in older persons. It has been shown that among 55-60% of older people difficulties or other mobility disabilities develop rather slowly, progressing from mild to moderate and, finally, to a severe stage. A rapid rate, where early mild stages do not occur, is seen in about 40-45% of older people (Guralnik et al. 2001, Onder et al. 2005). In the oldest age groups (age 85 and over), the slow type of decline seems to be more common, in about 80% of old persons (Guralnik et al. 2001).

Need of help. New need of help in any of the tasks of walking 350 m, climbing stairs or getting on a bus occurred during a one-year follow-up among 4% of women and 1% of men aged 65-70 and among 5% of women and 9% of men aged over 70 in a representative British sample (Ayis et al. 2006). Guralnik et al. (2001) analysed the occurrence and progression of dependence in walking indoors over 7 years among persons aged 65 or over, and incident need of help was found in 5%. It was shown that, in general, need of help developed first in walking half a mile and, after one or two years, in walking indoors.

Dependence in mobility is not necessarily a stable state in old age. According to monthly interviews by Gill et al. (2006), three quarters of older subjects experienced several transitions between dependence and independence in walking 400 m, and 52% experienced such in climbing a flight of stairs (Gill et al. 2006). In light of these results it seems that relying on just two measurement points in follow-up studies may cause measurement bias and underestimate the size of the change, both in decline and recovery.

Performance-based tests. The decline in mobility performance seems to be considerable over follow-up time of just a few years. For example, the three-year follow-up by Onder et al. (2002) showed that comfortable walking speed over 4 m decreased by 16% and the time to five chair stands increased by 21% among community-living women with at least some disability. The annual decline was largest among those aged 80 or over when compared to those between 65 and 79 (Onder et al. 2002).

2.3 Different methods of mobility measurement

The different methods used to measure mobility often represent different levels of mobility functions. For example, self-assessments usually describe how older persons experience coping with mobility tasks in their everyday life. This level is called the disability level in the disablement process models by Nagi (1991) and Verbrugge & Jette (1994) and the participation level in the ICF model by the WHO (2001). Performance-based tests capture a more general level of mobility as they usually measure quantitative characteristics, such as performance time, of standardized, often short-lasting tasks. This level is termed functional limitations by Nagi (1991) and Verbrugge & Jette (1994) and the activity level in the ICF model (WHO 2001).

Mobility measured by performance-based tests is associated with self-reported mobility (Guralnik et al. 1994, Simonsick et al. 2001, Wang et al. 2005), and the association is usually stronger if the test in question represents the same mobility function as the task asked about. For example, slow walking speed measured over a short distance has been shown to associate with self-reported difficulties in walking 0,4 km (Lan et al. 2002), 0,5 km and 2 km (Mänty et al. 2007). Also, a poor result in a chair-stand test has been found to associate with self-reported difficulties in walking, but the associations have been somewhat weaker than between walking speed test and self-reported walking difficulties (Lan et al. 2002). The same can be seen when analysing performance tests and self-reported need of help in mobility tasks. Researchers have found strong associations between walking speed over a short distance and need of help in walking half a mile (Guralnik et al. 1994). Significant but less strong associations have been shown between a walking speed test and need of help in climbing stairs, and between a chair-stand test and need of help in walking or stair climbing (Guralnik et al. 1994).

Discrepancies also usually emerge between self-reported ability and measured performance of the same tasks (Guralnik et al. 1994). For example, in a Spanish study it was found that about 40% of those who were not able to walk 4 m in the walking speed test had not reported need of help or inability in the interview (Ferrer et al. 1999). Also about 40% of those who walked slowly had not reported difficulty in walking (Ferrer et al. 1999). A comparison of stair climbing according to a performance test and self-report showed considerable disagreement; this was higher among women than men and among older than younger age groups (Sainio et al. 2006). However, in another study (Merrill et al. 1997), women showed higher agreement than men when their self-reported ability to walk across a room was compared to the ability to walk 2.4 m in a test.

Several studies have analyzed the predictive value of performance-based tests on the development of mobility problems. These studies apply the idea of the disablement process models, according to which mobility disability proceeds from one level of functioning to the next (Nagi 1991, Verbrugge & Jette 1994). Thus a poor result in performance tests may indicate an early phase of functional decline, the subject not yet experiencing difficulties in everyday life. For example, it has been shown that a poor result in a short-distance walk test predicts the onset of difficulties in walking or stair-climbing (Cesari et al. 2005) or the development of need of help (Guralnik et al. 1995, Ostir et al. 1998, Guralnik et al. 2000). In other studies a poor result in a longer distance walk test (400 m) predicted the onset of mobility difficulties (to walk a quarter of mile or climb stairs) (Newman et al. 2006, Simonsick et al. 2008). A poor result in a chair stand test has also been shown to predict future mobility dependence (Ostir et al. 1998, Wang et al. 2011). Researchers have also found that a poor score in the SPPB test (Short Physical Performance Battery, Guralnik et al. 1994), which includes usual walking speed over 2.4 m, time to five chair stands and standing balance measurements, predicts becoming unable to complete the 400-metre walk test (Chang et al. 2004, Vasunilashorn et al. 2009). Follow-up times in the above mentioned studies have varied between 1 and 6 years.

If it could be shown that only one mobility test gives all the necessary information to identify persons who are at risk for mobility decline, it would help the work of both clinicians and epidemiologists. Studies have been carried out to compare the value of gait speed measurements to the values of other performance-based tests of mobility in predicting the development of difficulties or need of help. Some researchers concluded that short distance gait speed alone predicts subsequent mobility disability so well that other performance measurements do not improve the strength of the predictive models (Guralnik et al. 2000, Onder et al. 2005). In these studies the predictive value of walking speed over 2.4 m (usual speed) has been compared to that of the score in the SPPB test which also included measurements of 5 chair stands and standing balance (Guralnik et al. 1994). However, other studies have shown that slow walking speed over a short distance, at usual or at high speed, was not as good a predictor of the development of difficulties or need of help in mobility as were other tests such as a stair climbing test (Weiss et al. 2007), time to walk 1 km (Hämäläinen et al. 2006) or the time to five chair stands (Wang et al. 2011). Weiss et al. (2007) conclude that a walking speed test may overlook a considerable proportion of subjects who have incipient problems in mobility and who would be potential targets for interventions. It is possible that different tasks and measurements represent different aspects of mobility which are related but do not substitute for each other. This indicates that it would not be reasonable to limit the measurements of mobility to only one test or task.

One way to identify early restrictions in mobility or other functioning is to ask persons who do not report any difficulties if they have changed their way of performing mobility tasks or decreased the frequency of performance due to health problems. This often happens unconsciously, before experiencing or realizing difficulties in performance. This approach uncovers the so called preclinical level of disabilities (Fried et al. 1991, Fried et al. 1996). Several studies have shown that self-reported modifications in mobility tasks predict incident difficulties in mobility (Chaves et al. 2000, Fried et al. 2000, Mänty et al. 2007).

3 FACTORS ASSOCIATED WITH MOBILITY AND ITS DECLINE

3.1 Demographic factors

Demographic factors are important from the point of view of mobility, as they are among the personal factors that interact with the different levels of functioning according to the ICF-model (WHO 2001). The associations between age and mobility were dealt with in the previous chapter.

3.1.1 Gender

Women seem to have more self-reported difficulties in mobility than men in old age (Merrill et al. 1997, Malmberg et al. 2002, Murtagh & Hubert 2004), and the difference remains significant after adjusting for socioeconomic indicators, chronic conditions and cognitive performance (Wray & Blaum 2001, Graciani et al. 2004, Shumway-Cook et al. 2005, Rueda et al. 2008,). Gender or sex differences seem to be clearest in the older age groups and in most strenuous tasks, such as climbing several flights of stairs or walking 100 m while carrying a heavy bag (Sainio et al. 2006). However, some studies have shown that women aged 60 or over significantly more often report difficulties in all mobility tasks than men of the same age, including rather light tasks like walking between rooms and getting in or out of bed (Ervin 2006). It is possible that the association of gender with self-reported difficulties in mobility is stronger than between gender and ADL functions (Activities of Daily Living, Wray & Blaum 2001).

Self-reported difficulties in running, climbing stairs or walking have been shown to be more common among women than men in Swedish cohort studies that compared older persons of the same age between the years 1968, 1974 and 1981 (Ahacic et al. 2000) and 1991-1992 and 2000-2002 (Fors et al. 2008). However, a significant decrease in the gender difference was found between the years 1968 and 1991 (Ahacic et al. 2000).

In a one-year follow-up (Ayis et al. 2006), the onset of need of help in mobility tasks occurred in equal proportion among both men and women. In longer follow-up studies, the onset of dependence has been more frequent among women than men (Leveille et al. 2000, Avlund et al. 2003). In a follow-up of 6-7 years, recovery from dependence in mobility tasks was higher among men (Leveille et al. 2000).

Gender differences are evident also in performance-based tests. For example walking speed over a short distance and time to five chair stands are slower among women than men (Guralnik et al. 1994, Merrill et al. 1997, Oman et al. 1999, Sainio et al. 2006). In spite of this, Oman et al. (1999) showed in their four-year follow-up study that the incidence of new inability to complete the mobility tests was at the same level in men and women.

The higher prevalence of disability among women is associated with gender differences in incidence, mortality and recovery. Women have been shown to have a lower mortality rate and recovery rate from disability than men, and their higher prevalence of mobility problems has been explained by higher incidence (Leveille et al. 2000) and longer duration (Oman et al. 1999) of disability. Probable reasons for gender differences are, on one hand, differences in physical characteristics and, on the other hand, differences in health status. In old age, women more often suffer from non-fatal disabling diseases, such as arthritis and osteoporosis and also depression (Murtagh & Hubert 2004). The fact that women both report more difficulties in mobility tasks and perform poorer in mobility tests than men indicates that the gender difference is not explained by differences between men and women in readiness to report problems (Merrill et al. 1997).

3.1.2 Income and poverty

Low income, as well as actual poverty, has been associated with poor mobility. Low income significantly increases the risk for reporting difficulties or need of help in walking in persons aged 65 and over (Shumway-Cook et al. 2005, Thorpe et al. 2008). According to Minkler et al. (2006), self-reported, health related mobility limitations (long lasting conditions that substantially limited one or more basic mobility tasks) increased progressively with decreasing household income, and the inverse association was significant up to the age of 85. Performance-based measurements of mobility also show associations with income. For example in the population study among moderately or severely disabled older women by Thorpe et al. (2008), it was found that poor white women walked more slowly than non-poor white women. However, in a comparison of 10 Western European countries, household income was not associated with difficulties in mobility among either men or women (Rueda et al. 2008).

Low income may also be associated with mobility decline, at least in follow-up studies lasting 5 to 10 years. Koster et al. (2005) showed that all income categories that were lower than the highest reference group predicted the incidence of self-reported mobility difficulties over six years, and the association was independent of several health and biomedical conditions. Low income was associated with decline in measured walking speed in a Finnish older population in follow-ups of 5 and 10 years (Rautio et al. 2005). However, in a 3-year follow-up study, poverty was not associated with decline in either self-assessed mobility or walking speed (Thorpe et al. 2008).

3.1.3 Education

In many European countries and in the USA strong associations have been reported between low education and self-reported difficulties in mobility (Østbye et al. 2002, Graciani et al. 2004, Shumway-Cook et al. 2005, Rautio et al. 2006, Rueda et al. 2008). For example, in the adult population in the Netherlands, the age- and sex-adjusted prevalence of major mobility difficulties was four times higher among those educated to only primary school level and about two times higher among those with vocational education, than among those with university education (Picavet & Hoeymans 2002).

However, in recent Finnish population studies the cross-sectional associations between education and mobility functions have varied. Low education was not significantly associated with self-reported difficulties in mobility tasks in the studies by Martelin et al. (2002) and Sulander et al. (2006). However, Martelin et al. (2002) showed that men with higher than basic-level education less often had marked difficulties in carrying 5 kg for 100 m. The association between longer education and reduced risk for difficulties in climbing stairs in women aged 65-84 years was significant and remained significant in the multivariate analyses by Rautio et al. (2006). In two other studies the associations between low education and self-reported difficulties or poor observed performance disappeared in men when adjusted for chronic conditions or other confounding factors (Sainio et al. 2007, Rautio et al. 2001). However, among women, some associations were shown to remain significant in multivariate models as well (Rautio et al. 2001, Sainio et al. 2007). Finland represents the Scandinavian welfare regime with a high level of social security; however, this seems not completely to remove inequalities in the socioeconomic situation of older people.

In a 1-year follow-up study, level of education did not significantly predict the onset of dependence in mobility in models controlled for several health conditions (Ayis et al. 2006). However, studies that have used longer follow-up times have shown significant associations between low level education and the development of new difficulties (Jagger et al. 2007, Nordstrom et al. 2007) or new need of help in mobility (Melzer et al. 2001).

It seems that chronic conditions are the main mediators in the association between poor socio-economic situation and mobility problems (Koster et al. 2005). However, poor socioeconomic situation may also have negative effects through the physiological functions that underlie mobility performance, such as muscle power, range of motion of lower extremity joints and visual acuity, as was shown by Coppin et al. (2006).

3.1.4 Occupation

Older persons with manual worker socioeconomic position are more likely to report mobility difficulties (Ahacic et al. 2000, Rautio et al. 2006, Fors et al. 2008) or to score poorly in performance tests (Russo et al. 2006) than clerical workers or managers. Rautio et al. (2006) showed that the association between previous occupation and difficulties in climbing stairs disappeared when number of chronic conditions, smoking and alcohol intake were introduced in the model. In the cohort study by Ahacic et al. (2000), the association between manual occupations and self-reported difficulties in mobility tasks remained the same across four cohorts between 1968 and 1991, even if the proportion of those reporting mobility difficulties decreased across cohorts. Longitudinal studies have also shown significant associations between occupation and mobility decline. According to Wannamethee et al. (2005), manual occupations were associated with greater risk for the onset of mobility difficulties than non-manual occupations among older men over four years.

3.1.5 Marital status

The associations of marital status with mobility problems seem to vary in different studies, some studies showing significant associations and others none. For example, Østbye et al. (2002) found no significant associations between marital status and self-reported difficulties in mobility. In a Finnish study, associations were found between marital status and some mobility tasks, but only among men (Martelin et al. 2002). Men who were widowed, single or divorced, significantly more often reported difficulties in the mobility tasks of getting in/out of bed and carrying 5 kg for 100 m than currently married or cohabiting men (Martelin et al. 2002). Also in the USA, married persons aged 65 and over reported less often difficulties or need of help in walking than currently non-married persons, according to Shumway-Cook et al. (2005). However, having never been married may protect from major difficulties in walking, carrying and lifting according to Picavet & Hoeymans (2002).

3.1.6 Living alone

Living alone seems not to have strong associations with mobility. In the countries of Western Europe, living alone has not been shown to associate with mobility difficulties when compared to living with a partner (Rueda et al. 2008). However, in one study from the Netherlands it was found that those living alone had higher probability for difficulties in mobility (walking, carrying, lifting something from the floor) when compared to those who lived in a two-person household (Picavet & Hoeymans 2002). The opposite was shown in the USA, where older persons living alone had less often mobility problems (self-reported difficulties or use of help or walking aids when moving about), than those who lived with others (Shumway-Cook et al. 2005). The association may be complicated, as living alone is not possible if a person needs lots of help in mobility or other everyday functions. In addition, those who live with someone may get help easier and thus report need of help more often. However, living alone requires more independent initiative, which may also promote functioning and mobility.

3.1.7 Nationality

Earlier studies have shown large inter-country differences in mobility functions. For example, in a comparison of 7 countries it was found that the proportion of persons aged 80-89 who needed help in moving outdoors was lowest (10%) in the city of Tampere, Finland and twice as high (21%) in Florence, Italy (Kozarević et al. 1989). The result was, at least in part, explained by the fact that only non-institutionalized persons were included in the study, and in Finland the proportion of older persons living in institutions at that time was much higher than in most of the other countries studied (Kozarević et al. 1989).

In another study comparing men from Finland, the Netherlands and Italy, it was found that self-reported need of help was significantly less common among older men in Finland in several mobility tasks (moving outdoors, using stairs, walking at least 400 meters and carrying a heavy object for 100 meters) when compared to the men from the Netherlands (van den Brink et al. 2003). The trend was the same, but not significant, when the men from Finland were compared to the men from Italy (van den Brink et al. 2003). However, in the study by Minicuci et al. (2003), no differences were found between European countries in the ability to walk indoors among subjects aged 65-84 years. In mobility performance tests, cross-cultural differences have varied. According to the comparison between Finland, the Netherlands and Italy, Finnish men scored lowest in the walking speed test (usual speed) and highest in the timed chair stand test (five stands) (van den Brink et al. 2003).

Not many cross-national comparisons on mobility have been reported, probably due to high research costs and problems in collecting uniform data in studies involving international cooperation. Even in studies using coordinated planning and standardized questionnaires, difficulties in interpreting the study protocol and translating the questionnaire may cause differences in the measurements and affect the results (Heikkinen et al. 1983).

3.2 Health status

Health status is a major concept in the ICF model by WHO (2001) and pathology is the starting point of the disablement process in the models by Nagi (1991) and Verbrugge and Jette (1994). ICF model assumes that health status interacts with all levels of functioning. According to the models, health may affect mobility functions directly or the effects may be mediated through the other levels of functioning.

3.2.1 Chronic conditions

Previous studies have sometimes classified chronic diseases and conditions as specific diseases and sometimes combined them in larger disease groups, which makes comparisons difficult. In the next section, the results of the earlier research have been organized into cross-sectional and longitudinal studies and are reported according to the measurement method used to analyse mobility.

Cross-sectional comparisons

Difficulties. Many studies have analysed the associations of chronic diseases and conditions with self-reported mobility difficulties. Musculoskeletal diseases and disorders, such as arthritis, hip fracture, osteoporosis or low back problems, as well as neurological diseases, such as stroke, are often found in the background of difficulties in mobility (Clark et al. 1997, Kriegsman et al. 1997, Odding et al. 2001, Oldridge & Stump 2004, Melzer et al. 2005, Puts et al. 2008). Also, cardiovascular diseases, lung diseases and diabetes mellitus are associated with self-reported difficulties (Clark et al. 1997, Kriegsman et al. 1997, Odding et al. 2001, Oldridge & Stump 2004, Melzer et al. 2005, Puts et al. 2008). According to some studies (Kriegsman et al. 1997, Oldridge & Stump 2004, Melzer et al. 2005), cancer seems to be associated with prevalent difficulties in mobility, but the associations have not been as strong as with other chronic diseases or conditions.

For example, Oldridge & Stump (2004) found that stroke, lung disease, arthritis, low back problems, diabetes, heart disease (particularly angina pectoris) and cancer increased the risk of the prevalence of self-reported difficulties in walking or climbing stairs in subjects aged 70 years or over. Diseases that were not associated with mobility difficulties were hypertension and myocardial infarction without other heart diseases (Oldridge & Stump 2004). In addition, certain disease groups (arthritis, diabetes, lung diseases and stroke) significantly increased the negative effects of heart disease when occurring together (Oldridge & Stump 2004). It seems probable that the combined effects of certain diseases are more deleterious than the individual effects of different diseases. Comorbidity as such also significantly explains the prevalence of difficulties or more severe mobility problems (Melzer et al. 2005, Shumway-Cook et al. 2005).

The importance of different diseases in explaining mobility problems probably vary between age groups. According to Melzer et al. (2005), the self-reported chronic diseases that had the strongest associations with self-reported walking difficulties among subjects aged 65-79 years were stroke, lung disease, recent cancer and arthritis. In the older age group (80 years or older), stroke and lung disease were still significantly associated with walking difficulty, as also were heart murmur and osteroporosis, but not arthritis or cancer (Melzer et al. 2005). Disease severity, indicated for example by disease-specific signs and symptoms and received medical treatment, may explain more about the association between a disease group and mobility difficulty than the disease group alone (Kriegsman et al. 1997). One explanation for differences between studies analyzing the effects of diseases on mobility or other functioning may be that age or disease severity are usually not taken into account.

Need of help. Few studies have analysed the cross-sectional associations between chronic conditions and need of help in mobility tasks. Guccione et al. (1994) analysed the effects of chronic conditions on self-reported need of help or inability to climb stairs and walk 1 mile among older subjects. Hip fractures and stroke were the diseases most often associated with need of help in both tasks. Also, knee osteoarthritis, diabetes and lung diseases had a significant impact on need of help. Heart diseases (angina pectoris or myocardial infarction) were associated with dependence in walking but not with dependence in stair climbing (Guccione et al. 1994).

Performance-based tests. Musculoskeletal diseases, heart diseases, diabetes mellitus, stroke and cancer have most often been found to be significantly associated with performance-based tests (Perkowski et al. 1998, Bootsma-van der Wiel et al. 2002, Wang et al. 2002, Newman et al. 2003). Peripheral arterial disease in particular explains performance in longer lasting mobility tests, such as the time to walk 400 m, as was shown in the study by Newman et al. (2003). The performance tests used in earlier studies have often also included measurements of other performance than pure mobility, like balance and grip strength tests (Perkowski et al. 1998, Wang et al. 2002). Cesari et al. (2006) showed that comorbidity (3 or more coexisting clinical conditions) was associated with slow walking speed over 4 m and a poor result in the SPPB test among older Italian persons.

<u>Longitudinal studies</u>

Difficulties. Disease groups that have been shown to be associated with the development of new self-reported difficulties in mobility are arthritis, diabetes, cardiovascular diseases and lung diseases (Wannamethee et al. 2005). Comorbidity seems to be an important risk factor for new self-reported mobility difficulties as well (Jenkins 2004). Peripheral arterial disease predicts incident difficulties in walking longer distances, such as half a mile (Brach et al. 2008).

Need of help. Cardiovascular diseases, diabetes mellitus, neurologic diseases and musculoskeletal diseases seem to be strong predictors for the onset of dependence in mobility in follow-up studies (Guralnik et al. 1993, Ho et al. 1997, Penninx et al. 1999). Metabolic syndrome has also been shown to predict need of help in mobility over a 4-year follow-up (Blazer et al. 2006). Guralnik et al. (2001) analyzed how the occurrence of new diseases impacts the development of dependence in walking indoors over 7 years. The occurrence of stroke, hip fracture and cancer strongly increased the risk for the development of dependence in walking but heart attack had no effect (Guralnik et al. 2001).

Performance-based tests. Earlier studies that have analysed the associations between chronic conditions and decline in mobility performance have shown conflicting results, even if in many cases the mobility performance measurements, age groups and follow-up times have been similar. For example, musculoskeletal diseases were associated with decline in performance in walking speed or chair stand tests in the studies by Pugh et al. (2007) and Forrest et al. (2006) but not in the studies by Wang et al. (2002) or Inzitari et al. (2006). Stroke or cerebrovascular diseases predicted decline in mobility performance according to Pugh et al. (2007), Wang et al. (2002) and Inzitari et al. (2006), but not according to Forrest et al. (2006). The impact of cardiovascular diseases is also unclear, with significant associations reported by Wang et al. (2002) and Inzitari et al. (2006) but not by Pugh et al. (2007) or Forrest et al. (2006). In single studies, other chronic conditions such as cancer (Wang et al. 2002), Parkinson's disease (Inzitari et al. 2006), peripheral arterial disease (Brach et al. 2008) and high number of chronic conditions (Oman et al. 1999) have also shown associations with decline in mobility performance.

3.2.2 Other health conditions and symptoms

Health conditions and symptoms other than diagnosed diseases may represent early effects or side effects of diseases and may contribute to disability. Different kinds of perceived symptoms have been found to be associated with mobility problems and to predict decline in mobility (Leveille et al. 2002). Indicators of subclinical diseases, such as high blood pressure, high fasting glucose and nonacute ECG abnormalities, may also significantly contribute to poor mobility (Newman et al. 2003). The importance of measuring symptoms and subclinical diseases has been emphasized, as they may yield important information on health, many of them are treatable, and treating them might reduce disability (Leveille et al. 2002, Newman et al. 2003).

Dyspnea was one of the main symptoms reported by older women as the cause of their difficulties in walking or climbing stairs (Leveille et al. 2002). Breathlessness has also been shown to relate to the onset of mobility difficulties (Wannamethee et al. 2005) and dependence (Guralnik et al. 2001, Guralnik et al. 1993). *Palpitation* has been found to predict the onset of dependence in mobility tasks over 18 months (Ho et al. 1997). *Dizziness* seems to be associated with self-reported inability to run 100 m, walk 100 m or climb stairs (Ahacic et al. 2007) as well as with poor performance in a walking test (Bootsma-van der Wiel et al. 2002). *Fatigue* has been associated with self-reported inability to walk and climb stairs (Ahacic et al. 2007) as well as with poor mobility in performance-based tests (Vestergaard et al. 2009). According to the study by Avlund et al. (2004), subjects who reported tiredness when performing daily activities had almost three times higher risk for substantial decline in walking speed over 5 years. About ten per cent of older women claim general *weakness* or leg weakness to be the main cause for their difficulties in walking or stair climbing (Leveille et al. 2002). *Fear of falling* has been shown to explain poor results in a short walking test among subjects aged 85 or over (Bootsma-van der Wiel et al. 2002).

Several studies have shown significant associations between *pain* and poor self-reported mobility as well as poor mobility performance or decline in mobility (Guralnik et al. 1993, Clark et al. 1997, Lamb et al. 2000, Odding et al. 2001, Leveille et al. 2002, Newman et al. 2003, Melzer et al. 2005, Wannamethee et al. 2005, Bryant et al. 2007). About 40% of older women report that musculoskeletal pain, most often in hips or knees, is the main reason for their difficulties in walking or stair climbing (Leveille et al. 2002). Leveille et al. (2007) reported that only widespread pain was associated with the development of new difficulties in stair climbing and walking a quarter of a mile over three years, when adjusted for demographic factors, number of diseases, physical performance and psychological factors. However, in some studies pain has not been associated with mobility performance tests such as walking speed or chair stand time (Bootsma-van der Wiel et al. 2002, Leveille et al. 2007).

To study the effects of symptoms on mobility, symptoms of various kinds have often been included in *summary scores of symptoms*. These have shown associations with poor results in mobility performance tests cross-sectionally (Whitson et al. 2009) and longitudinally (Jenkins 2004). Whitson et al. (2009) showed that a disease index of common diseases did not remain significant when the symptom score was added into the models of mobility performance. The authors concluded that summary scores of symptoms may be useful in identifying older adults whose situation is medically complicated and who are at high risk for functional decline (Whitson et al. 2009).

High body mass index, and particularly obesity, is associated with self-reported mobility difficulties (Davison et al. 2002, Goya Wannamethee et al. 2004, Oldridge & Stump 2004, Shumway-Cook et al. 2005, Ramsay et al. 2006), as well as with poor performance in mobility tests (Perkowski et al. 1998, Newman et al. 2003, Stenholm et al. 2007b). Goya Wannamethee et al. (2004) showed that slight overweight (BMI between 25.0 and 27.4) was not associated with mobility difficulty, and the association was significant only among subjects with higher BMI. In longitudinal studies, overweight or obesity also seems to increase the risk for the development of self-reported difficulties in mobility (Jenkins 2004, Lee et al. 2005, Houston et al. 2009), for the onset of need of help in mobility tasks (LaCroix et al. 1993, Penninx et al. 1999) and for the incidence of poor performance in mobility tests (Oman et al. 1999). However, Guralnik et al. (2001) did not find significantly increased risk for the onset of need of help in mobility among persons with high BMI.

Body composition has also been measured as fat mass using bioelectric impedance analysis, and *high fat mass* seems to be associated with poor mobility. For example, Sternfeld et al. (2002) and Visser et al. (1998) showed that high fat mass was associated with self-reported difficulties in walking and stair climbing. In addition, high fat mass may be predictive of developing new difficulties in mobility (Visser et al. 1998).

A *low body mass index* (defined as lower than 18 or 20, depending on study) may also be disadvantageous for mobility. It has been shown that a low body mass index significantly explains difficulties in walking or the use of walking aids (Shumway-Cook et al. 2005) as well as inability to perform the 2.4-m walk test or five chair stand test (Perkowski et al. 1998). According to Ho et al. (1997), a low body mass index predicted dependence in walking and climbing stairs in an 18-month follow-up study.

Self-reported fair or poor health seems to be associated with poor mobility performance, for example with poor results in walking speed and chair stand tests (Hirsch et al. 1997, Oldridge & Stump 2004, Shumway-Cook et al. 2005). Poor self-rated health may also predict the onset of dependence in walking, at least in follow-up times up to 7 years (Ho et al. 1997, Guralnik et al. 2001). In a 10-year follow-up, poor self-rated health at baseline was not associated with change in walking speed or chair-stand time when adjusted for chronic conditions and living habits (Forrest et al. 2006).

Using *multiple medications* simultaneously is common in old age, as people often have several chronic conditions at the same time and may suffer from many troubling symptoms. Multiple medications may have associations with poor mobility performance, as shown by Lord & Menz (2002), who measured mobility using the 6-min walking test. According Pugh et al. (2007), having 5 or more medications was predictive of the decline in the SPPB-test.

Hospitalization indicates usually low physical activity or even bed rest. This, as well as the medical reason for hospitalization, may have detrimental effects on several dimensions of functioning. Short-term hospitalization has been shown to be associated with decline in self-reported ADL functioning (Covinsky et al. 2003, Gill et al. 2004). The same seems to apply to mobility functions as well, as indicated in studies by Gill et al. (2004) and Suesada et al. (2007). However, in an experiment including 10 days of bed rest, the performance of healthy older adults in the SPPB test did not decline, even if knee extensor strength, stair-climbing power and maximal aerobic capacity had declined (Kortebein et al. 2008). The reason for the discrepancy may be that the subjects were healthy and the duration of bed rest was rather short.

3.3 Physiological functions

Physiological functions represent the body system level in the disablement process models (Nagi 1991, Verbrugge & Jette 1994, WHO 2001). Age affects all the physiological functions that are important to produce and control movements and locomotion. For example, it is well known that muscle strength and aerobic capacity decline by about 10% per decade from middle age onwards. However, the decline is individual and varies widely, depending on many factors such as health status and lifestyle, for example the level of physical activity.

3.3.1 Muscular functions

Different muscles have different roles in locomotion, such as in walking and climbing stairs. Muscles propel the body forward, support the body, control the loading of the foot etc. However, in spite of the different functions of muscles in mobility tasks, the strengths of the lower extremity muscle groups are highly correlated (Tiedemann et al. 2005). The strength or torque of different muscle groups or their summary scores have been used when analysing the determinants of mobility. In many studies, knee extension strength has been measured, as it is easy to measure accurately and may adequately represent overall leg strength, since the knee extensors are the largest muscle group in the lower extremity (Judge et al. 1996).

The associations between lower extremity strength and mobility have most often been analysed using performance-based mobility assessments. However, some researchers have shown significant correlations between knee extension strength and self-reported difficulties in standing up from low levels, such as from an easy chair or from the floor (Corrigan & Bohannon 2001). Puthoff and Nielsen (2007) analysed whether lower extremity extension strength affected self-reported difficulties in daily functions through mobility performance. The analyses showed indirect effects between strength and reported difficulties, and the effects were mediated by the level of performance in the mobility tests (Puthoff & Nielsen 2007).

Significant associations have been observed between knee extension strength or torque and timed mobility tests, such as time to stand up from a chair (Salem et al. 2000, Corrigan & Bohannon 2001, Cuoco et al. 2004), time to walk short distances at usual and fast speed (Salem et al. 2000) as well as time to climb stairs (Cuoco et al. 2004). In some studies, the associations have not been significant between knee extension strength and habitual walking speed (Cuoco et al. 2004), and only more vigorous mobility functions have been associated with strength (Salem et al. 2000). Parallel results were reported by Lamoureux et al. (2002), who showed that the association between knee extension strength and walking performance on an obstacle course was stronger when the obstacles on the walking course were more difficult to negotiate. This indicates that satisfactory muscle strength is more important when the way of moving or the environment is challenging. Also the correlation between knee extension force and sit-to-stand performance has been shown to be moderate at highest (Corrigan & Bohannon 2001, Lord et al. 2002a), which indicates that other factors than muscle force, or the force of one separate muscle group, contribute to the performance of this task. Ankle plantar flexor strength has been shown to be associated with gait speed (Posner et al. 1995) and with stair climbing and chair rising time (Suzuki et al. 2001). Also the strength of the knee flexors (Salem et al. 2000) and ankle dorsiflexors (Suzuki et al. 2001) has been found to significantly explain mobility performance in cross-sectional studies.

Longitudinal studies have shown that low knee extension strength also predicts the decline in mobility over the follow-up years. In a 2.5-year follow-up study, low knee extension strength predicted the incidence of self-reported difficulties in walking or climbing 10 steps (Visser et al. 2005). Poor quadriceps strength has shown an association with decline in walking speed over 2- and 4-year follow-ups (Gibbs et al. 1996).

Not only strength, but also leg extension power has shown an association with mobility performance and in some studies even more strongly than muscle strength. Associations have been found between the power of lower leg muscle groups and usual gait speed (Suzuki et al. 2001, Bean et al. 2003, Cuoco et al. 2004), maximal gait speed (Rantanen & Avela 1997, Suzuki et al. 2001), chair rise time (Suzuki et al. 2001, Bean et al. 2003, Cuoco et al. 2004), stair climb time (Suzuki et al. 2001, Bean et al. 2003, Cuoco et al. 2004), the SPPB test (Bean et al. 2002, Puthoff & Nielsen 2007) and the 6-min walking test (Puthoff & Nielsen 2007). Asymmetry between legs in leg extension power measurements has also been found to relate to slower maximal walking speed (Portegijs et al. 2005).

It has been suggested that the relationship between lower extremity strength and mobility performance is not linear but has a threshold after which the increase in strength is no longer linked to increased performance. Some studies have supported this view, analysing the strength of leg extensors and walking speed (Buchner et al. 1996, Kwon et al. 2001), between hip flexor strength and walking speed (Ferrucci et al. 1997) and between knee extensor and hip flexor strength and time to 5 chair stands (Ferrucci et al. 1997). In addition, some researchers have tried to identify knee extensor strength cut-off levels that are predictive of the development of mobility problems and thus would help to identify persons at risk (e.g. Ploutz-Snyder et al. 2002, Cress & Meyer 2003, Manini et al. 2007). The cut-points found differ widely, probably due to differences in study populations and measurement methods. The validity and applicability of such cut-off points in clinical populations or epidemiological samples are unclear.

3.3.2 Balance

Postural control during locomotion is challenging for humans because the locomotor pattern is bipedal with few points of support, and the centre of mass is positioned high above ground level. Most of the time in walking or stair climbing only one foot is in contact with the ground (Winter et al. 1990, Woollacott & Tang 1997). The large mass of the upper body (head, arms and trunk) and its movements during the gait cycle cause large forces that need to be controlled by the hip, knee and trunk muscles (Winter et al. 1990, Woollacott & Tang 1997).

Balance and its relationship to mobility have often been analysed using static balance tests, although locomotion requires dynamic stability. This probably explains why the associations between balance and mobility may be weak or even absent in some studies. Balance is measured usually by the movement of the centre of pressure on a force platform or with clinical tests that challenge the postural system. For example, in the study by Hughes et al. (1996) sway measures on a force platform were not associated with time to walk 10 m at usual speed, ability to rise from a chair, or the 6-minute walking test. However, some studies have shown that dynamic postural control on a force platform (weight shifting) is significantly associated with timed performance tests, such as stair climbing, walking speed, and getting out of a car (Topp et al. 1998, Marsh et al. 2003).

Some studies show associations between clinical balance tests and mobility functions. For example, significant associations have been found between the one-legged stance and tandem stance, Functional Reach -test, and Timed Up and Go (TUG) –test and the step-mounting height (highest step that the subject could mount in a single step, range 0-70 cm) among Norwegian women aged 75 or over (Bergland et al. 2008).

Longitudinal studies analysing the association between balance and mobility are scarce. Rantanen et al. (2001) showed the predictive value of poor balance in a clinical balance test for the development of self-reported walking disability over three years. In a 15-month follow-up, balance on a force platform was shown to have associations with change in the time to get in/out of a car (Marsh et al. 2003). However, in the same study, balance was not associated with change in walking speed or stair-climbing time when the covariates were controlled for (Marsh et al. 2003).

3.3.3 Aerobic capacity

To sustain physical activity over a given period of time depends on the ability of a person's cardiopulmonary system to supply energy by oxidative mechanisms (Pendergast et al. 1993). The degree of effort and breathlessness perceived when performing a task is determined by the relationship between the oxygen cost of the activity and the person's peak VO_2 (Fleg et al. 2005). In old age, particularly in the oldest age groups, cardiorespiratory fitness declines to thresholds that make everyday mobility difficult and fatiguing, as was shown in the review by Paterson et al. (2007). Tasks that are perceived as fatiguing and that require substantial effort are avoided, which decreases the physical activity level. This accelerates the loss of aerobic capacity, muscle mass and strength, and, finally, contributes to poor mobility (Fleg et al. 2005).

Several studies show that low peak or maximal VO_2 values are associated with poor mobility. According to Morey et al. (1998), low peak VO_2 values were associated with self-reported need of help in walking half a mile, climbing stairs or doing heavy housework in persons aged 65-90. Significant associations have been found between low peak or maximal VO_2 and a poor result in mobility performance tests such as walking speed (Posner et al. 1995, Binder et al. 1999a, Malatesta et al. 2004), chair-stand and stair climbing tests (Binder et al. 1999a) as well as the 6-min walking test (Alexander et al. 2003) in older subjects. However, Bean et al. (2008) showed that submaximal aerobic capacity, measured as duration (in minutes) of the exercise tolerance test, was not associated with mobility performance as measured by the SPPB test among older subjects who had some mobility problems.

3.3.4 Vision

Visual input is essential for route planning and proactive control of walking, such as avoiding obstacles or other sources of potential perturbation (Patla 1997). Older subjects have been reported to decrease their walking speed indoors on an uneven surface when their visual input is suddenly reduced by dimming the light (Moe-Nilssen et al. 2006). Vision also gives information about body posture and the movement of body parts and, with help of optic flow, about self-motion that is used to control the speed of walking (Patla 1997). When mounting high steps, vision is needed to evaluate the height of the step and the proper position of the feet for successful performance (Cesari et al. 2003).

The characteristics of vision that have been measured most often when studying the associations between vision and mobility are visual acuity, contrast sensitivity and visual field. Also self-reports of visual impairments have been used, and these have shown associations with self-reported difficulties in mobility tasks, as well as inability or need of help in walking or stair climbing (Crews & Campbell 2004, Whitson et al. 2007).

Some studies show that poor distance visual acuity is an important determinant of self-reported difficulties (Lamoureux et al. 2004), or need of help (Laitinen et al. 2007) in mobility, but conflicting results have also been reported. Rubin et al. (1994) showed that visual acuity was not significantly associated with self-reported difficulties in mobility. Poor visual acuity seem to explain poor results in performance-based mobility tests, such as walking speed tests (Klein et al. 1998, Bootsma-van der Wiel et al. 2002, Laitinen et al. 2007), and stair-climbing and chair-rise tests (Laitinen et al. 2007).

Associations have been found between poor contrast sensitivity and self-reported difficulties in mobility (Rubin et al. 1994) and slow walking speed (Klein et al. 1998). Visual field loss has been shown to be associated with self-assessed need of help or inability to walk several hundred metres and climb stairs (West et al. 2001). In addition, visual field loss seems to be associated with poor mobility performance according to the 1-minute back and forth walking test (West et al. 2002) and walking on an obstacle course (Turano et al. 2004).

In longitudinal analyses, visual problems have been associated with decline in self-reported ability to walk or climb stairs (Sloan et al. 2005, Chaudhry et al. 2010). Self-reported problems in vision seem also to explain decline in mobility performance tests such as walking speed and chair-rise tests (Oman et al. 1999). However, in a five-year follow-up of subjects aged 43 to 84 years, measured visual acuity or contrast sensitivity did not explain change in walking speed, even if the association was significant at baseline (Klein et al. 2003).

3.3.5 Reaction time

Fast reactions are needed for proactive control of mobility, for example to avoid other movers on the street who may appear unforeseeably on the same route. If the balance is disturbed, fast reactions are needed to quickly produce adequate torque in the muscles that control the movement of the centre of mass.

Slow reaction time is associated with slow walking speed (Lord et al. 1996, Menz et al. 2005, Tiedemann et al. 2005) and slow stair-climbing time (Tiedemann et al. 2007). The measured reaction time may directly reflect central processing speed, which becomes slower with age and slows down walking speed as well, or walking slower may be an indirect compensation strategy among people who have impaired ability to react quickly enough to unexpected perturbations when walking (Callisaya et al. 2009). It has been shown that old people react much more slowly than young people to a simple reaction time test stimulus or to a sudden cue to turn, when the stimulus is given during walking (Lajoie et al. 1996, Cao et al. 1997).

3.3.6 Range of motion of joints

The typical decrease in the range of motion (ROM) of the lower extremity joints in old age may affect step length and thus walking speed. Among many older persons, passive hip extension, ankle dorsiflexion and ankle plantarflexion movements are smaller than the active motions of the same joints during walking in younger subjects according to gait analysis (Roach & Miles 1991, Vandervoort et al. 1992, Winter 1983a). Persons with much impairment in hip and knee range of motion have been shown more often to report difficulties in walking compared to those without impairments (Lan et al. 2002). Cross-sectional associations have also been found between a limited range of motion in lower extremity joints and slow walking speed (Escalante et al. 2001) and poor score in Physical Performance Test, which includes both mobility and everyday function tests (Beissner et al. 2000). The longitudinal study by Gibbs et al. (1996) showed that impairments in lower extremity joints (tenderness, deformity and restricted motion) significantly predicted decline in walking speed over 2- and 4-year follow-up times in older persons.

3.3.7 Coimpairments

As several physiological functions are related to mobility, multivariate models combining more than two physiological functions in the same models have been used to analyse their simultaneous effects. Such analyses have, so far, mostly been cross-sectional. For example, coimpairment of standing balance (timed standing in different positions) and knee extension strength has been shown to have significant associations with severe walking disability among a group of older women who had at least some difficulty in daily functioning (Rantanen et al. 1999).

Standing balance (timed tests) and leg extension power were significantly associated with maximal walking speed in the analyses by Sallinen et al. (2011). However, usual walking speed has more often been used as the outcome variable in earlier multivariate analyses. For example, in the study by Tiedemann et al. (2005), usual walking speed over 6 m was explained by lower extremity muscle strength score, visual contrast sensitivity, reaction time and standing balance. About 40% of the variance of walking speed was explained in models which also included self-reported vitality, bodily pain and age (Tiedemann et al. 2005). In another cross-sectional analysis, knee extension strength, ankle flexibility, contrast sensitivity and reaction time explained 55%

of the variance of walking speed (Menz et al. 2005). Callisaya et al. (2009) showed in separate analyses for men and women that factors explaining faster walking speed, common to both sexes, were knee extension strength and reaction time. Among men, standing balance was also significant and among women, visual contrast sensitivity and proprioception (Callisaya et al. 2009).

Very much the same factors also seem to be associated with longer distance walking. According to Lord & Menz (2002), the distance walked in six minutes was explained by lower extremity strength, standing balance, visual contrast sensitivity and reaction time as well as pain, health and mood, number of medications and age. Over 50% of the variation of the six-minute walking test result was explained by the model, which, however, did not include any measure of cardiovascular fitness (Lord & Menz 2002).

The same factors that have been shown to explain walking performance on level ground, have largely also explained performance in tests that include moving the centre of mass vertically. Important determinants of chair rise and stair climbing tests include lower extremity strength, standing balance, visual contrast sensitivity reaction time and proprioception (Lord et al. 2002a, Tiedemann et al. 2007). Additional factors that have been reported to be significant in multivariate models are tactile sensitivity and some psychological measures such as self-reported anxiety, fear of falling, vitality and pain (Lord et al. 2002a, Tiedemann et al. 2007). Leg extensor strength and balance seem to be crucial determinants of mobility, and they also explained SPPB test performance according to Bean et al. (2008), in addition to leg velocity, which was calculated from the power measurement of the leg extensors.

Longitudinal analyses by Rantanen et al. (2001) showed that those who had both poor balance in a clinical balance test and poor knee extension strength had more than five times higher risk for developing walking disability over 3 years than those who had the best results in the balance and strength tests. In a seven-year follow-up, Chaudhry et al. (2010) found that the onset of self-reported difficulties in climbing 10 steps or walking half a mile was significantly predicted by several physiological functions such as low grip strength and self-reported problems in vision and hearing.

In the multivariate models different sensorimotor and musculoskeletal factors have remained significant even when the models have been adjusted for demographic and health variables. However, the percentage of the variation of the mobility functions studied that has been explained has rarely exceeded 50%. This indicates that several other physiological, psychological and behavioural aspects probably influence mobility, in addition to the most evident sensorimotor and musculoskeletal functions.

3.4 Psychological functions

Psychological functions, together with physiological functions, represent the body system level in the disablement process models (Nagi 1991, Verbrugge & Jette 1994, WHO 2001).

3.4.1 Cognitive functions

Tests of global cognitive functioning and memory tests usually show significant associations with mobility as well as with the decline of mobility among older persons. For example, significant associations have been found between low cognitive performance score and self-reported mobility difficulties (Blaum et al. 2002) and inability or need of help in mobility (Whitson et al. 2007). A poor result in the Mini-Mental State Examination (MMSE) test also seems to be associated with poor mobility performance (Hirsch et al. 1997, Bootsma-van der Wiel et al. 2002). Poor result in the delayed recall test of the MMSE has been shown to have associations particularly with mobility performance tests requiring fast speed (Bramell-Risberg et al. 2012).

Longitudinal studies have shown that poor results in the Short Portable Mental Status Questionnaire (SPMSQ) explain the development of need of help in mobility (Penninx et al. 1999, Guralnik et al. 2001). A poor score in a memory test or other global cognitive tests seem significantly to increase the risk for decline in mobility performance (Oman et al. 1999, Raji et al. 2002, Tabbarah et al. 2002, Atkinson et al. 2007, Buchman et al. 2011).

Tests that measure other, more specific cognitive processes, such as executive functions and psychomotor speed, seem also to be associated with gait and locomotion. Executive functions include components such as volition, self-awareness, planning, attention, response inhibition and response monitoring (Yogev-Seligmann et al. 2008), which are measured by specific cognitive performance tests. Several researchers have shown that tests of this kind, such as Digit Symbol Substitution Test, Trail Making Test and Clock Drawing Test are associated with poor mobility performance, most often walking speed, both cross-sectionally (Binder et al. 1999b, Ble et al. 2005, Holtzer et al. 2006, Kuo et al. 2007, Soumaré et al. 2009) and longitudinally (Atkinson et al. 2007, Inzitari et al. 2007, Soumaré et al. 2009).

Patients with dementia usually have pathology in the brain structures that produce and control movements, which explains why dementia is associated with different kinds of neurologic gait disorders, such as problems in gait initiation, foot placement, protective reactions, and cautious gait (Elble 2007). It has also been suggested that gait disorders may reflect early underlying cerebrovascular or neurodegenerative diseases (Snijders et al. 2007).

3.4.2 Emotional functions

Depressive symptoms are common in old age and seem to be related to mobility problems. However, the associations are complicated as depressiveness can be either a cause or a consequence of limitations in mobility and everyday functioning, or develop parallel with them due to a common aetiology (Blazer 2003, Hirvensalo et al. 2007). Cross-sectional analyses have shown an association between depressive symptoms and self-reported difficulties in mobility tasks (Melzer et al. 2005, Hirvensalo et al. 2007). Depressive symptoms also have significant associations with poor walking speed or other tests of mobility performance (Bootsma-van der Wiel et al. 2002, Wang et al. 2002).

In longitudinal studies, depressivity has been shown to predict the onset of dependence in walking or climbing stairs (Penninx et al. 1999) and the increase in need of help in mobility tasks (Blazer et al. 2006). Depressive symptoms also seem to predict decline in performance-based mobility tests (Oman et al. 1999, Wang et al. 2002, Inzitari et al. 2006) as well as poor performance in the SPPB test (Penninx et al. 1998, Raji et al. 2002) over follow-up times of 2 to 4 years. Both chronic depression (present at baseline and at follow-up) and emerging depression (not present at baseline) were associated with decline in mobility performance in a three-year follow-up study by Penninx et al. (2000). However, in the same study it was shown that the risk for decline in mobility performance was not higher among persons whose depression had disappeared during the follow-up, when compared to those who did not have depressive symptoms at either measurement point (Penninx et al. 2000). Depressive symptoms may also interact with cognitive functions. In a 2-year follow-up, the poorest results in the SPPB test was found among those who had both poor cognitive function and a high depressivity score (Raji et al. 2002).

3.5 Living habits

Living habits are among the personal factors that interact with different levels of functioning according to the disablement process models (Nagi 1991, Verbrugge & Jette 1994, WHO 2001). Of living habits, physical activity and its impact on health and functioning has been widely studied recently. In old age, poor health restricts participation in physical activity or exercise (Ashe et al. 2008), and it has been shown that the associations between physical activity and mobility may disappear when chronic conditions and other confounding factors are included in the models (Wannamethee et al. 2005). Thus, when analysing the effects of physical activity on mobility, health status needs to be controlled for, and this has been done in the studies reported here.

Older women who report less than moderate intensity physical activity may have up to five times greater risk for reporting difficulties in mobility functions when compared to women who report at least some moderate intensity activity weekly (Jerome et al. 2006). Cross-sectional studies have also shown that participating in even light intensity physical activity is more beneficial for mobility than being totally inactive. Brach et al. (2004) showed that those who reported light intensity physical activity performed better in mobility tests, particularly in short lasting tests, than physically inactive subjects. However, regular exercise probably yields additional benefit for mobility functioning, as in the same study, the best results in a more demanding mobility test (400-m walk) were achieved by those who reported vigorous physical activity (Brach et al. 2004).

Longitudinal studies have shown that older persons who do not report regular vigorous physical exercise have higher risk for developing self-reported difficulty in mobility than those who report regular exercise (Jenkins 2004, Visser et al. 2005). In addition, Visser et al. (2005) found that among those who reported only light physical activity, the risk for the onset of mobility difficulties was lower than among inactive subjects, but still significantly higher than among those who reported regular exercise. Remaining inactive or quitting physical activity during the follow-up time has been shown to be associated with higher rate of decline in mobility performance tests than remaining active (Visser et al. 2002).

Studies with follow-up times between 1 and 4 years have shown that a high level of physical activity helps to prevent self-reported difficulties in mobility functions (Simonsick et al. 2005), and helps individuals to remain independent (LaCroix et al. 1993) and to maintain good performance in mobility tests (Oman et al. 1999, Simonsick et al. 2005). If good performance in mobility tests cannot be maintained during the follow-up years, the decline seems, however, to be smaller among those who report a high level of physical activity (Visser et al. 2002, Buchman et al. 2007).

Smoking is probably harmful for mobility; however, the evidence is not totally consistent. Current smoking (Shumway-Cook et al. 2005) and having smoked formerly (Østbye et al. 2002) have been shown to be associated with self-reported difficulties in mobility among older persons in cross-sectional studies. According to Wannamethee et al. (2005), current smoking increased the risk for developing new difficulties in mobility tasks over four years. However, in another study with a 3-year follow-up (Jenkins 2004), current smoking was not associated with the development of self-reported difficulties in mobility. It has also been reported that the risk for losing independent mobility is significantly higher in current smokers than among older persons who have never smoked (LaCroix et al. 1993). In their 10-year follow-up study, Forrest et al. (2006) showed that lifetime smoking predicts decline in performance-based mobility tests.

Moderate alcohol consumption seems to decrease the risk for the onset of self-reported difficulties (Østbye et al. 2002) or dependence (LaCroix et al. 1993) in mobility. In turn, the associations between heavy alcohol consumption and mobility are not clear. For example, heavy drinking was shown to increase the risk for the development of difficulties in mobility over four years in the study by Wannamethee et al. (2005). However, in a 10-year follow-up study no association was found between heavy alcohol use and decline in mobility performance (walking speed, timed chair stands) (Forrest et al. 2006).

3.6 Living environment

According to the ICF model (WHO 2001), environmental factors represent the contextual factors, external to the subject, that interact with different levels of functioning and health. The physical environment can constrain or facilitate the independence and mobility of older persons (Satariano 1997, Gill et al. 1999a).

Our physical environments are usually designed for adult healthy persons of average height. According to the environmental docility hypothesis by Lawton and Simon (1968), which addresses the relationship between person and environment, competent, well-functioning persons should be able to live in physically or socially demanding environments. Correspondingly, persons with poor competence or poor functional ability will have problems living in such environments. In old age, people most often continue living in the same physical environment as before. This means that the effect of the environment on behaviour becomes more important as the dweller gets older and his/her physical function decreases (Lawton 1990, Iwarsson 2005, Iwarsson & Wilson 2006). On the other hand, environmental hazards, such as absence of grab bars in bath rooms and handrails on stairs, slippery rugs, furniture that obstructs walkways, low chairs, and poor lighting, are common in the homes of old people. Such defects which may affect transferring, balance and gait, have been found in almost all the homes of subjects aged 70 and over (Carter et al. 1997, Gill et al. 1999b). In addition, the presence of defects seems to be equally common among persons with poor mobility and poor balancing abilities as among persons without these problems (Gill et al. 1999a).

Impaired physical functioning may cause problems in moving about outdoors if the surroundings are characterized by uneven terrain, obstacles or hilly ground, or if distances are long. Icy and slippery streets prevent many older persons from walking outdoors during winter time. It has been shown that older persons with mobility disabilities tend to avoid certain features of the environment significantly more than older persons without disabilities. For example, Shumway-Cook et al. (2003) found that about one-half or more of disabled persons avoided crossing streets with traffic lights, terrain with steps and curbs, uneven surfaces and travelling alone. Older persons also seem to avoid travelling outdoors when it is dark (Shumway-Cook et al. 2002). Avoiding such environmental challenges may limit everyday activities and social contacts, and hence reduce physical activity, which further impairs mobility. In an observation study it was confirmed that among subjects with mobility disability, the number of trips made and the activities performed during one trip was smaller than among those without disability (Shumway-Cook et al. 2002).

On the other hand, smooth, non-slippery and peaceful streets with benches for rest may attract older persons to walk more than is necessitated by household errands, and thus increase their physical activity and mobility. It has been shown that older people's positive perceptions of safety for walking in the neighbourhood, as well as close proximity to recreational facilities, increases the amount of walking in the neighbourhood (Li et al. 2005).

It is noteworthy that both disabled and non-disabled older subjects usually carry something when outdoors (Shumway-Cook et al. 2002). This is a reminder that outdoor mobility tasks actually require the ability to divide the attention between several motor tasks (walking, carrying, avoiding obstacles) as well as cognitive tasks such as observing the environment, controlling one´s progress in the direction of the target destination and possibly talking with a companion.

Defects in the dwelling environment are not a cause of mobility problems, but among persons who have poor physical functioning they may restrict their possibilities to move about and to be physically active more than among well-functioning persons. For example, Clarke et al. (2008) showed that among adults who had no or only mild physical impairment (no or only some difficulties in stooping, rising from a chair, pushing, carrying, doing heavy housework), street and sidewalk quality had no effect on mobility disability. It was only among persons with more severe impairments (a lot of difficulties in the above mentioned tasks), that defects in the built environment increased mobility disability (Clarke et al. 2008). Environmental hazards also contribute to falls, even if the association is not straightforward and the existence of hazards does not directly cause falls (Lord 2006). It seems that defects in the home environment increase the risk for falling, particularly in older persons with poor balance, whereas good mobility helps people to cope with the environmental hazards and manage without falls (Lord 2006).

3.7 Summary of the factors associated with mobility

Earlier studies on the factors associated with mobility in older persons show many conflicting results. This is particularly evident in studies analysing the impact of health status, but it also concerns other factors. The reasons for the conflicting results may be due to differences between studies, such as different samples and different methods of measurement. Problems of selectivity and the representativeness of samples often affect the results. Large population samples would be preferable; however, large sample size may prevent the use of standardized measurements in laboratory conditions. In some studies, the participation rates have been rather low. It is difficult to interpret the results, if the age range of participants in a study is large and no age grouping, e.g., into 5- or 10-year age groups, is used. Men and women have also often been included in the same analyses. However, earlier studies show that age and sex affect almost all measurements of mobility, and consequently results may be biased if age and sex groups are not properly taken into account. The associations of age and gender on mobility seem to be stronger in performance-based mobility tests and vigorous mobility tasks. The physiological differences between the sexes are evident; however, mobility tasks are usually the same for all, despite differences in the characteristics of the person. Other important personal and environmental factors that affect mobility, according to earlier studies, are level of education, physical activity and the physical environment.

The associations found between major public health problems, such as cardiovascular diseases and musculoskeletal diseases, and mobility or decline of mobility, vary widely between studies. Many studies have analysed the impact of diagnosed or self-reported diseases on mobility, without taking into account the severity of the illness or the different symptoms that probably contribute to the associations. Self-reports of health conditions may not be reliable as they are susceptible to memory problems. The effects of some rare but clearly disabling illnesses may not be seen if cases of, for example hip fractures, do not happen to occur during the follow-up time. The impact of hospitalization or bed rest on mobility decline deserves more attention, as both are common among older people. The contribution of different kinds of symptoms, diseases and health events on mobility decline should receive more research attention.

Proper body system functioning is the primary requirement for moving about. Earlier studies have clearly shown the dependence of mobility tasks on lower extremity muscle function, but the variation explained may not be very high as many other factors also participate in producing and controlling movements. In everyday activities, biomechanical principles, such as momentum (Schenkman et al. 1990) and stiffness of connective tissue (Gajdosik et al. 2005), are also used to decrease the muscle force needed. The effects of many physiological factors on mobility at the population level have not yet been thoroughly studied. This applies particularly to the associations of reaction time and the ROM of the lower extremity joints with mobility. At the moment, much research is being done on cognitive functions that control movements, and their associations with mobility. The clinical implications of the results will become clear in the future. Analyses, particularly longitudinal analyses, on the simultaneous effects of several background factors on mobility and its decline are needed. Follow-up studies are, however, the only way to find out what combinations of factors have long-term predictive value, and what, consequently, would be the most important targets for prevention and rehabilitation.

4 PURPOSE OF THE STUDY

The general aim of this doctoral thesis was to examine mobility in older populations, the deterioration in mobility over five to sixteen years and the factors associated with this deterioration. More specifically, the aims of the present study were:

1. To investigate self-reported mobility and mobility performance, and changes in these over several years among older populations (I).

2. To analyse the associations between socioeconomic factors, dwelling environment and self-reported difficulties in mobility (II).

3. To investigate the associations between health conditions and mobility decline, and the contribution of cognitive functions and personal factors such as physical activity on the decline of mobility (III).

4. To analyse the associations of sensory, psychomotor and musculoskeletal factors with mobility, and with the change in mobility over five years (IV, V).

The summary includes also analyses that are not reported in the articles.

5 MATERIALS AND METHODS

5.1 Study design and participants

The present study is part of the Evergreen project, which is an extensive research project focusing on health and functioning in the older population of the city of Jyväskylä, Central Finland (Heikkinen 1997a, 1998). The first data were collected in 1988 and, in total, about 2 500 persons aged 65 or older have participated in different phases of this population-based study. Figure 1 shows the design of the Evergreen project and the data used in this study.

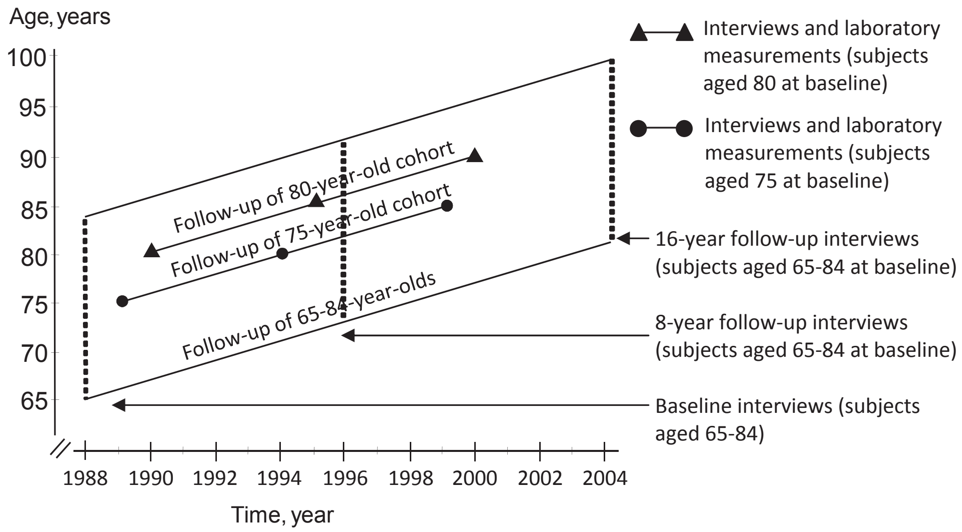


FIGURE 1 Samples of the Evergreen project used in the present study.

In 1988, two random samples of 800 persons were collected from the population register. The first sample comprised persons born in 1914-1923, aged 65-74 years, and the second sample persons born in 1904-1913, aged 75-84 years (Table 1). The samples represented 16.8% and 30.9%, respectively, of the populations in the corresponding age groups. People living in institutions were excluded. The subjects were invited to participate in a two-part interview, carried out in their homes (Heikkinen 1997a, Heikkinen 1998). The number of eligible persons includes those who were alive in the beginning of the interviews or who were alive and had not moved out of the area at the beginning of the follow-up interviews. Mortality data were collected from the Population Register Centre.

TABLE 1 Participants in the interviews in 1988, 1996 and 2004 (65- to 84-year-olds at baseline).

	65-74 yrs at baseline						75-84 yrs at baseline					
	Men		Women		Total		Men		Women		Total	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Baseline 1988												
Sample	288		512		800		242		558		800	
Died[a]	4		3		7		8		11		19	
Moved[a]	1		2		3		0		2		2	
In instit.[b]	4		3		7		9		21		30	
Eligible	279	(100)	504	(100)	783	(100)	225	(100)	524	(100)	749	(100)
Refused	34	(12)	101	(20)	135	(17)	43	(19)	105	(20)	148	(20)
Not found	4	(1)	9	(2)	13	(2)	3	(1)	9	(2)	12	(2)
Participated	241	(86)	394	(78)	635	(81)	179	(80)	410	(78)	589	(79)
8-year follow-up 1996												
Died[c]	72		78		150		109		190		299	
Moved[c]	4		9		13		1		8		9	
Eligible	165	(100)	307	(100)	472	(100)	69	(100)	212	(100)	281	(100)
Refused	19	(12)	41	(13)	60	(13)	2	(3)	24	(11)	26	(9)
Not found	0	(0)	2	(1)	2	(0)	1	(1)	1	(0)	2	(1)
Participated	146	(89)	264	(86)	410	(87)	66	(96)	187	(88)	253	(90)
16-year follow-up 2004												
Died[d]	78		111		189		58		170		228	
Moved[d]	3		8		11		0		2		2	
Eligible	84	(100)	188	(100)	272	(100)	11	(100)	40	(100)	51	(100)
Refused	10	(12)	39	(21)	49	(18)	2	(18)	6	(15)	8	(16)
Not found	1	(1)	2	(1)	3	(1)	0	(0)	3	(8)	3	(6)
Participated	73	(87)	147	(78)	220	(81)	9	(82)	31	(78)	40	(78)

[a]Before interview
[b]Lived in institution
[c]Between 1988 and 1996
[d]Between 1996 and 2004

In addition, two whole age groups were invited to participate in the interviews and laboratory tests. In 1989, all the inhabitants of Jyväskylä who were born in

1914 (75-year-olds) were included, and in 1990 all those who were born in 1910 (80-year-olds). Those living in institutions were also invited. The interviews were carried out in the participants' homes and the laboratory tests took place in the laboratory building of the Department of Health Sciences, University of Jyväskylä, Finland. In total, 355 persons aged 75 and 262 persons aged 80 participated in the baseline phase of the study (Table 2).

TABLE 2 Participants in the interviews and laboratory tests at baseline in 1989 (75-year-olds) and in 1990 (80-year-olds), and in the five- and ten-year follow-up phases of the study.

	75 yrs						80 yrs					
	Men		Women		Total		Men		Women		Total	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Baseline												
Target group	127		261		388		78		213		291	
Eligible	125	(100)	257	(100)	382	(100)	76	(100)	207	(100)	283	(100)
Refused	6	(5)	19	(7)	25	(7)	2		19		21	
Not found	0		2	(1)	2	(1)	0		0		0	
Interview	119	(95)	236	(92)	355	(93)	74	(97)	188	(91)	262	(93)
Laboratory tests	104	(83)	191	(74)	295	(77)	60	(79)	145	(70)	205	(72)
Five-year follow-up												
Died[a]	27		52		79		32		58		90	
Moved	5		3		8		2		3		5	
Eligible	87	(100)	181	(100)	268	(100)	40	(100)	127	(100)	167	(100)
Refused	4	(5)	13	(7)	17	(6)	4	(10)	15	(12)	19	(11)
Not found	0		1	(1)	1	(0)	0		0		0	
Interview	83	(95)	167	(92)	250	(93)	36	(90)	112	(88)	148	(89)
Laboratory tests	65	(75)	126	(70)	191	(71)	27	(68)	69	(54)	96	(58)
Ten-year follow-up												
Died[b]	40		51		91		22		64		86	
Moved	0		3		3		0		0		0	
Eligible	47	(100)	127	(100)	174	(100)	18	(100)	63	(100)	81	(100)
Refused	4	(9)	11	(9)	15	(9)	3	(17)	11	(18)	14	(17)
Not found	0		1	(1)	1	(1)	0		2	(3)	2	(3)
Interview	43	(92)	115	(91)	158	(91)	15	(83)	50	(79)	65	(80)
Laboratory tests	31	(66)	72	(57)	103	(59)	9	(50)	32	(51)	41	(51)

[a]Between 1989 and 1994 (75-year-olds) or between 1990 and 1995 (80-year-olds)
[b]Between 1994 and 1999 (75-year-olds) or between 1995 and 2000 (80-year-olds)

As part of the Evergreen project, Nordic collaboration was implemented in the NORA study (Nordic Research on Aging, Heikkinen 1997b, Odén et al. 2002). The 75-year-old residents of the city of Glostrup, Denmark, participated in the same kinds of interviews and laboratory tests as the subjects in Jyväskylä, Finland as part of the NORA study. The target group was not the whole age group, as in Jyväskylä, but a sample of about one-third of all persons aged 75. In Glostrup, the new sample consisted of 400 persons while the remaining subjects (171 persons) had already participated in an earlier longitudinal study

(Kauppinen et al. 2002). The participants at baseline and at the five-year follow-up are presented in Table 3. Mortality data were collected from the records of the Danish National Civil Person Registry. The data from Glostrup were used only in the article I and in the paragraphs 6.3 and 6.4. of the results section of this summary report.

TABLE 3 Participants in the interviews and laboratory tests at baseline, 1989 (75-year-olds) and in the five-year follow-up (1994) in Glostrup.

	Men		Women		Total	
	n	(%)	n	(%)	n	(%)
Baseline						
Target group	257		314		571	
Eligible	255	(100)	313	(100)	568	(100)
Refused or not found	33	(13)	54	(17)	87	(15)
Interview	222	(87)	259	(83)	481	(85)
Laboratory tests	198	(78)	213	(68)	411	(72)
Five-year follow-up						
Dead	72		59		131	
Eligible	150	(100)	200	(100)	350	(100)
Refused or not found	29	(19)	44	(22)	73	(21)
Interview	121	(81)	156	(78)	277	(79)
Laboratory tests	98	(65)	111	(56)	209	(60)

5.2 Measurement methods

The interviews at the subjects' homes included questions on sociodemographic characteristics, living arrangements, social activities, functioning and mobility, health, depressiveness and loneliness. The laboratory tests were carried out about 2-3 weeks after the interview. The laboratory day comprised about ten measurement stations, starting with a short interview and physical examination. During the day, the participants had breaks for a light snack and rest. The interviewers and the test personnel were students of the University of Jyväskylä from the Departments of Health Sciences and Psychology. They had all received 40 hours of special training. In Glostrup, the interviewers were qualified occupational therapists who were specially trained for the interviews (Heikkinen 1997b, Kauppinen et al. 2002).

Special attention was paid to ensure that the interviews and measurements were carried out uniformly to obtain comparable data. The same investigators trained the personnel for the laboratory measurements both in Jyväskylä and in Glostrup before the beginning of the measurements. The same kind of equipment was used, and for some measurements, such as balance, reaction time and muscle strength, the equipment was built in Jyväskylä and transferred to Glostrup (Heikkinen 1997b).

5.2.1 Mobility assessment

Self-assessments by 65- to 84-year-olds

Mobility was assessed by self-reports (in interviews) and performance-based tests (in the laboratory). In the interview with the 65- to 84-year-olds, four questions from the ADL (Activities of Daily Living) scale were used. The questions concerned the ability to *get about indoors and* to *get about outdoors*. The response alternatives were 1 = able without difficulty, 2 = able but slowly, 3 = able with great difficulty or gets tired, 4 = able with technical aids and 5 = not able without personal assistance. The response alternatives were dichotomized into 1 = those who reported no difficulties and 2 = all the other categories. The scales were constructed on the basis of the previous literature (Lawton & Brody 1969, Avlund & Schultz-Larsen 1991) and previous experiences of the study group. The test-retest reliability of the task of getting about outdoors was measured by a second interview (n=36) after two weeks, and the correlation between the answers was 0.82. An extension to the items on everyday mobility tasks was another set of questions about difficulties in managing various tasks that demand physical exertion. These tasks were *climbing up one flight of stairs without rest, running 100 m, walking in the woods, biking at least 2 km, skiing at least 2 km and swimming at least 25 m*. The response alternatives were 1 = able without difficulty, 2 = able with difficulty and 3 = not able. The three response alternatives were dichotomized into 1 = able without difficulties and 2 = able with difficulties or not able.

Self-assessments by 75- and 80-year-olds

From the interviews with the subjects aged 75 and 80 years, the mobility tasks chosen from the ADL questions were *transferring from/to bed or chair, walking indoors, walking outdoors in good weather, and climbing stairs*. The ADL questions had been developed and their reliability tested by Avlund et al. (1995). The subjects were asked first, whether they were able to manage the task. If yes, three additional questions followed: "Do you get tired?", "Does it take more time than earlier?" and "Do you need help from another person?" (yes or no). The subjects were dichotomized into those who were able to manage without *limitations* (did not report tiredness, slowness or need of help) and those with limitations (reported tiredness, slowness or need of help or not being able). In addition, three dichotomized variables, including the tasks getting about indoors and outdoors and climbing stairs, were combined to form a *mobility index*. The index comprised three categories (1 = need of help in any of the tasks, 2 = slowness or tiredness in at least one task but no need of help, and 3 = able without difficulties, no slowness or tiredness or need of help). An alternative dichotomization of the task getting about outdoors in good weather was also used, based on *major difficulties*, which category included those who reported both slowness and tiredness or need of help. A further dichotomy between those able to manage independently and those reporting *need of help* was also used. Need of help was analysed only in the data on the subjects born 1910 and 1914 (aged 75 and 80 at baseline), as this data also included subjects living in institutions. Older people living in institutions are more often dependent in their daily functioning than community-dwelling persons, and thus their exclusion would affect the dependency estimates.

Performance-based tests

Performance-based tests of mobility were used only among the subjects born in 1910 and 1914 (aged 75 and 80 at baseline). The tests used were maximal walking speed over 10 m and maximal step-mounting ability. *Maximal walking speed* over 10 metres was measured using a stopwatch in the laboratory corridor (Aniansson et al. 1980). At least two additional metres were allowed for acceleration and deceleration. The corridor was an ordinary quiet corridor with standard fluorescent lamps. The tester walked with the subject, half a step behind to see when the subject's body crossed the starting and stopping lines which were marked with pale tape on the floor. Subjects who normally used a walking aid were allowed to walk with the aid. In the five-year follow-up the proportion of the 80- or 75-year-old subjects who used a walking aid during the test was recorded. About 11% used a cane, 2% a walker and less than 1% (one person) used crutches. According to Bohannon (Bohannon 1997), measurement of maximal walking speed with stop-watch is highly reliable. Walking speed was used as continuous variable and also dichotomized to ≤ 1.2m/s and > 1.2 m/s. This cut-off point was chosen as it is the norm, according to the guidelines issued by the Finnish Road Administration, for signal control design to ensure safe crossing by pedestrians at light-controlled crossings (Traffic Signal Handbook 2005). *Maximal step-mounting ability* was measured using five 60 cm x 60 cm boxes, each 10 cm in height (Aniansson et al. 1980). The highest step that the subject could mount unsupported in a single step was recorded. The step heights were 0, 10, 20, 30, 40 and 50 cm. The subjects were allowed to use either leg.

5.2.2 Sensory, psychomotor and musculoskeletal functions

The sensory, psychomotor and musculoskeletal functions measured were maximal isometric muscle strength, standing balance, simple reaction time, visual acuity and limitations on Range of Motion (ROM) in hips and knees. The measurements were carried out in the laboratory among subjects aged 75 or 80 at baseline.

Maximal isometric muscle strength. Maximal isometric muscle strength of the knee and trunk extensors was measured by dynamometers (Viitasalo et al. 1985). Knee extension strength was measured in a dynamometer chair with the knee of the side of the dominant hand at 60^{o} flexion. The extension force applied against the ankle strap was measured by a strain gauge. Trunk extension strength was measured in a standing position with the pelvis fixed by a rigid support. The subject produced maximum extension force against the back support which was located higher, at the level of shoulder blades, and which included the strain gauge. The results of the strength measurements were adjusted to body mass (N/kg) and the best of three trials was recorded as the result.

Standing balance. Standing balance was measured on a force platform as the speed of anteroposterior and mediolateral sway (speed of movement of the centre of forces, mm/s) (Era et al. 1996). The subject was instructed to stand as still as possible during the measurement (40 seconds), feet comfortably apart and hands on hips. Sway was measured with the eyes both open and closed. Higher speed indicated poorer balance.

Simple reaction time. Simple reaction time to visual stimuli was measured in the dominant hand (Era et al. 1986). The subject was seated in front of the device, the index finger on the rest button. Simple reaction time was measured as the time from the onset of the light stimulus to the moment when the subject released the rest button in order to switch the light off by pressing the adjacent button. Of 12 trials, the average of the last 5 successful trials was recorded as the result (ms).

Visual acuity. Visual acuity was measured in two ways. When measured with a computerized refractometer (Topcon RMA2300), the lens correction was used if needed and the result of the best eye was chosen. When the illuminated Landolt ring chart (Oculus 4512) was used, the best result for either eye with or without eyeglasses was chosen.

Limitations on Range of Motion (ROM) in hips and knees. Limitations in the ROM of hips and knees were assessed as part of a routine medical examination, without any equipment. With the subject lying supine, a physician assessed the passive ROM of hip flexion, inner and outer rotation, and knee flexion and extension of the left and right leg separately. The number of clearly detectable limitations (about 20°, except in knee extension where the limitation criterion was less, about 10°) was recorded (range 0-10, a higher score indicating more limitations).

For technical reasons, balance, reaction time and visual acuity results were not obtained for all the subjects in the group born in 1914; however, this had no systematic effect on the results (Era et al. 1996). According to the t-tests, there were no significant differences in height, weight, self-rated health or number of chronic conditions between those who obtained a result in each test and those who did not (Era et al. 1996). The proportions of missing data were 26% for visual acuity, 28% for balance and 57% for reaction time.

5.2.3 Health status

Health status was assessed as chronic conditions, medications, self-reported symptoms, self-rated health, BMI (body mass index) and short-term hospitalization during the five follow-up years. Chronic conditions were assessed in all the study samples (both subjects aged 65-84 years and the samples of 75- and 80-year-olds). Among the subjects aged 75 or 80 at baseline, the other health variables were also used.

Chronic conditions. The recording of chronic conditions was based on self-reports in the interview of the 65- to 84-year-olds. By means of an open-ended question, the subjects were asked to report all the chronic diseases or injuries that had lasted or were known to last more than three months, and that had been diagnosed by their physician. In the study of the 75- and 80-year-olds, a physician recorded chronic conditions and diseases on the basis of a medical examination and other possible sources of information. The other possible sources were the health questionnaire filled at home in advance and prescriptions and medical information cards that the subjects brought with them to the laboratory. Diseases were coded according to the ICD-9 (International Classification of Diseases, version 9) (WHO World Health Organization 1977). Chronic conditions was used as a summary variable (dichotomized to 0-1 and 2 or more to show multimorbidity, according to van den Akker et al. 1998) and as disease groups. Cardiovascular diseases included ischemic diseases, hypertension, cardiac failure, myocardial infarction, arrhytmias, arteriosclerosis obliterans, TIA (Transient Ischemic Attack), and deep venous thrombosis. Musculoskeletal diseases and disorders included rheumatoid arthritis, osteoarthritis, back pain, fractures, endoprostheses and osteoporosis. Neurological diseases included stroke, Parkinson's disease and epilepsy. Pulmonary diseases were asthma, chronic bronchitis and emphysema. Diabetes was confirmed if the subject had diabetes medication.

General, musculoskeletal and depressive symptoms. Symptoms that had troubled the subjects a lot during the last fortnight were asked in a health questionnaire that the subject filled in at home and brought along to the laboratory, where the questionnaire was checked before embarking on the measurements. *General symptoms* were palpitations, difficulties in breathing or breathlessness, headache, fatigue, and sleeping disorders. *Musculoskeletal symptoms* were pain or other symptoms in the neck, back, lower or upper extremities that had troubled the subjects a lot during the last fortnight. *Depressive symptoms* were assessed by the CES-D scale (Center for Epidemiological Studies Depression Scale, Radloff 1977). The cut-off point of 16 was used (Beekman et al. 1997).

Multiple medications. Number of prescribed drugs was confirmed by prescriptions and multiple medications defined as using 4 or more medications simultaneously (Lord et al. 2002a).

Self-rated health. Self-rated health was asked with a question that had five response alternatives (very poor, poor, satisfactory, good and very good).

Anthropometric measurements. Height and weight were measured with ordinary scales in the laboratory and *BMI (Body Mass Index)* was calculated as kg/m^2.

Number of days spent in short-term hospital care. Information about short-term hospital care during the five follow-up years was gathered from the patient registers of public and private hospitals in the district of Jyväskylä as well as from the central registers of the Ministry of Health and Social Affairs of Finland. Here, short-term hospital care means hospital episodes of less than 3 months duration among subjects who were not long-term patients or did not live in an institution. Total number of days spent in hospital, comprising one or more episodes, was dichotomized into 15 or more days during the five follow-up years vs. less.

5.2.4 Sociodemographic factors, cognitive function, physical activity and dwelling environment

Marital status, education and income. Marital status was elicited during the home interview with the subjects in all the samples. The socioeconomic factors assessed in the present study were *length of education* (in years) and personal as well as family *monthly net income*.

Digit Symbol test. Cognitive function, particularly psychomotor speed, was assessed by the *Digit Symbol test* from the Wechsler Adult Intelligence Scale (Wechsler 1955). The test was performed as part of the psychometric test battery (cognitive and memory tests) among the subjects aged 75 or 80 at baseline and were carried out in the laboratory by a psychologist.

Physical activity. Level of physical activity was elicited by one question which included both physical exercise and daily activities (Grimby 1986). The respondents were asked how they would describe their free time activity over the past year and 6 response alternatives were given. These were 1 = mainly sitting in one place, 2 = light physical activity, 3 = moderate physical activity about 3 hours per week, 4 = moderate physical activity over 4 hours per week or intense physical activity up to 4 hours per week, 5 = active sports at least 3 hours per week, 6 = competitive sports. The question was dichotomized into high physical activity (those who reported moderate physical activity at least 4 hours per week or more vigorous activity) and low physical activity (those reporting less intense activities). The physical activity variable was used among subjects aged 75 or 80 at baseline.

Defects and modifications in the home environment. The home environment was evaluated by the trained interviewers at the end of the home visit among the subjects aged 65-84 at baseline. The interviewers observed and recorded the standard of equipment and functionality of the dwelling (e.g., existence of high thresholds, stairs, elevator, bathtub). After filling in the questionnaire concerning the ADL functioning of the subjects and observing the dwelling, the interviewers were asked to record the *defects in the home environment* that made the respondent's independent functioning difficult.

5.3 Statistical methods

The bivariate analyses used were cross-tabulation with the χ^2-test in the case of discrete variables and t-test and correlation for continuous variables. Logistic regression modelling was used to analyse multivariate associations between explanatory factors or predictors and outcomes, and to control for confounding and mediating factors. In the interview study with persons aged 65 to 84 years, the sampling technique overestimated the older age group (aged 75 to 84) and therefore the data were weighed when dealing with both age groups together (coefficient 1.245 for the younger age group and 0.736 for the older age group).

LISREL (SPSS: LISREL 7 and PRELIS 1990, Jöreskog et al. 1999) was used for structural equation modelling to analyse both cross-sectional and longitudinal associations between sensory, psychomotor and musculoskeletal functions and mobility. In the baseline situation, the analyses were based on polychoric (between discrete), polyserial (between discrete and continuous) and Pearson's product moment correlation coefficients calculated by PRELIS. Recursive path models were constructed including the explanatory factors, measured mobility performance and the self-reported mobility index. When analysing the longitudinal associations between mobility and its determinants, confirmatory factor analysis was used as part of structural equation modelling to build up latent mobility variables on the basis of the two mobility performance tests (walking speed and step-mounting ability). One latent mobility variable was constructed to represent mobility performance at baseline and another mobility performance at follow-up. The loading structures of the latent variables were analysed. The recursive models were constructed on the basis of the sample covariance matrices. Both direct and indirect effects were estimated. All the models were constructed separately for men and women.

In the longitudinal analyses on mobility performance and its sensory, psychomotor and musculoskeletal determinants, baseline missing data were handled with imputation using the EM algorithm. The procedure was acceptable according to Little's MCAR test, which showed that the values were missing wholly at random (Graham et al. 2002).

6 RESULTS

6.1 Self-reported mobility at baseline and at the 5- to 16-year follow-ups

The prevalence of difficulties in mobility tasks was analysed in two age groups, one with subjects aged 65-74 (cohort born in 1914-1923) and the other with subjects aged 75-84 (cohort born in 1904-1913) at baseline (n=1224), and the analyses were repeated after 8 and 16 years. The results reported in this chapter are supplementary information that has not been included in the articles. In the younger age group less than 10% of the subjects reported difficulties in walking indoors at baseline (Figure 2). The proportions of those who reported difficulties were higher in the other mobility tasks at baseline, e.g. about 30% in walking two km, and 60% in running 100 m. In general, the subjects in the older group reported having difficulties statistically significantly more often than the subjects in the younger group. The numbers in Figure 2 represent the cross-sectional proportions of subjects reporting difficulties. Several persons died during the follow-ups, which explains the decreasing numbers of subjects in the follow-up measurements in 1988 and 1996.

The number of subjects reporting difficulties increased during both the 8-year follow-up phases in each age and sex group, and in the last follow-up measurement about 60% of men and women in the older age group (aged between 91 and 100 years) reported difficulties in both walking tasks (Figure 2). The highest frequencies of difficulties in each age and sex group in both the 8-year follow-up phases was found in running 100 m. Sex differences were found most often in climbing stairs and walking 2 km without rest, and women more often reported difficulties than men of the same age.

The change between the baseline and eight-year follow-up was analysed in both age groups. In the easier tasks (walking indoors and climbing stairs one flight without rest), remaining without difficulties was the most common situation (white sections of the bars in Figure 3). The appearance of new difficulties was the next most common situation. A minor proportion of

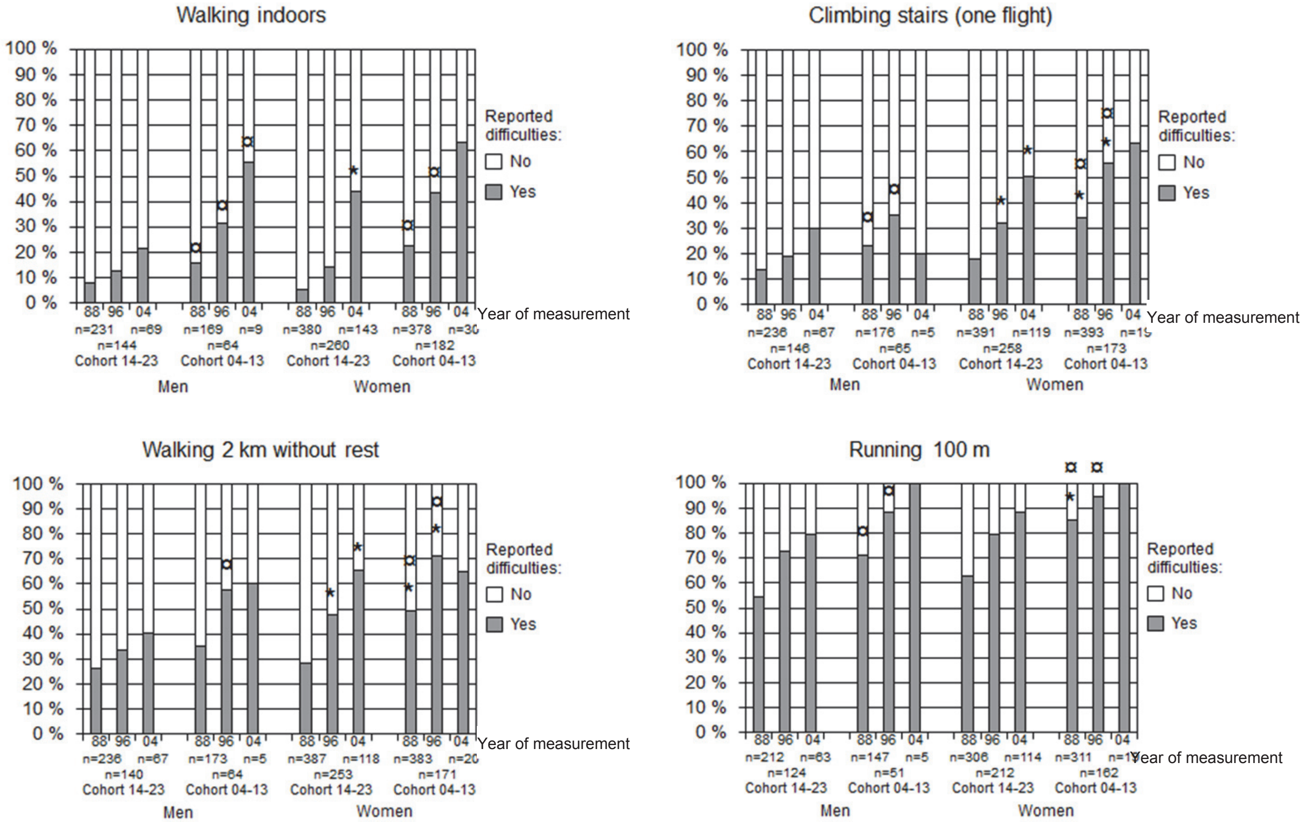


FIGURE 2 Proportions of subjects reporting difficulties in mobility tasks in the different study years. In the cohort born in 1914-1923, the subjects were aged 65-74 in 1988, 73-82 in 1996 and 81-90 in 2004. In the cohort born in 1904-1913, the corresponding ages were 75-84, 83-92, and 91-100. *Women reported difficulties more often than men in the corresponding age group ($p < 0.05$); ¤Subjects in the older age group more often reported difficulties than subjects in the younger age group in the corresponding task ($p < 0.05$).

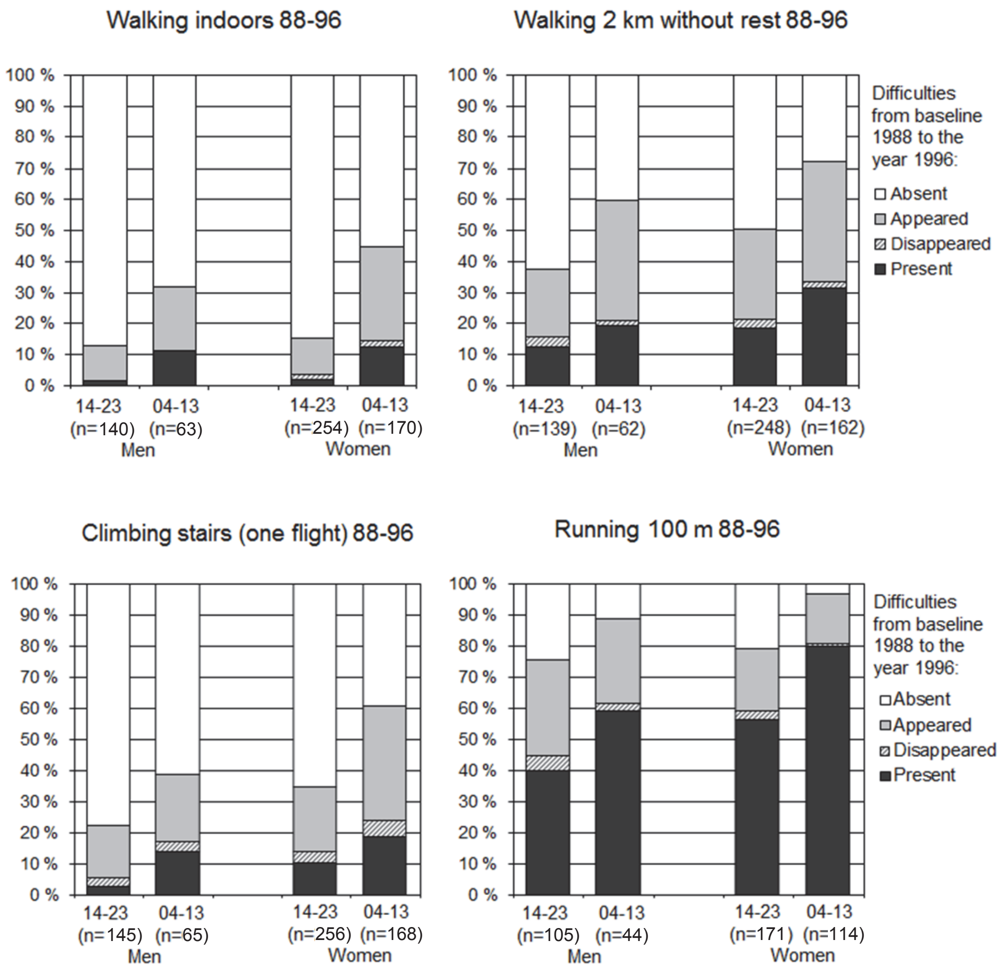


FIGURE 3 The proportions of subjects who remained without difficulties (absent), who reported new difficulties (appeared), whose difficulties disappeared and whose difficulties remained present across the study years 1988 and 1996.

subjects reported difficulties both at baseline and at follow-up, which was evident particularly in the older age group and among women. Among a few persons the difficulties had disappeared during the eight-year follow-up.

Need of help was studied among subjects aged 75 or 80 at baseline (n=588). In the analyses, the three mobility tasks (walking indoors, walking outdoors and climbing stairs) were combined and the proportions of those needing help refer to reporting need of help in one or more of the tasks. Self-assessments of coping with these tasks were used as the outcome variable in article IV. Of the 75-year-olds, 12% of men and 14% of women reported need of help in one or more of the three tasks. Among the 80-year-olds the proportion was higher (27 and 29%, respectively). No sex differences were found. After five years, new need of help in one or more of the three mobility tasks was found among 14% of men and 19% of women in the younger age group, and 16% of men and 37% of women in the older age group (aged 80 at baseline).

6.2 Performance-based mobility and its change over 5 and 10 years

The results presented in this chapter are based on data not reported in the articles published as part of this dissertation. Performance-based mobility was measured as maximal walking speed and step-mounting height in 75- and 80-year-old subjects. At baseline, the men walked faster than the women both at age 75 (1.8±0.5 m/s vs. 1.5±0.4 m/s, $p < 0.001$) and at age 80 (1.5±0.5 m/s vs. 1.3±0.3 m/s, $p < 0.002$). The measurements were repeated after five years, when the subjects were 80 and 85 years old, and again after ten years (85 and 90 years old).

The decline in walking speed was analyzed in the two five-year follow-ups. The change was analyzed in the younger age group between age 75 and age 80 and, again, between age 80 and age 85. In the older age group, walking performance was analyzed between ages 80 and 85 and between age 85 and age 90. Walking speed decreased significantly during the five-year follow-ups (p = 0.001 or less, Figure 4). Mean walking speed was higher at the beginning of the next five-year follow-up period than at the end of the previous follow-up period in each group as the next follow-up period did not include those who had died during the previous period. Among women, by age 85, average walking speed had declined to about 1.2 m/s or below. In men, this occurred only among 90-year-olds.

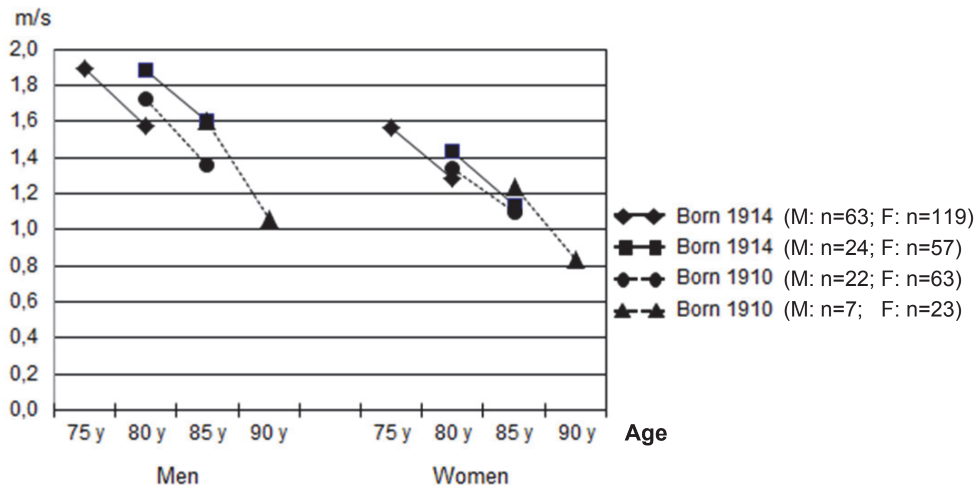


FIGURE 4 Maximal walking speed (means, m/s) in the five-year follow-ups of two groups of men and women (born 1914 and 1910).

The analysis of individual change in walking speed over the same five-year periods showed that performance most often declined during the five years (difference between baseline and five-year follow-up negative, below the zero level, Figure 5). However, until age 85 some persons showed an increase in walking speed (positive difference). In the oldest age group, between ages 85 and 90, no participant any longer showed a better result than at baseline.

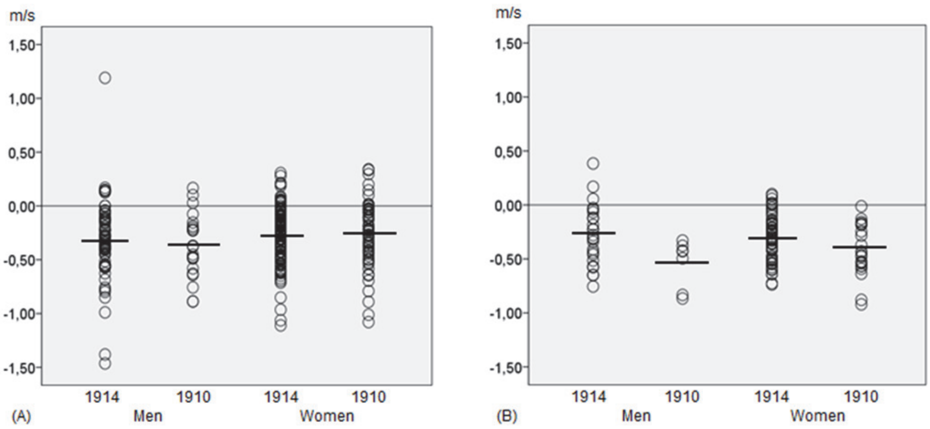


FIGURE 5 Individual change in walking speed in the five-year follow-ups. Subjects born in 1914 between the years 1989 and 1994 (from age 75 to 80) and subjects born in 1910 between the years 1990 and 1995 (from age 80 to 85) (A); subjects born in 1914 between the years 1994 and 1999 (from age 80 to 85) and subjects born in 1910 between the years 1995 and 2000 (from age 85 to 90) (B). Each circle represents one individual. Short horizontal lines represent group means (m/s).

Of the 75-year-old subjects, 74% of men and 28% of women were able to mount the highest step (50 cm) in the step-mounting test without handrails ($p < 0.001$ between sexes). The possible step heights were 0, 10, 20, 30, 40 and 50 cm. In the group of 80-year-olds, the corresponding proportions were 60% for men and 19% for women ($p < 0.001$). At baseline, about 10% of men and 23% of women were not able to mount a step higher than 20 cm (Figure 6). Step-mounting ability did not appreciably change in any five-year follow-up period among men. Among women the decline was clearer.

FIGURE 6 Proportions of men and women whose step-mounting ability was less than 30 cm at the three measurement phases of the 15-year follow-up.

6.3 Comparison of mobility between Jyväskylä and Glostrup (I)

Self-reported limitations and performance-based tests of mobility were measured in the same way in Jyväskylä, Finland and Glostrup, Denmark, among 75-year-old men and women. Also the five-year follow-up measurements were carried out in the same way in both cities, which facilitated comparisons.

Limitations in mobility tasks (defined as tiredness, slowness or need of help) in the 75-year-old subjects were reported more often by the women from Glostrup than those from Jyväskylä (Table 4). No significant differences between cities were found in the proportions of subjects reporting need of help.

At baseline, the men and women from Jyväskylä walked at a significantly faster speed than their counterparts from Glostrup (Table 4). Also, the proportion of women who walked slower than 1.2 m/s was somewhat higher in Glostrup than in Jyväskylä. There were no significant differences between cities in the proportions of those able to mount a step with a height less than 30 cm.

TABLE 4 Mobility limitations, need of help and performance-based mobility at baseline among 75-year-old subjects from Jyväskylä and Glostrup.

Mobility task	Jyväskylä Men n (%) mean±SD	Jyväskylä Women n (%) mean±SD	Glostrup Men n (%) mean±SD	Glostrup Women n (%) mean±SD	p Men	p Women
Self-reported limitations						
Walking indoors (75 yrs)	46 (39)	105 (45)	116 (53)	151 (58)	0.018	0.003
Walking outdoors (75 yrs)	68 (58)	129 (55)	144 (65)	187 (72)	0.203	<0.001
Climbing stairs (75 yrs)	68 (59)	149 (67)	97 (64)	146 (66)	0.178	0.018
Need of help						
Walking indoors (75 yrs)	6 (5)	9 (4)	6 (3)	3 (1)	0.261	0.052
Walking outdoors (75 yrs)	7 (6)	19 (8)	18 (8)	24 (9)	0.470	0.652
Climbing stairs (75 yrs)	14 (12)	20 (9)	20 (9)	24 (9)	0.382	0.922
Performance-based tests						
Walking speed (m/s)	1.8±0.5	1.5±0.4	1.7±0.4	1.4±0.4	0.027	0.009
Walking speed < 1.2 m/s (%)	13 (13)	34 (18)	18 (10)	53 (26)	0.412	0.047
Step-mounting height <30 cm (%)	10 (10)	42 (22)	17 (9)	47 (23)	0.727	0.845

The incidence of limitations and dependence was analyzed for walking indoors, walking outdoors and climbing stairs. There were no significant differences between Jyväskylä and Glostrup in the onset of new self-reported limitations among those who did not report such limitations at baseline (Table 5, I). For example, in walking outdoors, new limitations were found among about 45% of the men and among 60% of women from both Jyväskylä and Glostrup. Also sex differences were not significant in either city. New need of help in mobility tasks among those who did not report need of help at baseline was reported by 12-15% of subjects, and there were no significant differences between cities.

The incidence of poor mobility performance (decline in walking speed or step-mounting ability below the cut-off point among those whose result was above the cut-off at baseline) over five years was also compared between Jyväskylä and Glostrup (I). The proportions varied between 4% and 36% in the men and women from the two cities (Table 5). The differences were not significant.

TABLE 5 Proportions of men and women from Jyväskylä and Glostrup aged 75 at baseline who reported new limitations in mobility tasks or whose performance had declined below the cut-off point after the 5-year follow-up at age 80*.

	Jyväskylä		Glostrup	
	Men	Women	Men	Women
Mobility task	n (%)	n (%)	n (%)	n (%)
Self-reported limitations	n=36-57	n=53-112	n=47-92	n=41-117
Walking indoors	14 (28)	37 (40)	22 (33)	33 (43)
Walking outdoors	17 (47)	50 (60)	23 (45)	32 (59)
Climbing stairs	16 (44)	26 (49)	21 (45)	24 (59)
Performance tests				
Walking speed < 1.2 m/s	7 (12)	39 (36)	10 (11)	22 (26)
Step-mounting < 30 cm	2 (4)	16 (17)	9 (10)	24 (28)

* Includes only those who did not report tiredness or slowness in the mobility tasks or whose mobility performance was above the cut-off points at baseline (walking speed ≥ 1.2 m/s or step-mounting ability ≥ 30 cm).

6.4 Comparison of different methods of mobility measurement (I)

The baseline associations between mobility variables, measured by self-assessments and performance-based tests, were analyzed among the 75- and 80-year-old men and women in Jyväskylä, Finland. Those who had a poor result in step-mounting test, limitations in walking outdoors (tiredness, slowness or need of help), or need of help in any of the three mobility tasks walking indoors, walking outdoors and climbing stairs had a slower walking speed than those without these mobility impairments (Table 6, information supplementary to that reported in the articles published as part of this dissertation). The differences in walking speed between groups with poor and intact mobility were statistically significant in almost all cases.

TABLE 6 Walking speed (m/s) in groups with or without impairments in other mobility functions among 75- and 80-year-old subjects at baseline.

	Men	p	Women	p
75-year-olds				
Step-mounting height: 0-20 cm	1.1±0.4	<0.001	1.1±0.4	<0.001
>30 cm	1.9±0.4		1.6±0.3	
Self-rep. limitations in walking outdoors:				
Yes	1.6±0.5	<0.001	1.4±0.4	<0.001
No	2.0±0.5		1.6±0.3	
Need of help in mobility tasks: Yes	1.4±0.6	0.015	1.2±0.5	0.087
No	1.8±0.5		1.5±0.3	
80-year-olds				
Step-mounting height: 0-20 cm	0.7±0.2	<0.001	0.9±0.3	<0.001
>30 cm	1.6±0.5		1.4±0.3	
Self-rep. limitations in walking outdoors:				
Yes	1.4±0.5	0.027	1.2±0.3	0.003
No	1.7±0.5		1.4±0.3	
Need of help in mobility tasks: Yes	0.7±0.2	<0.001	0.9±0.4	<0.001
No	1.7±0.4		1.3±0.3	

The longitudinal associations between the mobility variables measured with different methods were studied by comparing the baseline and five-year follow-up data of the initially 75-year-old men and women from Jyväskylä, Finland, and Glostrup, Denmark. In the analyses, the decline in performance-based mobility was associated with the onset of new self-reported limitations in mobility among the 75-year-old men and women in both locations (I, Table 7). Those whose performance-based walking speed declined below 1.2 m/s or whose step-mounting ability decreased below 30 cm during the five-year follow-up more often reported onset of limitations in common mobility tasks. The numbers of those whose mobility declined were small, particularly among men. One man (17%) and 11 women (39%) of those whose walking speed declined below 1.2 m/s during the five year follow-up did not report new limitations in walking indoors. Of those without limitations at baseline but who reported such at the follow-up, 25-51% had not declined according to the performance-based tests of mobility.

TABLE 7 Onset of new self-reported limitations according to decline in performance-based mobility in men and women from Jyväskylä and Glostrup aged 75 at baseline.

	Walking speed			Step-mounting ability		
	Decline below 1,2 m/s n (%)	Remained at 1,2 m/s or above n (%)	p-value	Decline below 30 cm n (%)	Remained at 30 cm or above n (%)	p-value
Walking indoors						
Men						
New limitations	5 (83)	22 (24)	0.002	6 (100)	20 (23)	<0.001
No limitations*	1 (17)	68 (76)		0	68 (77)	
Women						
New limitations	17 (61)	25 (29)	0.003	10 (67)	30 (32)	0.010
No limitations*	11 (39)	61 (71)		5 (33)	63 (68)	
Walking outdoors						
Men						
New limitations	2 (67)	31 (42)	0.395	2 (100)	31 (42)	0.102
No limitations*	1 (33)	43 (58)		0	43 (58)	
Women						
New limitations	16 (80)	37 (51)	0.022	12 (92)	39 (51)	0.006
No limitations*	4 (20)	35 (49)		1 (8)	37 (49)	
Climbing stairs						
Men						
New limitations	2 (67)	24 (37)	0.300	2 (100)	24 (37)	0.071
No limitations*	1 (33)	41 (63)		0	41 (63)	
Women						
New limitations	10 (83)	25 (46)	0.020	6 (86)	28 (50)	0.074
No limitations*	2 (17)	29 (54)		1 (14)	28 (50)	

* Remained without limitations both at baseline and at follow-up.

6.5 Demographic factors, dwelling environment and mobility (II)

The associations of demographic factors and dwelling environment with mobility were analyzed in the baseline interview data of the subjects aged 65-84 years (n=1224, II). The majority of the men aged 65-74 years (78%) and the men aged 75-84 years (74%) were married. The women were more often widowed (40% of those aged 65-74 years and 62% of those aged 75-84). Marital status differed significantly between men and women (p < 0,001 in chi-square test). The men who were widowed, unmarried or divorced more often had difficulties in walking outdoors than the married men (Table 8, supplementary information to that presented in article II). About 20% of the men lived alone while the proportion was higher among the women: 50% in the younger age group and 66% in the older age group. Living alone was not associated with self-reported difficulties in mobility.

In the group aged 65-74, length of education was 5 years or less in 28% of the subjects. In the older age group (75-84 years), 5 years or less education was reported by 57% of the subjects. There were no differences between the sexes. The participants with 5 years or less of education more often reported difficulties in walking outdoors than those with education lasting 6 years or more (Table 8).

Family income, divided by the number of persons living in the same household, was lower among women in the younger age group ($p = 0.005$ in t-test), whereas in the older age group, no sex differences were found. No significant differences in the income were observed between the age groups. In men, family income did not differ between those with and those without mobility problems. However, in women, those who reported difficulties in walking outdoors had significantly lower family income ($p = 0.011$ in t-test).

TABLE 8 Self-reported difficulties in walking outdoors at baseline according to marital status, living alone and length of education among subjects aged 65-74 and 75-84.

	Men			Women		
	Diff. n (%)	No diff. n (%)	p	Diff. n (%)	No diff. n (%)	p
65-74-year-olds						
Marital status:						
not currently married*	18 (38)	30 (63)	0.026	50 (21)	190 (79)	0.256
married	40 (22)	143 (78)		36 (26)	103 (74)	
Living alone: yes	15 (36)	27 (64)	0.080	36 (19)	155 (81)	0.072
no	43 (23)	146 (77)		50 (27)	138 (73)	
Length of education: ≤ 5 yrs	22 (35)	41 (65)	0.045	32 (30)	76 (70)	0.044
> 5 yrs	36 (22)	128 (78)		53 (20)	212 (80)	
75-84-year-olds						
Marital status:						
not currently married*	16 (36)	28 (64)	0.383	157 (51)	150 (49)	0.555
married	36 (29)	87 (71)		38 (55)	31 (45)	
Living alone: yes	12 (30)	28 (70)	0.859	123 (49)	128 (51)	0.086
no	40 (32)	87 (69)		73 (58)	52 (42)	
Length of education: ≤ 5 yrs	30 (33)	60 (67)	0.339	117 (57)	89 (43)	0.029
> 5 yrs	19 (26)	53 (74)		73 (45)	88 (55)	

* Widowed, divorced or never married.

Factors in the dwelling environment that may challenge mobility were, for example, stairs or steps indoors or outdoors, high thresholds, and unsafe carpets. One-third of the subjects reported that they had outdoor steps and one fifth reported steps or stairs indoors. Of those who had steps or stairs inside their apartments, 20% reported some degree of trouble because of them. High thresholds were reported by about every tenth subject. About 15% of the subjects reported that they had unsafe carpets in their home.

The interviewers recorded defects that they observed in the participants' dwelling environments that could hamper the dweller's functioning. These were found among about 15% of men and women in the age group 65-74; however, among women aged 75-84, this proportion was somewhat higher (24%) than among men of the same age (14%, $p = 0.009$). Defects were found more often in the homes of subjects who reported difficulties in walking indoors and/or outdoors than those reporting no difficulties in either task ($p < 0.001$ in both men and women).

A logistic regression model was constructed to analyze the association of socioeconomic factors and defects in the dwelling environment with difficulties in walking outdoors. The results were essentially the same regardless of which mobility variables were used as the outcome. According to the model, having defects in the dwelling environment (as assessed by the interviewer) increased the probability of difficulties in walking outdoors almost fourfold compared to not having defects (Table 9). In addition, reporting two or more chronic conditions and less than 6 years of education significantly increased the risk for difficulties in walking outdoors, compared to those with 0-1 chronic conditions and longer education.

TABLE 9 Logistic regression model for self-reported difficulties in walking outdoors.

	OR	(95% CI)	p-value
Age group (75- to 84-year-olds vs. 65- to 74-year-olds)	2.4	(1.8-3.3)	< 0.001
Sex (women vs. men)	1.0	(0.7-1.5)	0.821
Marital status (married or unmarried couple vs. other)	1.0	(0.7-1.3)	0.793
Length of education (0-5 years vs. 6 or more)	1.5	(1.1-2.0)	0.017
Personal income (continuous variable)	1.0	(1.0-1.0)	0.250
Defects in the dwelling environment (yes vs. no)	3.6	(2.5-5.1)	< 0.001
Number of chronic conditions (2 or more vs. 0-1)	3.7	(2.7-5.1)	< 0.001

Walking aids (canes, crutches or wheeled walkers) were used by about 10% of those aged 65-74 and by 28% of those aged 75-84. A larger proportion of those who reported difficulties in mobility tasks used walking aids compared to those without difficulties (23% vs. 4% in the younger age group, $p < 0.001$ in χ^2-test and 46% vs. 8% in the older age group, $p < 0.001$).

For this summary, the predictive value of socioeconomic factors and defects in the dwelling environment was analyzed using the eight-year follow-up data in the same subjects (men and women aged 65-74 and 75-84 at baseline). This was done by logistic regression among those who did not report difficulties at baseline (n=478). It was found that neither socioeconomic factors nor defects in the dwelling environment predicted the development of new difficulties in walking outdoors over the eight-year follow-up.

6.6 Health status, physical activity, cognitive function and the decline in mobility (III)

The associations between health status and mobility were analyzed using data from the baseline and 5-year follow-up interviews and laboratory measurements of the subjects aged 75 and 80 at baseline. The results of the baseline medical examination showed that more than 90% of the 75- and 80-year-old men and women had one or more diagnosed conditions. Cardiovascular diseases were the most common disease group. About 60% of the men and women aged 75 had cardiovascular diseases, while among those aged 80, the proportion was 50% in men and 70% in women. About one-third of the men and women aged 75 had musculoskeletal diseases; in the older age group, the proportion was somewhat higher (about 45%). About 15% of men and women in both age groups had neurological diseases. Diabetes and COPD were less common. When subjects living in long-term institutions were excluded, the number of hospital days during the five-year follow-up was 15 or more among about one-third of all the men and women, except the women in the older age group (aged 85 at the 5-year follow-up), among whom the corresponding proposition was 50%.

About two thirds of the 75- and 80-year-old subjects reported low physical activity level (moderate physical activity three hours per week or less). According to the χ^2-test, low physical activity was significantly associated with poor mobility mostly among women (Table 10, supplementary information that is not presented in article III).

In the Digit Symbol Test, the mean score (±SD) was 21 (±10) both among the men and women aged 75, and 18 (±9) among the men and 19 (±10) among the women aged 80 (range 0-65). According to the t-tests, the means of the Digit Symbol Test were significantly lower among those who had slow walking speed or poor self-reported mobility than among those with better results in mobility, particularly in the younger age group (Table 11, supplementary information that is not presented in article III).

TABLE 10 The associations between physical activity level and mobility.

	Men			Women		
	Physical activity			Physical activity		
	Low[1]	High[2]		Low[1]	High[2]	
	n (%)	n (%)	p	n (%)	n (%)	p
75-year-olds						
Walking speed < 1.2 m/s	10 (16)	3 (8)	0.212	27 (21)	7 (12)	0.146
≥ 1.2 m/s	53 (84)	37 (93)		102 (79)	51 (88)	
Major diff.[3] in walking outdoors						
yes	23 (34)	7 (18)	0.067	61 (42)	14 (24)	0.013
no	45 (66)	33 (83)		83 (58)	45 (76)	
Need of help in mobility[4]						
yes	8 (12)	2 (5)	0.247	19 (14)	1 (2)	0.011
no	59 (88)	37 (95)		122 (87)	58 (98)	
80-year-olds						
Walking speed < 1.2 m/s	14 (37)	0	0.002	42 (47)	11 (24)	0.009
≥ 1.2 m/s	24 (63)	19 (100)		47 (53)	35 (76)	
Major diff.[3] in walking outdoors						
yes	22 (48)	6 (32)	0.229	60 (50)	25 (46)	0.615
no	24 (52)	13 (68)		59 (50)	29 (54)	
Need of help in mobility[4]						
yes	11 (26)	2 (11)	0.179	42 (36)	3 (6)	<0.001
no	32 (74)	17 (90)		74 (64)	50 (94)	

[1]Moderate physical activity three hours per week or less.
[2]Moderate physical activity more than three hours per week or more vigorous activity.
[3]Self-reported tiredness and slowness or need of help in walking outdoors.
[4]Need of help in any of the following tasks: walking indoors, walking outdoors, climbing stairs.

Logistic regression was used to reveal the associations between health conditions and the decline in mobility during the five-year follow-up. As outcome variables, three different mobility measurements were used and the analyses were carried out among those who had a good result in the mobility test in question at baseline. The mobility measurements were performance-based walking speed (decline was defined as a result in the lowest tertile of the percentage change among those whose result was above 1.2 m/s at baseline), self-reported major difficulties in walking outdoors (subjects who reported both tiredness and slowness but were able to walk outdoors), and need of help in any of the following three tasks: walking indoors, walking outdoors or climbing stairs. Three models were constructed, one for each mobility outcome variable. As no essential differences emerged between the models for the men and women in the different age groups, the combined models, adjusted for age and sex, are shown here. The models were adjusted for several other potential confounders such as physical performance (maximal isometric knee extension strength, N/kg), anthropometry (height, m, and weight, kg), self-reported physical activity, cognitive function (Digit Symbol Test score) and length of education (years).

TABLE 11 Digit Symbol Test score according to performance-based and self-reported mobility.

	Men		Women	
	DST score Mean±SD	p	DST score Mean±SD	p
75-year-olds				
Walking speed < 1.2 m/s	14.5±9.9	0.003	17.2±10.1	0.006
≥ 1.2 m/s	22.9±9.3		22.2±9.2	
Major difficulties[1] in walking				
outdoors: yes	16.8±10.7	0.003	19.0±9.7	0.036
no	23.2±9.3		22.1±9.6	
Need of help in mobility tasks[2]				
yes	12.4±10.6	0.001	14.1±10.3	0.002
no	22.4±9.5		21.6±9.5	
80-year-olds				
Walking speed < 1,2 m/s	15.3±10.6		16.6±9.5	
≥ 1,2 m/s	20.7±8.6	0.068	20.9±9.9	0.018
Major difficulties[1] in walking				
outdoors: yes	16.9±9.8	0.222	17.1±8.7	0.053
no	19.9±9.3		20.3±10.5	
Need of help in mobility tasks[2]				
yes	11.9±9.3	0.007	15.2±10.2	0.047
no	20.1±9.1		19.2±9.5	

[1]Self-reported tiredness and slowness or need of help.
[2]Need of help in any of the following tasks: walking indoors, walking outdoors, climbing stairs.

The final models showed that musculoskeletal diseases predicted decline in walking speed (Table 12). Only a few health variables remained in the models. Of the potential confounders, physical activity and cognitive functioning did not remain significant. According to the Odds Ratios and 95% Confidence Intervals, decline in walking speed was explained by musculoskeletal diseases, multiple medications and days spent in short-term hospital care during the five-year follow-up. Development of major difficulties in walking outdoors was explained by cardiovascular diseases, self-rated health and days spent in hospital care. Onset of dependence in mobility was explained by cardiovascular diseases and days spent in hospital care. For the incidence of major difficulties in walking outdoors, an alternative model was found that included multimorbidity (OR 2.2, 95% CI 1.11-4.48) instead of cardiovascular diseases. In this model also self-rated health and short-term hospital care remained significant, although the OR's were somewhat lower than those presented in Table 12.

TABLE 12 Final logistic regression models for the decline in mobility according to the walking speed test and self-reports of difficulties and dependence.

	Walking speed[a]	*Self-reported mobility*	
	Substantial decline[b]	Incident major difficulties in walking outdoors[c]	Onset of dependence in mobility tasks[d]
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Disease groups			
Musculoskeletal: yes vs. no	**2.1 (1.13-3.92)**	-	-
Cardiovascular: yes vs. no	-	**3.1 (1.59-6.09)**	**2.5 (1.17-5.53)**
Other health indicators			
Multiple medications: ≥ 4 vs. less	**2.0 (1.11-3.76)**	-	-
Self-rated health: poor or satisfactory vs. good	-	**4.3 (1.41-13.35)**	-
Ac. hospital care: ≥ 15 days vs. less	**2.3 (1.21-4.52)**	**3.0 (1.44-6.29)**	**3.7 (1.86-7.46)**
Potential confounders			
Age (80 yrs vs. 75 yrs)	1.2 (0.58-2.32)	1.3 (0.60-2.74)	2.0 (0.98-4.06)
Sex (women vs. men)	0.7 (0.26-2.09)	1.9 (0.63-5.85)	0.9 (0.30-2.89)
Height (cm)[e]	1.0 (0.95-1.07)	1.0 (0.96-1.09)	1.0 (0.95-1.06)
Weight (kg)[e]	1.0 (0.94-1.01)	1.0 (0.97-1.04)	1.0 (0.94-1.02)
Physical activity (at least moderate ≥ 4 hrs/wk vs. less)	1.1 (0.57-2.08)	0.7 (0.35-1.50)	1.6 (0.75-3.44)
Knee extension strength (N/kg)[e]	0.9 (0.67-1.23)	**0.6 (0.46-0.92)**	**0.7 (0.46-0.94)**
Digit symbol test (score)[e]	1.0 (0.95-1.03)	1.0 (0.96-1.05)	1.0 (0.91-1.00)
Length of education (years)[e]	1.0 (0.84-1.10)	0.9 (0.81-1.06)	1.1 (0.91-1.21)

NOTE. [a]Only included subjects whose walking speed was higher than 1.2 m/s at baseline; [b]Result in the lowest tertile of percentage change in walking speed; [c]Only included subjects who did not report incident major limitations; [d]Only included subjects who were independent in the same mobility tasks at baseline; [e]Continuous variables.
OR = Odds Ratio; CI = Confidence Interval; N = Newton.

6.7 Sensory, psychomotor and musculoskeletal determinants of mobility (IV, V)

Sensory, psychomotor and musculoskeletal determinants of mobility were analyzed cross-sectionally among the 75-year-old men and women at baseline, using data gathered through interviews and laboratory measurements. The purpose was to analyze the associations between physiological functions and performance in mobility tests and, further, mobility disability (self-reported difficulties or need of help in everyday mobility tasks).

At baseline, the associations between sensory, psychomotor and muscular functions, performance-based mobility and self-assessed mobility were analyzed using structural equation modeling (SEM, IV). Structural equation modeling was chosen as it allows the use of several outcome variables at the same time, as well as the analysis of complex structures and indirect effects between variables. At baseline, the aim was to delineate the associations between the sensory-motor determinants and both performance-based and self-assessed mobility and to examine the structure between the variables. The outcome variables were a mobility index, based on self-assessment of walking indoors and outdoors and climbing stairs, and the performance tests of maximal walking speed and step-mounting ability. The variables chosen as probable determinants were maximal isometric knee extension and trunk extension strength, standing balance on a force platform, visual acuity and reaction time.

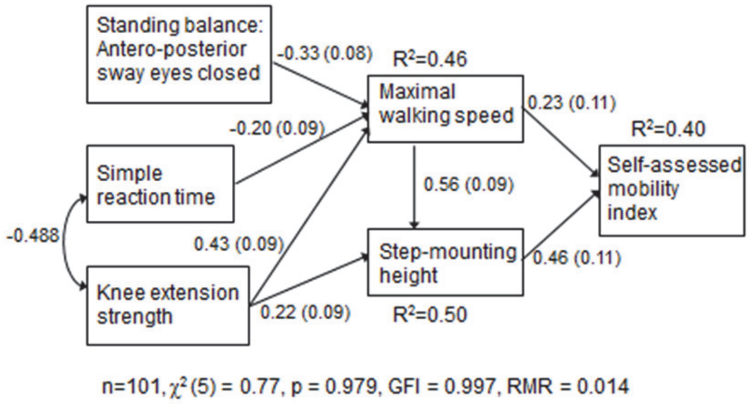
The models were based on sample correlation matrices between the observed variables (polychoric correlations between discrete variables, polyserial between discrete and continuous variables and Pearson's product moment correlation coefficients between continuous variables, calculated by PRELIS) (SPSS: LISREL 7 and PRELIS 1990). Figure 7 shows the results for the 75-year-old men (a) and women (b). In *men*, standing balance, maximal isometric knee extension strength and simple reaction time explained maximal walking speed and/or step-mounting height. Both of the performance-based mobility tests explained the mobility index. The variation in the mobility variables explained by the models varied between 40% and 50% according to the R^2 values. Maximal walking speed had a significant indirect effect on the mobility index (coefficient 0.26, standard error 0.07).

Among *women*, the same determinants were significant as among men; however, maximal isometric trunk extension strength and visual acuity also remained significant in the model (Fig 7, b). The variation in the mobility variables explained by the models varied between 42% and 52% according to the R^2 values. Also among women, maximal walking speed had an indirect effect on the mobility index (coefficient 0.23, standard error 0.04). The directions of the associations were as expected, as poor sensory-motor functions explained poor results in the mobility measurements in both men and women. According to the goodness-of-fit statistics, both the men's and women's models fitted the data well.

Longitudinal SEM analyses were conducted among the men and women aged 75 at baseline to find out to what extent the sensory, psychomotor and musculoskeletal determinants measured at baseline predicted mobility performance over five years (V). The determinants used in the models were the same as in the baseline models; however, range of motion (ROM) limitations in hips and/or knees, assessed as part of a routine physical examination, also were included. Two latent mobility performance variables were constructed on the basis of the maximal walking speed and step-mounting height results, one at baseline and one at follow-up. Among *men*, aging from 75 to 80 years, mobility performance at baseline explained 86% of the variation in mobility performance at follow-up (Fig 8 a). In addition, knee extension strength, standing balance, visual acuity and ROM limitations measured at baseline had significant indirect effects on mobility performance at follow-up, explaining up to 59% of the variation in this variable.

The longitudinal LISREL model for *women* was similar to the model of men, with the exception that the significant determinants of mobility performance included simple reaction time instead of ROM limitations (Fig 8 b). At the follow-up, 58% of the variation in mobility performance was explained. The significant indirect effects of the sensory, psychomotor and musculoskeletal functions explained 30% of the variation in mobility performance at follow-up. All the directions of associations in the models of men and women were as expected (poor functioning explained poor mobility performance). According to the goodness-of-fit statistics, the longitudinal models of both the men and the women also fitted the data well.

(a)



(b)

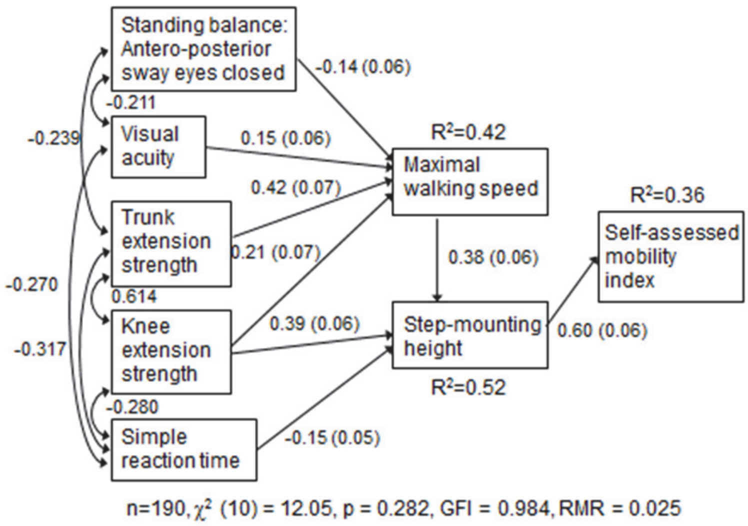
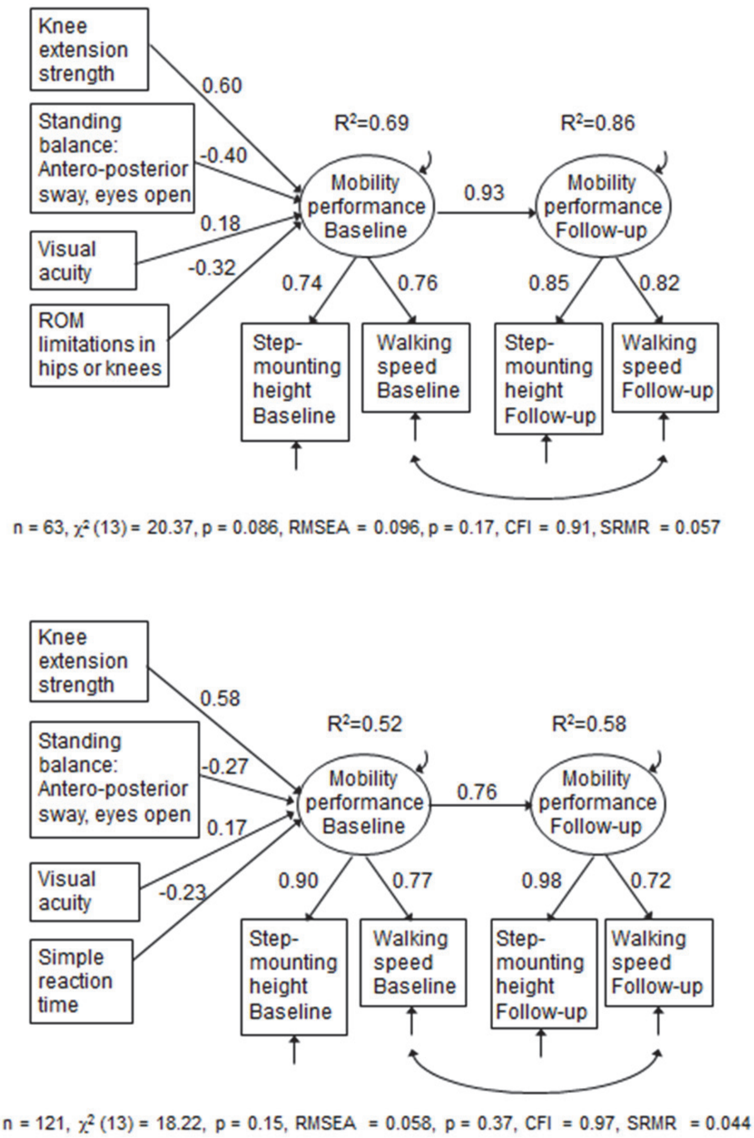


FIGURE 7 The sensory-motor determinants of mobility functions at baseline in LISREL models among men (a) and women (b) aged 75. The straight arrows indicate significant associations and their directions between variables. The coefficients and their standard errors (in brackets) are shown. In standing balance and reaction time higher values indicate poorer performance, which causes negative coefficients. The curved arrows indicate significant correlations between independent variables. Model fit indices: GFI = goodness-of-fit index, RMR=Root mean square residual.

(a)



(b)

FIGURE 8 Sensory, psychomotor and musculoskeletal determinants of mobility performance at baseline and at five-year follow-up among men (a) and women (b) aged 75 at baseline. LISREL models with completely standardizes solutions (standardized coefficients). ROM = Range of motion. Squares indicate measured variables and circles latent variables, which load on the measured mobility performance variables. In standing balance, reaction time and ROM limitations, higher values indicate poorer performance, which causes negative coefficients. Loose arrows indicate residuals or measurement errors.

7 DISCUSSION

According to the main findings of this study, difficulties in mobility increased rapidly with age and particularly among women. Performance in the walking speed test decreased clearly among both men and women over five- and ten-year follow-up times. In a minor proportion of subjects, self-assessed and performance-based mobility improved during the 5- to 8-year follow-ups. Most of those whose mobility performance decreased during the five years, also reported incident difficulties in mobility. However, in a considerable proportion of the subjects, new difficulties appeared even if no essential decrease in mobility performance was found.

Hazards in the living environment were associated with mobility difficulties in the cross-sectional analyses, as also was length of education. Musculoskeletal diseases or disorders in particular predicted decline in mobility performance while cardiovascular diseases predicted decline in self-reported mobility over 5 years among the subjects aged 70 or 80 at baseline. Also, a high number of days spent in short-term hospital care during the follow-up time predicted decline in mobility. Sensory-motor and musculoskeletal functions were associated with mobility according to both the cross-sectional and longitudinal analyses. In the 5-year follow-up among men and women aged 75 at baseline, important determinants of mobility were knee extension strength, standing balance and visual acuity, as well as reaction time and limitations in the Range of Motion of the lower extremities.

7.1 Decline in mobility according to self-reports and performance-based tests (I)

The general trends in mobility over the study years were that self-reported difficulties and need of help increased and measured maximal walking speed and step-mounting height declined. In old age, the development of different kinds of problems in or constraints on mobility and living with them for a prolonged period is common. Remaining free of mobility constraints is more frequent in younger age groups and particularly in men. In some older persons, mobility problems disappear during their years of old age, but the proportion is small, especially if the interval between assessments is several years. However, population estimates of mobility problems and their change depend, among other factors, on the mobility tasks measured, the methods of measurement used, and the age and sex of the subjects. Comparison with earlier studies is difficult also because studies that have used similar questions and tasks in self-reports, have often summed the results in differing combinations to obtain an overall estimation of mobility (Visser et al. 2005, Brach et al. 2007).

In the present study, the proportions of persons aged 65 and over who reported difficulties in mobility in the two 8-year follow-ups was high, as has been shown in earlier cross-sectional studies as well (Odding et al. 1995, Ervin 2006, Sainio et al. 2006, Jagger et al. 2007). When the present results were compared with those of a Finnish study by Sainio et al. (2006), some differences in the proportions of subjects reporting difficulties emerged. At the baseline of the present study, the proportions of subjects reporting difficulties was somewhat smaller than in the study by Sainio et al. (2006), particularly among women and in the age group of 75-84 years. The most likely reason for the differences is that the study by Sainio et al. (2006) included subjects living in institutions, which was not the case in the baseline measurements of the present study. The most difficult mobility tasks in the study by Sainio et al. (2006), of those that were measured similarly in both studies, were the same as in the present study. Running 100 m was the most difficult, walking 2 km without rest the second most difficult and climbing stairs one flight somewhat less difficult.

The increase in the proportions of subjects reporting difficulties over the two 8-year follow-ups was similar to that reported in their 16-year follow-up by Malmberg et al. (2002). However, in the study by Malmberg et al. (2002), difficulties were reported by somewhat higher proportions of subjects than in the present study. In the present study, the proportions reported included all those who were alive and eligible at each study phase, while the study by Malmberg et al. (2002) only included those who were alive at the end of the follow-up time. Those who survive the follow-up time usually have better health at the beginning. Incident limitations over five years were found in walking indoors in the present sample of 75-year-old subjects somewhat more often than were incident difficulties in the six-year follow-up study by Dunlop et al. (1997). The difference may be caused by different wording in the questionnaire, as limitations in the present study were defined as tiredness and slowness, which may occur before difficulties are actually experienced. The development of limitations in walking outdoors was comparable to the results of earlier studies (Visser et al. 2005, Brach et al. 2007), again when taking into account different wording of the questions.

The proportions of subjects reporting need of help in mobility tasks were about twofold in subjects aged 80 when compared to subjects aged 75. Earlier studies, which have also included younger subjects, have reported lower prevalence of needing help in walking outdoors (Shumway-Cook et al. 2005).

The onset of new need of help in walking outdoors over five years among 75- and 80-year old persons was close to the figures reported by Leveille et al. (2000). However, comparisons between the present study and earlier studies are difficult due to differences in age groups, follow-up times, mobility tasks included and the wording of the questions.

Walking speed values measured at baseline in the 75- and 80-year-old persons in the present study were somewhat higher than the values reported in the study by Sainio et al. (2006). However, Sainio et al. (2006) classified age groups differently, and the walking distance was shorter (6.1 m). Step-mounting heights at baseline among women aged 75 and 80 in the present study were in line with the heights reported by Bergland et al. (2008) among women aged 75 years or more.

Positive change in mobility during the follow-up time was found in a minor proportion of subjects, as has also been shown in earlier studies (Jagger et al. 2007). Improvements were seen both in self-reported and measured mobility, and they occurred more often in younger age groups. Improvement may be due to the characteristics of underlying illnesses, for example if these respond to treatment (Guralnik & Simonsick 1993). Improvement has been shown more likely to occur in individuals who have relatively good functional capacity or when their disability is not serious and has not lasted for long (Crimmins & Saito 1993). Even if the positive change happened only in a small proportion of old subjects, it is encouraging and indicates that, in general, improvement can take place as a consequence of appropriate interventions, despite age. Averages or estimates that show overall decline may, by ignoring individual pathways in functioning, oversimplify the situation and conceal important information.

The comparison of mobility functions between two Nordic cities showed some differences at baseline in the proportions of self-reported limitations in favor of the subjects living in Jyväskylä, Finland, compared to those in Glostrup, Denmark. No differences were found in need of help. In an earlier study, Finnish men reported less need of help in mobility than men from the Netherlands or Italy (van den Brink et al. 2003); however, in another, the ability to walk indoors without assistance did not differ between Finland and Israel, Spain and Sweden even if differences between these countries were found in other daily functions (Minicuci et al. 2003). In the maximal walking speed test, the men and women in Jyväskylä obtained better results than those in Glostrup. In an earlier comparison of walking test results between Finland, Netherlands and Italy, Finnish men showed the worst results (van den Brink et al. 2003). However, van den Brink et al. (2003) used usual walking speed, which hampers the comparison. Cross-national differences in disability may be due to many factors, such as differences in sociodemographics, culture, history, living environment, climate, morbidity and genetics (Pluijm et al. 2005). In spite of baseline differences, the incidence of new mobility restrictions, according to self-reports and performance-based tests, was similar in both cities of the present study.

7.2 Comparison of different methods of measuring mobility (I)

The associations of measured step-mounting height, self-reported limitations in walking outdoors and need of help in mobility tasks with walking speed were strong and statistically significant in the men and women aged 75 and 80, with the exception of walking speed and need of help in the 75-year-old women. Strong relationships between mobility measurements have also been shown in earlier studies (Guralnik et al. 1994, Lan et al. 2002, Mänty et al. 2007). It is noteworthy that, in the present study, the most consistent associations across the age and sex groups were between walking speed and step-mounting height, even if the tests measure slightly different aspects of mobility. The result is logical if the performance-based measurements used represent the same level of functioning of the disablement process models (Nagi 1991, Verbrugge & Jette 1994, WHO 2001).

The decline in the results of the performance-based tests was strongly related to the decline in self-reported ability to cope with mobility tasks over the five-year follow-up among the 75- and 80-year-old subjects in Jyväskylä, Finland and in Glostrup, Denmark. The development of new difficulties in mobility was analyzed among those whose walking speed or step-mounting ability had declined below the clinically important cut-off point. Changing the cut-off point so that more subjects were located in the group of declining performance did not essentially affect the results. Most of those whose performance-based mobility had declined over the five years had also developed new difficulties in coping with mobility tasks. This is in line with earlier studies which have shown that poor performance in mobility tests is associated with the onset of new difficulties in self-reported mobility (Cesari et al. 2005, Newman et al. 2006, Simonsick et al. 2008). The decline may have been caused by larger changes in health status, which affected both actual performance and the experiences of moving about at the same time. Another possibility is that the decline followed the paths of the disablement models (Nagi 1991, Verbrugge & Jette 1994, WHO 2001). According to these models, mobility performance might have declined first, with the subjects only beginning to experience difficulties somewhat later; however, both events occurred within the five follow-up years.

An interesting finding was that in a substantial proportion of subjects their performance-based mobility had not declined but nevertheless these subjects had started to experience new difficulties in coping with mobility tasks. This discrepancy may be caused by several reasons, such as miscoding, inaccurate reporting or misunderstanding in the interview (Guralnik et al. 1994). For example, people may understand and use some words in several different ways. Porter et al. (2007) showed that some older women denied having difficulty with a certain task, but described the task instead as irksome, time-consuming, unhandy, bothersome or tedious. In addition, the associations between performance-based and self-reported ADL functions have been found to be weakened due to poor cognitive functions (Kempen et al. 1996b), depressive symptoms (Cress et al. 1995) and certain personality characteristics, such as perceived physical competence and mastery (Kempen et al. 1996a). Also the threshold levels of performance-based mobility, at which subjects report difficulties, have been shown to vary according to age and income (Melzer et al. 2004). However, an alternative logical explanation would also be that performance-based measures represent different aspects of mobility than self-reports and are not comparable as such. Performance-based tests usually last a few seconds during which the subject may be able to struggle maximally. The experience of everyday mobility is based on longer-lasting tasks which are done several times a day and which may cause sensations like pain, breathlessness, tiredness or dizziness, and thus are perceived as inconvenient or troublesome. The result suggests that self-assessments and performance-based measurements of mobility represent different dimensions, or different levels of functioning, and cannot substitute for each other. If a thorough view of mobility is required, using a single method of measurement, either tests or self-reports, is not enough.

7.3 Demographic factors and mobility (II)

The increase in the proportions of those reporting difficulties was somewhat higher in the older subjects (aged 75-84 at baseline) when compared to the younger subjects (aged 65-74 at baseline). This is line with the findings of cross-sectional studies showing that the amount of self-reported difficulties multiplies in the oldest age groups (Odding et al. 1995, Ahacic et al. 2000, Sainio et al. 2006).

Sex differences in self-reported mobility were found, particularly in the older age groups, indicating poorer function in women. Earlier studies also have shown that mobility difficulties are more common in women than in men, and particularly in older age groups (Ahacic et al. 2000, Wray & Blaum 2001, Murtagh & Hubert 2004, Sainio et al. 2006, Rueda et al. 2008). There were no differences between the sexes in incident limitations over the five-year follow-up, but new need of help in walking outdoors was found more often among women than men aged 80 at baseline. The greater incidence of dependence in mobility among women was in line with the study by Leveille et al. (2000).

The sex differences were stronger in the performance-based mobility tests of walking speed and step-mounting height, where women obtained poorer results than men. This is in line with earlier studies (Guralnik et al. 1994, Oman et al. 1999, Sainio et al. 2006). Sex differences have been shown to be most prominent in functions that require strength and other physical abilities, somewhat less prominent in mobility, and weakest in ADL functions (Wray & Blaum 2001, Murtagh & Hubert 2004).

However, in the present study, contrary to the results of earlier studies (Graciani et al. 2004, Shumway-Cook et al. 2005, Rueda et al. 2008), the sex difference in self-reported difficulties in walking outdoors disappeared in the logistic regression models when health status, and sociodemographic or environmental defects were included. Also in some earlier studies, sex differences in the overall disability (summary score of difficulties in IADL, ADL and mobility) disappeared when chronic health conditions were included in the model (Murtagh & Hubert 2004). This result is reasonable, as differences in morbidity and mortality are considered to be one of the main reasons for sex differences in disability estimates (Verbrugge & Wingard 1987, Crimmins, et al. 1996, Murtagh & Hubert 2004). The generally lower level of strength and physical fitness of females may become more notable in old age, as women have less reserve capacity and may thus have to function near their maximal performance levels in everyday mobility tasks.

Marital status differed substantially between older men and women, and being widowed was most common among women, particularly in the oldest age groups. Marital status or living alone was not associated with impaired mobility, which is in parallel with earlier findings (Martelin et al. 2002, Østbye et al. 2002). However, becoming widowed may affect many aspects of the life situation, for example by diminishing the possibilities to receive practical help with problems of everyday living.

Educational status was described by years of education. Finnish older people generally have shorter education than older people in several other developed countries, for example the USA (Murtagh & Hubert 2004) or United Kingdom (Jagger et al. 2007). However, in some European countries the length of education is even shorter than in Finland (Coppin et al. 2006). In earlier Finnish studies, the association between mobility and education has not been very clear (Martelin et al. 2002, Sulander et al. 2006, Sainio et al. 2007), which may partially be due to low education in general as this limits differentiation between educational groups (Grundy & Holt 2001). However, in the present study, the association between short education and difficulties in mobility remained significant in a logistic regression model adjusted for sociodemographic and health factors. Significant associations between low level of education and poor mobility have also been found in several studies in the USA and Europe (Picavet & Hoeymans 2002, Østbye et al. 2002, Graciani et al. 2004, Rueda et al. 2008). The effects of education on health, and presumably on mobility function in old age as well, may have several causes, including better resources available for health care. Higher education also may increase receptivity to information concerning health (Blane 2003). Childhood circumstances may even contribute, as the material and cultural resources of the childhood family affect the child's educational attainment, and the same resources may have also had a long-term influence on health in adulthood and in old age (Blane 2003). The supplementary multivariate analyses of the present study showed, however, that education did not have predictive value on the development of new difficulties in mobility.

In the present study, the association between low income and self-reported difficulties in mobility did not remain significant in a logistic regression model which included sociodemographic factors, chronic conditions and defects in the dwelling environment. The result was in line with earlier studies in Western Europe (Rueda et al. 2008). However, in earlier studies in the USA, the associations have remained significant in comparable models (Koster et al. 2005, Shumway-Cook et al. 2005). It is possible that the Finnish welfare state has been able to level at least some socioeconomic inequalities so that other determinants than income alone are more important from the point of view of poor mobility. However, the result emphasizes the unfavorable situation of older women, as they tend to have inadequate economic resources to relieve the problems caused by poor mobility.

7.4 Dwelling environment and mobility (II)

In the baseline study, among the subjects aged 65-74 and 75-84 years, about one-fifth of those who had stairs in their dwellings reported at least some trouble using them. In the study by Gitlin et al. (2001), problematic stairs were observed in 41% of the dwellings of older persons (no handrails, too steep, poor lighting, or can't use without assistance). In the present study, the interviewers recorded defects or environmental hazards in the dwellings of the subjects and these were found more often in the dwellings of women than of men. This finding was in accordance with earlier reports (Gitlin et al. 2001). Those who had defects such as stairs or high thresholds in their apartments, more often reported difficulties in their mobility functions. Associations between poor mobility and environmental hazards have also been found earlier (Gill et al. 1999a, Gitlin et al. 2001). However, other studies have found no difference in home environment hazards between those with and those without ADL disability (Gill et al. 1999b). The different results may be due to different methods of measurement. Overall assessments of the home environment are not necessarily associated with functional disability in general, but if a specific environmental feature is linked with a specific functional outcome that is related to that feature, the associations are more evident (Wahl et al. 2009).

The association between disability and environmental barriers may be two-directional: disability may lead to poor fit between person and environment, which in turn may lead to increased disability (Gitlin et al. 2001). It is important to attempt systematically to diminish environmental barriers inside and outside older people's homes to provide better possibilities for safe mobility. It has been shown that mobility disability leads to avoidance of physically challenging features in the environment (Shumway-Cook et al. 2003), probably further reducing willingness to move about, and, consequently, negatively affecting physical status.

7.5 Health status and the decline in mobility (III)

The associations between chronic conditions and incident mobility restrictions in the present study showed that having musculoskeletal diseases in particular increased the risk for decline in walking speed and that cardiovascular diseases increased the risk for onset of self-reported difficulties in walking outdoors and dependence in mobility tasks. Musculoskeletal diseases and disorders, such as arthritis and hip fracture, have predicted decline in mobility performance also in some earlier studies (Forrest et al. 2006, Pubh et al. 2007) but not in others (Wang et al. 2002, Inzitari et al. 2006). Cardiovascular diseases predicted the development of new self-reported difficulties in mobility over 4 years in the study by Wannamethee et al. (2005), which is in line with the results of the present study. However, in the study by Wannamethee et al. (2005), arthritis was another strong predictor of mobility difficulties. Onset of dependence in mobility has been associated with cardiovascular diseases also in earlier studies, but in the same studies the impact of musculoskeletal diseases has also been significant (Guralnik et al. 1993, Penninx et al. 1999).

The relationship between chronic conditions and declining mobility varies between studies and is affected, for example, by methods used to measure mobility, disease status, follow-up time, and the confounding factors included in statistical models. In most studies, mobility is not targeted as a distinct outcome but assessed as part of other, more general ADL scales or performance batteries. In longitudinal studies, individual health conditions change due to natural progression and/or fluctuation in the progression of diseases and possible medical and other treatments. The prevalence of some chronic conditions that are known to have strong effects on mobility may be low, which prevents detecting statistical associations in small samples. At population level, the prevalence of diseases changes across cohorts, and such changes may also be different between men and women (Reynolds et al. 1998). Diseases may also have important secondary consequences through, for example, lower physical activity or the experience of pain.

Everyday walking tasks, such as going shopping, are endurance activities that require adequate cardiorespiratory function. In particular, persons with cardiovascular diseases may begin to experience difficulties or even need of help when performing routine low-intensity mobility functions. Such information can be elicited through questionnaires. Musculoskeletal diseases in turn may more directly affect the musculoskeletal system itself, restricting effortful performance, such as walking with maximal speed over a short distance. However, persons with musculoskeletal disorders may use compensatory strategies and thus cope without problems when walking at their own pace in their own living environment. In practice, the impact of chronic conditions cannot be dichotomized in this way, but it is possible that, due to the small sample size in the present study, only the most important predictors of mobility decline reached significance in the statistical analyses.

In the present study, the effects of many of the other indicators of poor health did not extend over the five-year follow-up. For example, in the longitudinal analysis, the effect of high body mass index did not remain significant, in contrast to the results of a previous Finnish 22-year follow-up study by Stenholm et al. (2007a). Older people living in Jyväskylä, Finland, are known to have a rather high physical activity level (Hirvensalo et al. 1998), which might counteract the negative effects of high BMI.

General and musculoskeletal or depressive symptoms did not remain significant predictors of mobility decline in the logistic regression models. However, earlier studies have shown that, in particular, general symptoms may predict decline in mobility (Guralnik et al. 1993, Ho et al. 1997, Guralnik et al. 2001, Jenkins 2004, Wannamethee et al. 2005). Many studies with similar follow-up times (4-6 years) have also shown that depressiveness is associated with decline in mobility performance (Oman et al. 1999, Wang et al. 2002) or with the development of dependence in walking or stair climbing (Penninx et al. 1999, Blazer et al. 2006).

Multiple medications (using 4 or more prescription drugs at the same time) was related to decline in mobility performance, which is in line with the results of Pugh et al. (2007). The relationship between medication and functioning is complicated as different drugs may have either beneficial or detrimental effects from the point of view of mobility, balance and general functioning. However, the interactions of several medications usually produce ill effects. Poor self-rated health predicted the onset of major difficulties in walking outdoors in the present study. Self-rated health has been shown earlier to predict the onset of dependence in walking (Ho et al. 1997, Guralnik et al. 2001).

In the adjusted models, the number of days spent in short-term hospital care (15 days or more) during the follow-up predicted decline in both performance-based and self-reported mobility. The health problem that caused hospitalization may have direct effects on mobility, and the need for hospital care probably indicates that the problem is severe. However, hospitalization may also have indirect effects on mobility. Bed rest and inactivity are common in hospitalized older adults, even if medical care of the condition does not require staying in bed and the subjects are able to walk (Brown et al. 2004, Callen et al. 2004). Negative effects of bed rest and short-term hospitalization on mobility have also been shown in earlier studies (Ferrucci et al. 2000, Gill et al. 2004, Suesada et al. 2007). It has been shown that even short periods of bed rest significantly weaken muscle strength and power and aerobic capacity in older persons (Kortebein et al. 2008). It is necessary to keep in mind that already before hospitalization, older persons have less muscle mass and strength compared to young persons, and they also seem to lose muscle mass and strength faster than younger persons as a result of bed rest (Kortebein 2009, English & Paddon-Jones 2010).

Physical activity level and cognitive functions were included in the models as they were assumed to be important factors affecting mobility functions. In the bivariate cross-sectional analyses, the associations of physical activity and cognitive function with self-reported and performance-based measures of mobility were statistically significant, as has been shown earlier (Brach et al. 2004, Holtzer et al. 2006, Jerome et al. 2006, Kuo et al. 2007). However, in the longitudinal models, which also included health status variables and other control variables, the associations did not remain significant.

7.6 Sensory, psychomotor and musculoskeletal functions and mobility (IV, V)

Sensory, psychomotor and musculoskeletal functions were associated with mobility in both the cross-sectional and longitudinal analyses, and the directions of the associations were as expected (poor function explained impaired mobility). The results obtained were in line with the disablement models (Nagi 1991, Verbrugge & Jette 1994, WHO 2001), as the body systems explained performance-based mobility, which in turn explained self-reported mobility. Men and women were analyzed separately; however the structure of the models was mainly similar. The minor differences were probably related more to differences in sample size and other technical aspects than to actual difference in the determinants of mobility.

The results of the cross-sectional models are in line with earlier findings showing that knee extension strength (Lord et al. 1996, Salem et al. 2000, Bean et al. 2002, Ploutz-Snyder et al. 2002, Menz et al. 2005, Sayers et al. 2005) and balance, measured as standing balance (Bergland et al. 2008) or as more dynamic balance (Topp et al. 1998, Marsh et al. 2003, Bergland et al. 2008), are two important factors behind mobility performance. The impact of lower extremity strength and balance on gait or stair climbing has also been shown in several multivariate analyses (Rantanen et al. 1998, Rantanen et al. 1999, Tiedemann et al. 2005, Tiedemann et al. 2007, Callisaya et al. 2009,). The effect of knee extension strength on self-reported mobility disability was mediated through measured mobility performance in the cross-sectional analysis of the present study. This is in line with the results of an earlier study where lower extremity strength and power affected self-reported disability through functional limitations, measured as performance-based tests (Puthoff & Nielsen 2007). The step-mounting test used in the present study probably requires more balance ability than usual stair-climbing up a staircase. The climber needs to raise the stepping foot and place it onto the step, and then to move the center of mass over this foot and extend the leg (Cesari et al. 2003). Both these phases take longer than in usual staircase climbing as the step is higher and more effort is also needed due to the higher vertical distance and higher external torque created by body weight. The higher external force is caused by the longer moment arm at the more flexed knee joint, i.e. longer perpendicular distance between the line of force of the body's center of mass and the axis of rotation at the knee. In addition, the movement stops after the first step is completed, so that balance cannot be adjusted during the next steps, as happens in level walking, and probably walking up a staircase as well.

The longitudinal models included in the present study showed that poor strength and balance were the most important determinants of poor mobility, both at baseline and after five years. This result was in line with an earlier finding in a 3-year follow-up study (Rantanen et al. 2001) where the outcome was the onset of severe walking disability (defined as normal walking speed below 0.4 m/s and inability to walk a quarter of a mile). However, in another longitudinal study, standing balance, measured on force platform, did not have predictive value for normal walking speed, nor the time to climb 5 steps, over a 15-month follow-up (Marsh et al. 2003). The results of the present study are in agreement with the earlier finding by Gibbs et al. (1996), according to which quadriceps strength, along with lower extremity joint impairments, such as limitations in range of motion, predicted decline in normal walking speed over 2 and 4 years.

Poor visual acuity was one of the significant determinants of poor mobility performance at baseline in the present study. Similar associations have also been found earlier (Lord et al. 1996, Bootsma-van der Wiel et al. 2002, West et al. 2002, Laitinen et al. 2007). Moreover, poor vision has been shown to have a significant impact on self-reported mobility difficulties (Crews & Campbell 2004, Laitinen et al. 2007, Whitson et al. 2007) and need of help in mobility (West et al. 2002). However, in studies where other characteristics of vision, in addition to visual acuity, have been measured, contrast sensitivity has more often remained a significant predictor of poor mobility in multivariate models than visual acuity (Menz et al. 2005, Tiedemann et al. 2005, Tiedemann et al. 2007).

In the present study, visual acuity was also associated with mobility problems longitudinally. Visual acuity and contrast sensitivity were not associated with change in walking speed in the five-year follow-up by Klein et al. (2003). Klein et al. (2003) measured visual acuity with an eye chart, corrected with the subjects' own eyeglasses if needed, as in the longitudinal part of the present study. However, in the study by Klein et al. (2003), the age group (which also included persons younger than 65) and measurement of walking speed (normal speed over a 3-m course) differed from those used in the present study. Self-reported visual impairments have also been found to predict the onset of mobility disability (reporting a lot of difficulties or inability to climb 10 steps or walk 0,5 km) over a median follow-up time of 5 years (Chaudhry et al. 2010).

The significant impact of reaction time on mobility performance found in the present study is in line with earlier cross-sectional findings (Lord et al. 1996, Menz et al. 2005, Tiedemann et al. 2005, Tiedemann et al. 2007, Callisaya et al. 2009).

In previous studies, the walking speed measured has most often been usual and not maximal speed. Some studies, however, have also analyzed the associations between muscle functions and fast walking speed (Bean et al. 2002, Ploutz-Snyder et al. 2002). Maximal and usual walking speeds differ in several aspects, for example in their biomechanical characteristics (Brach et al. 2001, Arnold et al. 2007, Latt et al. 2008), and therefore the determinants may also differ somewhat.

In general, longitudinal studies on the sensory, psychomotor and musculoskeletal determinants of mobility are scarce. In old age, the rate and extent of changes in physiological functions due to aging and health status show high individual variation, which makes longitudinal analyses between physiological functions and mobility difficult. However, the information obtained aids understanding of the factors underlying changes in mobility in old age and offers valuable tools for preventive actions.

7.7 Methods

The samples investigated in this study were population samples of the older inhabitants of the cities of Jyväskylä, central Finland and Glostrup, Denmark. Two of the samples from Jyväskylä included whole age groups (all subjects born in 1914 and 1910, aged 75 and 80 at baseline). The other two samples from Jyväskylä (subjects born 1914-1923 and 1904-1913, aged 65-74 and 75-84 at baseline) each comprised 800 subjects and accounted for large proportions of the corresponding populations. The samples were thus representative of the older age groups of the city of Jyväskylä. The sample from Glostrup, Denmark, consisted of almost 600 persons aged 75, of whom about two-thirds were from a new sample drawn for this study and the rest from samples used in earlier population studies. Using representative population samples of different age groups of older people was strength of the present study. However, the performance test results are not generalizable to the most disabled old people, as the performance tests were carried out in the laboratory and those with very poor health were not able to visit the laboratory.

The follow-ups in the present study were of 10 years duration divided into two 5-year follow-ups and of 16 years duration divided into two 8-year follow-ups. Five and eight years are long periods in old age during which a lot of things may happen in an older person’s own situation or in the situation of that person’s relatives or friends. The length of the follow-up times was thus one limitation of this study. Moreover, due to long follow-up times the death rates were high, limiting the number of participants and causing an attrition bias. Earlier comparisons between those who had died prior to, and those who participated in, the follow-ups have shown that the latter had somewhat better health and functioning at baseline, an expected outcome as poor health and functioning are related to higher mortality (Lyyra et al. 2005, Lyyra et al. 2006). Hence the longitudinal results of the five-year follow-ups are generalizable only to older, rather well-functioning persons, as the participants were only those who were able to come to the laboratory for the measurements of mobility performance five years later. The decreased sample sizes due to high mortality might have affected the results of the present study so that only the most important factors remained significant in the multivariate models. In addition, the small sample size in the follow-up measurements narrowed the possibility to select the clinically most relevant cut-off points for some variables.

The deployment of the disablement models (Nagi 1991, Verbrugge & Jette 1994, WHO 2001) as part of the study design helped to structure the statistical models and to contemplate the possible relationships between different factors. The three disablement models were also useful when interpreting the results. They were not applied literally but in a broad way which allowed combining the most useful information in them. In this way, the models had an important and fruitful impact on the analyses.

The results of the study indicate that different methods of measuring aim at capturing different dimensions of mobility. On the one hand, self-reports represent the subject's own viewpoint, which is based on everyday life experience. Self-reports incorporate the effects of many other factors in addition to physical mobility itself, such as environmental barriers, visual impairments and the person's attitudes (Melzer et al. 2003, Montero-Odasso et al. 2009). On the other hand, performance tests represent easily quantified, objective measurements in special test situations which may, however, conceal the problems that subjects experience in their personal life situations. The results obtained by questionnaires and performance tests cannot be directly compared and they do not substitute for each other. The question is not which method is better or more reliable, as both have problems and neither would give a comprehensive picture of a person's movement abilities.

The mobility-related questionnaire items used in the present study have been found to show acceptable inter-rater and intra-rater reliability (questions for 75- and 80-year-olds, Avlund et al. 1995, and questions for 65-84-year-olds, Laukkanen et al. 1995). High reliability values have been shown particularly for the items concerning dependency (Avlund et al. 1995). The mobility tasks included common, simple tasks that people are used to carry out in their everyday lives, which probably increases the reliability of the results. Also, the validity of self-assessments of mobility has been shown earlier (Schulz-Larsen et al. 1992, Avlund et al. 1994). The wording of the questions about mobility tasks in the five-year follow-ups of the 75- and 80-year-old subjects in the present study differed from the questions used among subjects aged 65-84 at baseline and from questions used in several other studies. The difference was that the questions did not directly concern perceived difficulties but other limitations such as tiredness and reduced speed. This makes comparisons with earlier studies difficult. The purpose of asking about tiredness and reduced speed was to increase the sensitivity of the questionnaire among subjects who represented mainly healthy, well-functioning population (Avlund et al. 1995). This goal was also achieved, as the proportions of subjects from the group aged 75 or 80 at baseline reporting these mobility problems seemed to be somewhat higher than the estimates reported in earlier studies or those of the 75-84-year-olds in the present study (Laukkanen et al. 1994, Laukkanen et al. 1997).

Different outcome variables of mobility and different cut-off values were used in separate analyses of this study. This was necessary due to the differences in data collection and follow-up designs in separate parts of the study. Even if the baseline sample was extensive, the long follow-up times and the use of subgroups decreased the number of subjects in some cases so that it was not possible to use the same cut-off values as in the baseline analyses. The gender affects physical performance, which was taken into account by carrying out all the analyses with performance tests separately for men and women. The height of the subject also affects performance, especially in step mounting. Therefore the results were standardized by height in one article (IV) but it did not essentially change the results. In other analyses the practical point of view was followed; in everyday functioning people need to climb stairs of different heights, for example when entering buses, despite of their own height.

Measuring mobility performance with short distance walking tests is valuable and recommendable, as walking speed has been shown to be a valid and reliable indicator of mobility in older people (Guralnik et al. 1994, Bohannon 1997, Guralnik et al. 2000, Pajala et al. 2005, Mänty et al. 2007). Several studies have shown that usual walking speed is a good predictor of the onset of disability (Guralnik et al. 2000, Onder et al. 2005). However, measuring maximal walking speed might be even more valuable than measuring usual walking speed when trying to capture those whose mobility is at risk for deterioration in the near future. Weiss et al. (2007) showed that among high-functioning older women usual walking speed did not predict decline in mobility over three years, while more demanding mobility tests did (time to 5 chair stands and to climb 10 steps). Walking at maximal speed is more demanding than walking at usual speed, and in the present study, the predictive value of maximal walking speed on the development of mobility problems over five years was high. The distance walked is another important question. It has been shown that in a test situation, older subjects choose a higher gait speed strategy when walking over distances longer than 20 m than when walking a distance of less than 10 m (Najafi et al. 2009). In the present study, the distance was 10 m.

The step-mounting test yielded an important picture of the subjects' ability to move the body vertically. In Finland, people usually need to climb a couple of steps without a handrail when entering public buildings. Also, boarding public transport may require the ability to mount a high step; however, nowadays kneeling buses and low-floor buses are becoming more and more common. The step-mounting test thus has practical validity, but in the present study its predictive value on the development of mobility problems was somewhat weaker than that of the walking speed test. In older men, a clear ceiling effect was also found, which limits the usability of the test.

7.8 Implications

In older women in particular, several factors leading to poor performance may accumulate in old age and affect well-being and quality of life. Poor mobility has more often been found in women than in men. The rate of decline does not necessarily differ between men and women, but women usually live longer with their mobility problems. Women more often have chronic conditions, which also may last longer and increase in severity, and lead to disability. In addition, widowhood is more common in women and the women have lower incomes than men. In the women's dwellings, defects that make functioning difficult are found more often than in men's dwellings. If women with incident dependence no longer have anyone to help them, they will not be able to manage their shopping or other errands, use public transport or walk for exercise. Unfortunately, communal home help does not offer help with outdoor activities. The above-mentioned factors indicate that we should try to improve the situation of older women more actively, not only by targeting their physical abilities but also their physical and social environment. The question remains, however, how to influence the societal structures that maintain socioeconomic inequalities in old age.

More attention should be paid to defects in the dwelling environment of older people. Inside dwellings, many simple solutions increase the possibility to move about safely, such as removal of thresholds and unsafe carpets. This requires practical actions, such as assisting the dweller in obtaining and installing appropriate devices, as shown by Wyman et al. (2007). Individual counselling alone may be insufficient to reduce environmental hazards in the homes of older people (Wyman et al. 2007). Outside dwellings, access roads should be easy and safe for walking, even in the wintertime. The terrain should be smooth, without bumps or cracks, and planned so that the outdoor environment tempts walking. Benches for rest, good lighting and well-cared–for plantings make walking outdoors both safe and pleasurable. During wintertime, it is necessary to keep the sidewalks clean of ice, and/or grit them well. During mild winters, particularly, the fluctuation in the ambient temperature below and above zero causes slipperiness. It has been shown that wet ice at zero degrees is about four times more slippery than dry ice at -10 degrees (Grönqvist & Hirvonen 1995). In addition, the shoe types that have highest friction on wet ice, have the lowest friction on dry ice (Grönqvist & Hirvonen 1995). This indicates that better soling materials need to be developed and the use of studs or other aids promoted. Studs and other devices should also be easily removable indoors. If older people are not able to walk outdoors during wintertime, when the roads may be slippery for several months, as in Finland, their physical fitness declines, causing harmful and often irreversible effects on mobility.

In practice, the development of mobility problems often begins gradually after the onset of chronic conditions. The presence of any chronic condition usually decreases physical activity (Toth & Poehlman 2000), which lowers physical fitness. As age-related changes affect in the same direction as inactivity, the consequence is soon visible as decline in functioning, usually first in the heavier mobility tasks and performance tests. Many musculoskeletal and neurological diseases also have direct effects on the locomotor system, causing, for example, joint pain or muscle weakness. Various symptoms such as dizziness, dyspnea and fatigue may further contribute to the vicious circle. This means that the preventive actions should start immediately after a health condition has been diagnosed. As soon as an effective medical treatment has been found, the decline of fitness and mobility functioning should be prevented with appropriate physical exercise. It has been recommended that the detrimental effects of bed rest due to hospitalization or diseases should be aggressively resisted with strength training or physical therapy, combined with nutritional support to ensure adequate daily protein intake (Kortebein et al. 2008, English & Paddon-Jones 2010). The provision of appropriate exercise programs after short-term hospitalization or a period of bed rest at home should be an essential component of elderly care. Health care professionals should pay more attention to the indirect effects of medical conditions, in addition to their immediate symptoms. This is clearly an issue that involves resources and their proper allocation.

The sensory, psychomotor and musculoskeletal functions measured in this study had significant associations with mobility or decline in mobility. Many of these functions could be improved by suitable interventions. The trainability of muscle strength is not dependent on age (Fiatarone et al. 1990, American College of Sports Medicine 1998, Knight & Kamen 2001, Kryger & Andersen 2007). Balance, coordination and functional exercises as well as programs combining multiple types of exercises may improve balance (Howe et al. 2007), while some studies using progressive resistance training have also shown good results (Howe et al. 2007, Orr et al. 2008). However, not all studies have shown positive effects, and thus more randomized controlled trials, using large samples and interventions based on the principles of effective exercise, with long follow-up times are needed. Physical exercise has also been shown to have a positive effect on reaction time in some intervention studies (Lord et al. 2003, Kalapotharakos et al. 2006), although conflicting results have also been reported (Madden et al. 1989, Hassmén et al. 1992). Studies have shown that feasible stretching programs may increase range of motion of the lower extremity joints of older people, particularly ankle and hip joints (Swank et al. 2003, Gajdosik et al. 2005, Christiansen 2008, Cristopoliski et al. 2009). Improvement in range of motion of the joints also has positive effects on gait (Gajdosik et al. 2005, Christiansen 2008, Cristopoliski et al. 2009), without compromising the important passive stiffness of the calf muscles that contributes to plantarflexor torque during the push-off phase (Gajdosik et al. 2005). A recent review showed that the majority of exercise programs were effective in improving at least one mobility performance measure in frail older people (Chin A Paw et al. 2008). The intensity of the exercise programs targeted at frail people is often too low and the attitudes of professionals tend to be very cautious (Lazowski et al. 1999, Chin A Paw et al. 2008), which may explain why improvements have not always been found.

Poor vision is often, but not in all cases, correctable in older people. Possible intervention strategies include regular eye examinations, prescription and use of the correct spectacles, cataract surgery and environmental modifications to prevent tripping due to poor vision (Lord 2006). Self-assessed functioning seems to improve after cataract surgery (Applegate et al. 1987, Foss et al. 2006). Wearing multifocal spectacles when walking is clearly a safety risk as the lower part of the lens that is used for near vision blurs the ground in front of the walker (Lord et al. 2002b). Multifocal glasses may increase the risk of falling both in level walking and on stairs (Lord et al. 2002b). The lower visual field is used to modify lower limb trajectory and foot placement, particularly when walking on uneven terrain (Marigold & Patla 2008). Using proper single lens distance vision spectacles instead of multifocals increases foot control when stepping and improves the safety of walking (Johnson et al. 2008). It has been recommended that older people should use single lens distance glasses when moving about outdoors and in unfamiliar surroundings (Haran et al. 2010).

The determinants and pathways to mobility decline in old age are variable and individually developed during the life course. Different contributing factors often depend on each other, tend to accumulate and do not appear in any clear order of importance. This means that when trying to prevent or slow mobility decline, targeting one component may, in theory, reverse the vicious circle, but in practice a focus on several factors simultaneously could yield better results. For example, people with inappropriate spectacles will probably continue walking slowly in order to maintain balance even if their improved muscle strength after a training program would allow them to walk faster. Further, restricted dorsiflexion of the ankle would prevent the taking of longer steps, and thus walking faster would not be possible even if balance control had improved due to a balance training program. Even if it is possible to improve the functioning of the cardiovascular, musculoskeletal and psychomotor determinants of mobility, it may not be reasonable to assume that such improvements would automatically transfer to better mobility. Probably, the movement patterns typical to an individual in old age are so well learned that improvements in mobility cannot necessarily be observed without task-specific training of movement strategies and motor re-learning.

The statistical models used in this study showed that the structures of the mobility variables and their determinants were essentially the same among men and women, both at baseline and in the longitudinal analyses. This means that when seeking to identify people at risk for declining mobility, the same set of functions can be examined in both sexes. However, several important aspects were not included in the present study, for example aerobic capacity and several aspects of psychological functions, and the impact of these factors on declining mobility should be identified in future analyses.

Both self-assessments and performance-based tests of mobility have shown their value in epidemiological research as well as in clinical practice. To gain a comprehensive picture, both methods of measurement are needed. Questionnaires or interviews are a quick way to obtain information about mobility tasks that it would be too time consuming to observe. However, measuring mobility with performance tests can also be quick and safe and does not necessarily require expensive equipment or special facilities. A walking test over a short distance is probably the most revealing test. Measuring both maximal and comfortable speed would give a more comprehensive picture than either speed alone. This can also be recommended owing to the fact that it is somewhat unclear which speed is more sensitive to exercise. It has been suggested that exercise has a greater effect on comfortable speed (Lopopolo et al. 2006) but the opposite results have also been published (Kalapotharakos et al. 2005). The ability to move the body vertically would complete the test battery. For clinical purposes, a chair stand test or stair-climbing test on a staircase would be preferable to the step-mounting test used in the present study. The specific goal of an assessment defines what measurements and tests, and how many, are needed to obtain adequate information about an older person’s movement ability.

YHTEENVETO (SUMMARY)

Iäkkäiden ihmisten liikkumiskyvyn ongelmat ja niihin yhteydessä olevat tekijät

Kyky liikkua itsenäisesti on keskeistä päivittäisistä toiminnoista selviytymisen ja elämänlaadun kannalta. Liikkumiskyky heikkenee yleensä iän myötä ja selvimmin fyysisesti voimakkaasti kuormittavassa liikkumisessa. Aikaisempien tutkimusten perusteella liikkumiskyky näyttäisi vaikeutuvan joissakin toiminnoissa jo ennen 75 vuoden ikää, esim. noin kolmannes 65-74-vuotiaista ilmoittaa vaikeuksia ulkona liikkumisessa ja portaissa kävelyssä kun sisällä liikkumisesta tässä iässä lähes kaikki selviytyvät vaikeuksitta. Yli 85-vuotiaista sisällä liikkumisessakin on vaikeuksia noin puolella. Myös liikkumiskyvyn suoritustesteissä tulokset heikkenevät iän myötä ja naiset saavat tavallisesti miehiä heikompia tuloksia.

Liikkumiskykyyn yhteydessä olevia tekijöitä voi ryhmitellä toimintakyvyn heikkenemisen mallien mukaan elinjärjestelmien tason toimintoihin, terveydentilatekijöihin, yksilöllisiin tekijöihin ja ympäristötekijöihin. Elinjärjestelmien tason toiminnoista liikkumiskykyyn on aikaisempien tutkimusten mukaan ollut yhteydessä erityisesti lihasvoima ja tasapaino. Terveydentilatekijöistä esimerkiksi pitkäaikaissairauksilla ja monilla koetuilla oireilla on havaittu olevan yhteyksiä heikentyneeseen liikkumiskykyyn. Yksilötekijöistä iän ja sukupuolen lisäksi sosioekonominen tilanne voi vaikuttaa liikkumiskykyyn iäkkäänäkin. Iäkkäiden ihmisten liikkumiskykyyn vaikuttavia ympäristötekijöitä voivat olla esimerkiksi asunnon fyysiset epäkohdat. Tämän tutkimuksen tarkoitus oli selvittää 65-84-vuotiaan väestön liikkumisvaikeuksia, liikkumiskyvyn heikkenemistä sekä heikkenemiseen liittyviä tai sitä ennustavia tekijöitä 5-16 vuoden seuruuaikana.

Tämä tutkimus oli osa laajaa Jyväskylän yliopiston ja Jyväskylän kaupungin yhteistä tutkimusprojektia (Ikivihreät-projekti), joka keskittyi iäkkäiden ihmisten terveyteen ja toimintakykyyn. Tutkimukseen sisältyi 65-84-vuotiaiden henkilöiden haastattelut (n=1224) ja seuruuhaastattelut kahdeksan ja kuudentoista vuoden kuluttua. Lisäksi 75- ja 80-vuotiaita henkilöitä haastateltiin ja he osallistuivat laboratoriomittauksiin alkututkimuksen (n=617) jälkeen kaksi kertaa viiden vuoden välein. Samat haastattelut ja mittaukset, joihin jyväskyläläiset 75-vuotiaat henkilöt osallistuivat, toteutettiin myös Glostrupissa, Tanskassa, samanikäisille henkilöille (NORA-tutkimus, n=481). Heidän tutkimuksensa toistettiin viiden vuoden kuluttua. Liikkumiskykyä mitattiin haastattelukysymyksillä ja suoritustesteillä (maksimaalinen kävelynopeus 10 m matkalla ja maksimaalinen portaalle nousukorkeus). Suoritustestit tehtiin vain 75- ja 80-vuotiaiden henkilöiden ryhmille alku- ja seuruumittauksissa. Lisäksi 75- ja 80-vuotiaat tutkittavat osallistuivat laboratoriotutkimuksiin, jotka sisälsivät lääkärintarkastuksen, toimintatestejä, lihasvoima-, tasapaino- ja reaktioaikamittauksia, aistitoimintojen mittauksia ja kognitiivisia testejä. Haastattelussa selvitettiin myös sosioekonomista tilannetta, terveyteen liittyviä oireita ja fyysistä aktiivi-

suutta. Seuruuaikana sairaalahoidossa vietettyjen päivien lukumäärä saatiin Sosiaali- ja terveysministeriön laitoshoitorekisteristä. Haastattelijat havainnoivat kotikäynnin aikana tutkittavan asunnon fyysisiä epäkohtia kuten korkeita kynnyksiä, kaiteettomia portaita ja lähimaaston vaikeakulkuisuutta.

Tutkimuksen tulokset osoittivat, että liikkumiskyky heikkeni iän myötä sekä itsearviointien että suoritustestien perusteella ja erityisesti vanhimpien ikäryhmien naisilla. Eri menetelmillä tehdyt liikkumiskyvyn mittaukset olivat yhteydessä toisiinsa, mutta huomionarvoista oli, että suurella osalla iäkkäistä tutkituista itsearvioitu liikkumiskyky heikkeni vaikka suoritustestit eivät osoittaneet merkittävää muutosta liikkumiskyvyssä. Lyhyempi koulutus ja asunnon epäkohdat olivat yhteydessä 65-84-vuotiaiden liikkumiskykyyn, mutta logistisessa regressiomallissa asunnon epäkohdat eivät ennustaneet liikkumisvaikeuksien ilmaantumista kahdeksan vuoden seuruussa. Terveydentilatekijöistä krooniset tuki- ja liikuntaelinsairaudet olivat yhteydessä erityisesti suoritustestein mitattuun liikkumiskyvyn heikkenemiseen kun taas krooniset sydämen ja verenkiertoelimistön sairaudet selittivät voimakkaimmin itseilmoitetun liikkumiskyvyn heikkenemistä. Monimuuttujamallien perusteella niillä, jotka olivat viettäneet enemmän kuin 14 päivää laitoshoidossa viiden vuoden seuruun aikana, riski liikkumiskyvyn heikkenemiseen oli kaksin-, kolmin- tai lähes nelinkertainen verrattuna niihin, joilla laitoshoidossa vietettyjä päiviä oli vähemmän. Aistitoiminnoista, psykomotorisista toiminnoista ja tuki- ja liikuntaelinten toiminnoista lihasvoima, seisomatasapaino, näöntarkkuus, reaktioaika ja lonkka- ja polvinivelten liikerajoitukset olivat yhteydessä liikkumiskyvyn heikkenemiseen viiden vuoden aikana.

Liikkumiskyvyn heikkeneminen tutkituilla iäkkäillä henkilöillä tapahtui samansuuntaisesti kuin aikaisemmissakin tutkimuksissa. Tulokset osoittavat, että sekä itsearviointeja ja suoritustestejä tarvitaan, jos halutaan selvittää kattavasti iäkkäiden ihmisten liikkumiskykyä. Monimuuttujamallit osoittivat, että liikkumiskyvyn heikkeneminen ei useinkaan ole kiinni yhdestä yksittäisestä tekijästä, vaan asiat vaikuttavat toisiinsa, usein lisäksi kumuloituvasti. Liikkumiskyvyn heikkenemisen ehkäisemiseksi tulee sosiaali- ja terveydenhuollossa suunnata toimenpiteitä systemaattisesti henkilöihin, jotka viettävät lyhyitäkin aikoja laitoshoidossa. Vaikka sairaus ei suoraan vaikuttaisi liikkumiskykyyn, epäsuoria vaikutuksia aiheutuu todennäköisesti nopeasti fyysisen aktiivisuuden vähenemisen vuoksi. Ennaltaehkäisyä ja kuntoutusta kehitettäessä tulee iäkkäiden ihmisten kohdalla kiinnittää huomiota lihasvoiman ja tasapainon lisäksi muihinkin liikkumiskyvyn heikkenemisen osatekijöihin kuten alentuneeseen näkökykyyn, reaktioaikaan ja alaraajojen nivelten liikerajoituksiin. Parhaat tulokset voidaan todennäköisesti saavuttaa interventioilla, jotka keskittyvät useampaan kuin yhteen tekijään. Monet liikkumisvaikeuksiin yhteydessä olevista tekijöistä ovat sellaisia, joihin on mahdollista vaikuttaa fyysisellä harjoittelulla ja muilla preventiivisillä tai kuntouttavilla toimenpiteillä.

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ORIGINAL PAPERS

I

THE INCIDENCE OF MOBILITY RESTRICTIONS AMONG ELDERLY PEOPLE IN TWO NORDIC LOCALITIES. A FIVE-YEAR FOLLOW-UP

by

Sakari-Rantala R, Avlund K, Frändin K, Era P. 2002

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The incidence of mobility restrictions among elderly people in two Nordic localities. A five-year follow-up

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ABSTRACT. The aim of this study was to investigate the incidence of limitations in self-reported mobility as well as the decline in measured walking speed and stair-mounting ability over five years among men and women aged 75 at baseline in two Nordic localities. Another purpose was to analyze the relationship and its consistency over time between self-reports and performance-based measures in the decline of mobility. Identical interviews and performance tests were carried out in Jyväskylä, Finland (N=244) and Glostrup, Denmark (N=275) at baseline and five years later. The subjects were asked about their ability to manage with transferring from chair or bed, walking indoors and outdoors and climbing stairs. The occurrence of new limitations in these tasks was analyzed among those who did not report limitations in the same task at baseline. Maximal walking speed and step-mounting height were measured in the laboratory. The decline in walking speed below 1.2 m/s and stair-mounting height below 30 cm was analyzed among those whose results were, initially, above these limits. Most frequently, new limitations occurred in walking outdoors and in climbing stairs (44-60%). Walking speed and stair-mounting ability deteriorated below the thresholds mentioned in 4-36% of the participants, depending on gender and locality. There were only minor differences between the two Nordic localities in the decline in mobility functions. A substantial proportion of those whose performance had declined had developed limitations in self-reported mobility as well. However, the relationship between different methods of measurement was not straightforward. This indicates that multiple approaches are needed to obtain thorough knowledge about mobility and its decline among elderly people.
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INTRODUCTION

Problems in mobility are common in old age and hamper daily living and social activities. Difficulties in mobility generally develop before limitations in basic ADL (Activities of Daily Living) (1, 2). Both self-reported difficulties in mobility (3-5) and performance-based measures of mobility (6-9) have been shown to predict subsequent disability in everyday functions. Studies focusing on the construct validity of ADL scales have found that mobility functions form a separate dimension, and should not be combined with basic and instrumental ADL (10-13). Consequently, the development of mobility problems should be analyzed separately from other ADL functions.

Numerous studies have shown that it is common to develop new mobility difficulties with increasing age (1, 2, 14, 15). However, the proportion of old people who develop new mobility difficulties has been found to vary from about 10% in two years (14) to almost 50% in ten years (15). These large variations in the development of new mobility difficulties may be due to the interview questions used, or the use of single items (14, 15) or combined scales in the analysis (2). Performance-based measures of mobility show decline with age as well; for example, walking speed declines substantially with age according to both cross-sectional

Key words: Aging, longitudinal study, mobility, NORA Study, performance-based measures, self-reports.

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(16, 17) and longitudinal (7, 13, 18-20) studies. Variations in decline in mobility performance may be due to the tests used and different cut-off points (13, 19, 21). In addition to the subjects' age, different length of follow-up times and measurement methods, the level of baseline functional capacity might also contribute to the differing incidence rates across studies on the development of mobility restrictions.

Many researchers have found significant associations between performance-based measures of mobility and self-reports (22, 23). In longitudinal designs, measures of walking speed and timed chair stands have been shown to have a linear association with subsequent inability to walk half a mile and climb stairs without help (9, 22). However, the strength of the associations between performance-based measures of mobility and self-reports seems only moderate (23, 24) and many studies have revealed obvious discrepancies between measurement modalities. The level of agreement between performance-based tests and self-reports has been low even when the target functions have been identical (18, 25). In addition, in the studies by Guralnik et al. (22) and Ferrer et al. (25), a substantial proportion of persons who were not able to perform the walking speed test did not report need for help in walking. In a cross-sectional study by Myers et al. (18), walking speed was significantly associated with observed difficulties in walking but not with self-perceived difficulties.

Independent mobility in the community requires the ability to walk rapidly and to climb high steps. Most traffic lights in Nordic countries are set to change with a safety margin which requires a walking speed of 1.2 m/s or more if the pedestrian steps onto the pedestrian crossing just before the lights change. However, Hoxie and Rubenstein (26) found that 96% of older pedestrians crossed the street at a walking pace slower than 1.2 m/s at an intersection with traffic lights, and that 27% were not able to reach the opposite curb before the lights changed. Lerner-Frankiel et al. (27) found that 18-20 cm curb heights were common in residential and commercial city areas. In addition, climbing capacity is needed when entering buildings, which very often means mounting a couple of steps, usually without handrails, before reaching the door. However, the highest steps are encountered when boarding buses or trains (28) and, according to Lundgren-Lindquist et al. (29), low step-mounting ability was associated with difficulties in using public transportation.

Even if the associations between performance-based measures of functional capacity and self-reported disability have been abundantly studied in recent years (6-9, 22, 23), few studies have focused on mobility functions in particular, and even fewer of these have used longitudinal procedures. The aims of this study were: 1) to investigate the occurrence of new limitations in self-reported mobility among men and women aged 75 at baseline in two Nordic localities; 2) to investigate the decline in measured walking speed and stair-mounting ability; and 3) to analyze the relationship between self-reports and performance-based measures in the decline in mobility.

METHODS

This study is part of the NORA study (Nordic Research on Ageing) and comprises data gathered through interviews and laboratory examinations in Glostrup, Denmark and Jyväskylä, Finland. In Glostrup, a random sample of 571 persons was drawn from the national population register. In Jyväskylä, the study population consisted of all residents born in 1914 (N=388). The interviews and laboratory tests were carried out for the first time when the subjects were 75 years old, and a second time 5 years later, at age 80. In total, 835 persons were interviewed at baseline. At the 5-year follow-up, 213 persons had dropped out because of death (25.5%) and 95 persons (11.4%) were lost for other reasons, mostly due to refusal. The present study was conducted among the 519 persons who participated in both the baseline and follow-up interviews concerning mobility tasks. Of these, 82 men and 162 women came from Jyväskylä, and 120 men and 155 women from Glostrup.

During the interview, the subjects were asked about their ability to manage four mobility tasks (transferring from/to bed or chair, walking indoors and outdoors, and climbing stairs) (30). If the subjects reported that they were able to manage the task, they were asked whether they got tired, moved at a slower speed than earlier, and/or were in need of help in performing the activity. A positive answer to one or more of these three questions was defined as limitations in mobility. The development of new limitations in each task was analyzed among those who did not report limitations in the same task at baseline.

Maximal walking speed and maximal stair-mounting ability were measured in the laboratory. Maximal walking speed over 10 metres was measured in the laboratory corridor using a stopwatch (31, 32). The subjects were allowed to use walking aids if they usually did so. The subjects started walking about five metres before the first line in order to achieve maximal speed before timing started, and continued walking for a couple of metres after the second line. Maximal stair-mounting ability was measured using five 60 cm × 60 cm boxes each 10 cm in height (31, 32). The highest step that the subject could mount without support in a single step was recorded (step heights 0, 10, 20, 30, 40 and 50 cm).

A decline in walking speed below 1.2 m/s and maximal stair-mounting height below 30 cm was analyzed among those whose baseline result in the same test was above the threshold mentioned. These cut-off points match the requirements for independent mobility in the community. Men have the advantage over women with regard to physical performance, but we chose the same cut-off points for both sexes because the physical environment in the community is the same regardless of gender or bodily dimensions. In addition, self-reported mobility is based on perceived ability to move about in that environment. A weak but significant negative correlation was found between body weight and stair-mounting height among men (r= -0.207, p=0.022), and a positive correlation between body height and walking speed among women (r=0.242, p=0.002).

In this report, the word 'limitations' refers to poor mobility revealed in self-reports and the word 'restrictions' more generally to results obtained in self-reports and/or laboratory measurements. Both the self-reports and performance-based measurements were analyzed as dichotomized variables. With regard to the self-reported mobility tasks, we distinguished between persons managing with and those managing without limitations (tiredness, slowness or need of help). The performance tests were classified as good and poor performance according to the above-mentioned threshold levels. The statistical method used was cross-tabulation with the χ^2 test.

RESULTS

The proportions of all the participants of the 5-year follow-up who did not report limitations in different mobility tasks or whose walking speed or stair-mounting ability was above the cut-off point at baseline are shown in Table 1. The numbers represent the subjects who were included in the analysis of declining mobility. The easiest task was transferring from chair or bed (managed by 70-77% without limitations). The hardest task was climbing stairs (managed without limitations by less than half of the men and about one third of the women). No large differences were seen between the localities or sexes. A smaller proportion of the women in Glostrup managed to walk outdoors without limitations at age 75 compared to the women in Jyväskylä (p=0.002). In Glostrup, a smaller proportion of women than men were able to manage stairs without limitations (p=0.018). The proportion of persons who were able to walk at the speed of 1.2 m/s or faster and to climb steps 30 cm or higher varied between 85 and 97%. The proportion of the women in Glostrup who were able to walk faster than 1.2 m/s was smaller than that of their male counterparts (p=0.029). No significant differences were seen between localities in the performance tests.

Table 1 - *Proportions of 75-year-old subjects who did not have limitations in the different mobility tasks (*) and whose walking speed or stair-mounting ability was above the cut-off point (**) at baseline.*

Mobility task	Jyväskylä		Glostrup	
	Men N (%)	Women N (%)	Men N (%)	Women N (%)
Self-reports	N=79-82	N=149-162	N=113-120	N=150-155
Transferring	57 (71.3)	112 (69.6)	92 (76.7)	117 (75.5)
Walking indoors	50 (61.0)	93 (57.4)	66 (55.5)	77 (49.7)
Walking outdoors	36 (45.6)	84 (52.5)	51 (43.2)	54 (35.1)
Climbing stairs	36 (45.6)	53 (35.6)	47 (41.6)	41 (27.3)
Performance tests	N=58-63	N=111-119	N=92-95	N=96-100
Walking speed ≥1.2 m/s	58 (92.1)	108 (90.8)	89 (96.7)	84 (87.5)
Stair-mounting ≥30 cm	54 (93.1)	95 (85.6)	89 (93.7)	85 (85.0)

(*) did not report slowness or tiredness.
(**) walking speed ≥1.2 m/s or stair-mounting ability ≥30 cm.

Table 2 - *Proportions of men and women aged 75 at baseline who reported new limitations in the different mobility tasks or whose walking speed or stair-mounting ability had declined below the cut-off point at follow-up (*).*

Mobility task	Jyväskylä		Glostrup	
	Men N (%)	Women N (%)	Men N (%)	Women N (%)
Self-reports	N=36-57	N=53-112	N=47-92	N=41-117
Transferring	17 (29.8)	36 (32.1)	36 (39.1)	57 (48.7)
Walking indoors	14 (28.0)	37 (39.8)	22 (33.3)	33 (42.9)
Walking outdoors	17 (47.2)	50 (59.5)	23 (45.1)	32 (59.3)
Climbing stairs	16 (44.4)	26 (49.1)	21 (44.7)	24 (58.5)
Performance tests	N=54-58	N=95-108	N=89	N=84-85
Walking speed <1.2 m/s	7 (12.1)	39 (36.1)	10 (11.2)	22 (26.2)
Stair-mounting <30 cm	2 (3.7)	16 (16.8)	9 (10.1)	24 (28.2)

(*) includes only those who, at baseline, did not report limitations (slowness or tiredness) in the different mobility tasks or whose mobility performance was above the cut-off point in walking speed (≥1.2 m/s) or stair-mounting ability (≥30 cm).

The proportions of new self-reported limitations in the different mobility tasks at follow-up among those who did not have limitations at baseline are shown in Table 2. The proportions of new limitations were lowest in walking indoors (28-43%), except for the women in Jyväskylä, where the proportion of new limitations was smallest in transferring from chair or bed (32%). The largest proportions of new limitations were reported in walking outdoors (45-60%). The only significant difference between the localities was seen in transferring, where a larger proportion of the women in Glostrup than in Jyväskylä reported new limitations (p=0.015). The differences between the sexes were not significant. A walking speed lower than 1.2 m/s was measured among 12% and 11% of men, and among 36% and 26% of women in Jyväskylä and in Glostrup, respectively, who walked faster at baseline. The proportion of women whose walking speed fell below 1.2 m/s was greater than that of men both in Jyväskylä (p=0.001) and in Glostrup (p=0.018). In the stair-mounting test, the proportions of those whose step heights declined below 30 cm during the follow-up varied from 4% and 10% (men) to 17% and 28% (women) in Jyväskylä and in Glostrup, respectively. The difference between sexes was significant in both localities (p=0.019 in Jyväskylä and p=0.003 in Glostrup). There were no significant differences between the localities in declining mobility performance.

The next step was to analyze the relationship between self-reports and performance-based tests in the deterioriation of mobility among persons with good mobility at the baseline. Figures 1-4 show that, in general, a large proportion of those whose performance-based mobility had declined below the cut-off point had also developed new self-reported limitations at follow-up. Correspondingly, large proportions of those whose performance-based mobility remained good did not report new limitations in mobility tasks during the follow-up. For example, of those

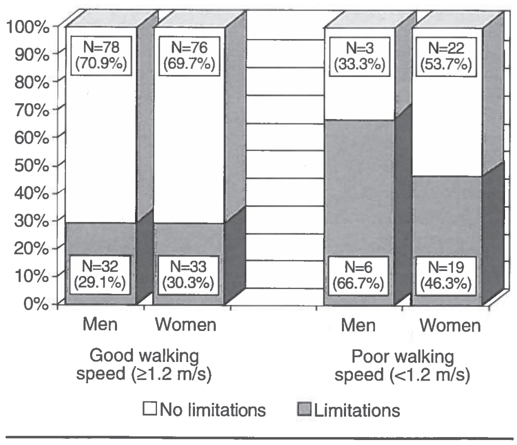

Figure 1 - *Self-reported limitations in transferring according to walking speed at follow-up among men and women aged 75 at baseline who did not have limitations and whose walking speed was faster than 1.2 m/s at baseline.*

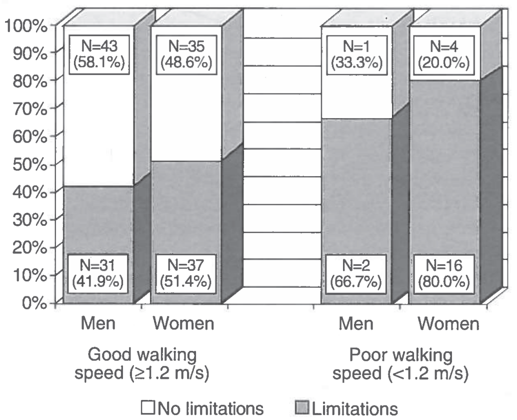

Figure 2 - *Self-reported limitations in walking outdoors according to walking speed at follow-up among men and women aged 75 at baseline who did not have limitations and whose walking speed was faster than 1.2 m/s at baseline.*

whose walking speed remained above 1.2 m/s, more than two thirds did not report limitations in transferring (Fig. 1). Almost all persons whose stair-mounting ability declined below 30 cm reported new limitations in stair climbing (Fig. 4). To save space, only the results about transferring and walking outdoors are shown. Comparing new self-reported limitations in walking indoors with the decline in the performance-based tests gave very much the same results as shown in the Figures 1 and 2 about transferring. Cross-tabulations about new limitations in climbing stairs and declining performance-based mobility were similar to the results for walking outdoors (Figs. 2 and 4).

However, among a substantial proportion of subjects the changes were not consistent across self-reports and performance-based tests. For example in transferring, among those whose walking speed declined, 33% of men and 54% of women did not report new limitations after five years (Fig. 1). In the heavier mobility tasks such as walking outdoors, the performance declined without the development of new limitations among only very few persons (one man and five women, Figs. 2 and 4). Raising the cut-off point in the performance-based tests (up to 1.8 m/s in walking speed and 50 cm in stair-mounting height), so that minor limitations were classified as poor functioning, somewhat increased the proportion of those whose performance declined but who did not report new limitations (analyses not shown).

The situation was the same in the other direction as well. Of those who remained in the well-performing group, a substantial proportion reported limitations in mobility tasks. For example, 26-30% of those whose performance in walking speed or the stair-mounting test remained good reported new limitations in transferring (Figs. 1 and 3). Again, raising the cut-off

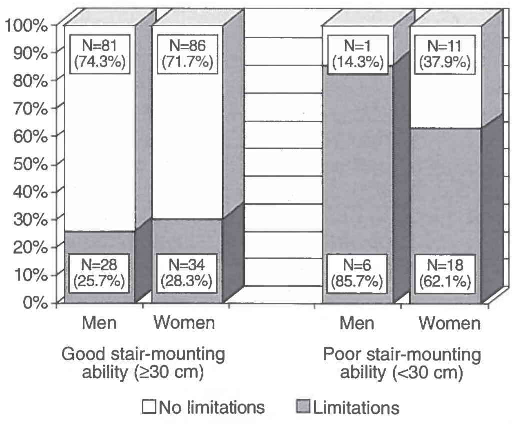

Figure 3 - *Self-reported limitations in transferring according to stair-mounting ability at follow-up among men and women aged 75 at baseline who did not have limitations and who were able to climb at least 30 cm steps at baseline.*

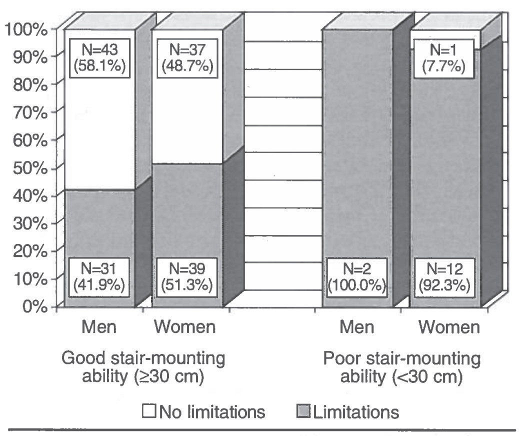

Figure 4 - *Self-reported limitations in walking outdoors according to stair-mounting ability at follow-up among men and women aged 75 at baseline who did not have limitations and who were able to climb at least 30 cm steps at baseline.*

points in the performance-based tests did not have any essential effect on the figures. The proportion of those who continued performing well but who reported new limitations diminished somewhat but did not disappear (analyses not shown).

DISCUSSION

During the 5-year follow-up, self-reported mobility had declined among a large proportion of the 80-year-old men and women who did not have limitations 5 years earlier. The proportions of reported new limitations were highest in the heavier tasks (walking outdoors and climbing stairs), where about half or more of the men and women reported limitations at follow-up. In the initially well-performing group, the proportions of those whose results in the performance-based tests declined below the critical level (1.2 m/s in walking speed or 30 cm in stair-climbing ability) were smaller than the proportions of those who reported new limitations, especially among men.

The present results concerning the occurrence of new limitations in mobility are in agreement with the findings by Dunlop et al. (1) and Jylhä et al. (15). In a 6-year follow-up of 70-99 year-old people by Dunlop et al. (1), the incidence of new difficulties in mobility was 34% in walking and 19% in transferring among men, and 38% and 23% among women. In a 10-year follow-up of 70-79 year olds by Jylhä et al. (15), new difficulties in moving outdoors appeared for almost one third of the men and one half of the women. In studies with shorter follow-up times, the rates of occurrence of new mobility difficulties were lower than in the present study (2, 14, 33).

Previous studies have shown that mobility limitations increase sharply after age 80 (34, 35). In the present study, the incidence of limitations was high even somewhat earlier, between 75 and 80 years. The sensitivity of the mobility questions probably contributed to this by capturing relatively mild limitations as well. The high incidence of mobility limitations indicates that a large proportion of 80-year olds are at risk of losing their independent functioning (3-5). Targeting preventive measures to these people is important and might be quite successful, as improvements in functional capacity have been found to be more likely in this age group than after age 80 or 85 (36, 37).

It is more difficult to compare the results of the performance-based tests with those of previous studies because of different cut-off points and study designs. A decline in performance-based tests has been found earlier in studies with 3- to 6-year follow-up times (7, 13, 19). In the study of Hoyemans et al. (13), the cut-off point in walking speed was set to the lowest quartile at baseline, and the proportion of men (mean age 75.1 years) whose result was below that cut-off point more than doubled in three years. In the present study, performance-based results were dichotomized into good and poor functioning according to cut-off points regarded as indicating the performance levels necessary for independent mobility in the community. However, the use of dichotomized variables creates problems, especially when analyzing change over time, as the magnitude of that change is not taken into account. In some persons, because of normal variation in daily performance, the result might have been very near the cut-off point at both time points, which implies that a possible shift from the good to poor category indicates no clinically important change.

In self-reported mobility, the proportions of those who developed new limitations were somewhat higher among women than men in all four tasks, but the trend was not statistically significant. In previous studies it was shown that women are more likely than men to develop new mobility difficulties (1, 2, 33, 38); however, contrary results have been reported as well (4). There is also evidence that gender differences might be task-specific (14). In performance-based tests, gender differences are more obvious; men have been shown to have a significantly higher walking speed (25, 28, 29, 32, 39, 40) and stair-mounting ability (28, 29, 32, 40) than women. The results of the present study support these findings; probably because no gender-specific cut-off points were used, the decline was greater among women than men.

Several factors contribute to a decline in mobility. Old age, chronic conditions, certain health behaviors, and socio-economic situation seem to be associated with increasing mobility problems (19, 41, 42). A high number of chronic conditions as such has an impact on declining mobility (43) as well as various diseases or health conditions, such as previous heart attack, high blood pressure, stroke, cancer, diabetes, pain, poor eyesight, joint impairments and high body mass index (19, 21, 41, 42, 44). Chronic conditions diminish one's possibilities of doing physical exercise but, equally, a low level of physical activity has been found to predict dependence in mobility functions, even when health status has been controlled for (43, 44).

Not all of those whose walking speed or stair-mounting ability decreased below the defined functional level developed limitations in self-reported mobility tasks in the present study. However, the proportion of those showing this discrepancy was small and evident only in the easier tasks (transferring, walking indoors). In previous cross-sectional studies the discrepancy between these two methods of measurement has consistently been confirmed (22-24). Further, the discrepancy in the present study holds in the other direction as well; a substantial proportion of persons whose mobility performance remained good reported new mobility limitations. Anthropometric differences could not have had strong effects on the results, especially because changing the cut-off points in the performance-based tests did not essentially affect the results (analyses not shown). At least part of the differences observed between performance-based measures and self-reports can be explained by normal individual variation in declining functional capacity. Other explanations for the discrepancy should be considered as well.

It has been suggested (6, 13, 22) that the weakness of the associations between performance-based measures and self-reports of mobility or ADL is caused by the fact that these measurement modalities capture different levels of the disablement process. According to the models of the disablement process by Nagi (45) and Verbrugge and Jette (46), different kinds of pathologies cause impairments at the organ system level, leading to functional limitations in different body functions and, finally, disability in one's own living environment. Performance-based tests can be seen to represent functional limitations in the model, and self-reported mobility can be seen as an indicator of disability. The predictive value of performance-based tests on subsequent disability supports the assumptions about causal associations between these levels. In the present study, the proportion of those whose performance declined but who did not report new limitations was in line with these assumptions; some of those whose performance had decreased during the five years had not yet started to perceive problems with everyday mobility tasks.

However, the discrepancy in the other direction in the present study is somewhat at odds with the disablement model. The discrepancy was quite large and consistent across different tasks, and did not disappear when the cut-off level was changed. It is possible that asking about tiredness and slowness rather than difficulties captures mobility problems in an early, incipient phase, when the subject is still able to perform maximally for a very short time. In addition, this discrepancy may indicate the complexity of the disablement process, and the importance of the backward loops in its course. When people begin to perceive problems in their daily functioning, they frequently also begin to avoid difficult tasks or slow down, which does not lead to a decline in their measured performance until later.

Other reasons for the discrepancy between performance-based measurements and self-reports of mobility or ADL functions have been suggested. Both measurement modalities have weaknesses which can affect the results. For example, the results might be impaired by misunderstandings, inaccurate reporting in the interview or miscoding (22). Answers to interview questions are probably based on the participant's usual state of functioning while her/his performance might be affected by some temporary factor (22). Performance in a test only yields information about a single unique event which can be successfully executed, while performing the same task several times a day may cause difficulties such as pain or tiredness. In addition, performance tests do not necessarily capture all the factors that might influence participants' self-reports (13, 22), and vice versa. For example, performance-based tests do not reflect adaptation or compensation mechanisms to everyday life which affect self-perceived difficulties (18, 24). In the present study, some aspects of perceived mobility functions were probably not captured as the questions did not concern problems caused by pain or impaired sight etc. Further, cognitive functions (24), depressive symptoms (23) and certain personality characteristics, such as perceived physical competence and mastery (47), have been found to contribute to the weakness of the associations between self-reports and measured performance.

The present study is based on a longitudinal population study. The sample size and the participation rate were quite high, and the drop-out rate for reasons other than mortality low over the five years. Nonetheless, the size of the groups in which the performance-based tests of mobility declined below the threshold values was small, especially in the men. This should be noted, as it disallows the drawing of any far-reaching conclusions on the discrepancies in the results between performance and self-reports.

There were only minor differences between the two Nordic localities, and only between the women. Differences were found in the prevalence of limitations in walking outdoors and in the development of new limitations in transferring, both in favor of the women in Jyväskylä. It was previously shown that differences in basic ADL functions are minor between cultures because these activities are basic and necessary for everybody (48). The same may apply to mobility functions as well. In an earlier comparative study within the NORA project utilizing the same baseline data, it was found that the women in Glostrup, especially, reported more tiredness in ADL tasks than the women in Jyväskylä. The authors suggested that it might be more acceptable in Denmark to express feelings of tiredness than in Finland (30). This assumption about cultural differences in expressing difficulties is supported by the fact that no differences between the localities in the performance tests were found in the present study. In addition, the performance tests used were simple everyday tasks which can be measured more reliably than unfamiliar or unusual activities (49).

The results of this study suggest that a large proportion of 75-year olds will develop limitations in performing their daily mobility tasks over the following five years, while a smaller proportion will decline below the level which can be seen as required for independent mobility in the community. The discrepancies found here between the self-reports and performance-based measures in detecting change over time indicate that the different approaches capture different dimensions of mobility. Thus, multiple approaches are needed to obtain thorough knowledge of mobility and its decline among elderly people. In aiming to prevent dependence, it is first necessary to identify those at risk of declining mobility before greater difficulties have developed.

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II

DIFFICULTIES IN MOBILITY A MONG ELDERLY PEOPLE AND THEIR ASSOCIATION WITH SOCIOECONOMIC FACTORS, DWELLING ENVIRONMENT AND USE OF SERVICES

by

Sakari-Rantala R, Heikkinen E, Ruoppila I. 1995

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Difficulties in mobility among elderly people and their association with socioeconomic factors, dwelling environment and use of services

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ABSTRACT. The purpose of this study was to clarify the extent to which elderly people have difficulties in mobility, and determine their association with socioeconomic factors, dwelling environment and use of services. The study groups were composed of two random samples of 800 persons aged 65-74 and 75-84, respectively. In all, 1224 non-institutionalized persons (80%) were interviewed at home. The respondents were asked to assess their ability to get about the house, negotiate stairs and walk outdoors, as well as manage certain physical exercise tasks. Difficulties in getting about outdoors were found most frequently among the women in the older age group (52% reported difficulties), and least frequently among the women in the younger age group (23%). Logistic regression analyses showed that difficulties in getting about outdoors were significantly explained by length of education and defects in the dwelling environment. Also, difficulties in getting about outdoors explained significantly the use of home help. It is concluded that difficulties in mobility among elderly people, especially among elderly women, should be reduced more actively either by improving their physical abilities or by developing compensation strategies for their own use or in regard to the environment.
(Aging Clin. Exp. Res. 7: 433-440, 1995)

INTRODUCTION

To maintain mobility, e.g., the ability to walk, negotiate stairs and use public transportation, in old age is essential for independent functioning in daily life (1-3), as well as for social participation and leisure activities (4). Preventing or postponing functional disabilities and promoting independence is important for the quality of life of older people (5). The information yielded by epidemiological research on mobility problems and related factors will facilitate the planning and development of preventive interventions.

The pathways that lead to mobility problems in late life are not precisely known, but there usually are one or more chronic conditions in the background, the number of which was found to be connected with difficulties in or loss of mobility (3, 6-8). Further, the ability to move contributes to how older people perceive their health (9, 10). Age as such (3, 7, 11-14), and being female (11-14) are associated with an increased prevalence and incidence of reported mobility difficulties.

Previous research has shown that socioeconomic factors, such as low income (3, 8), low education (7, 15), and social class as a combination of these (16), are related to mobility problems or loss of mobility. In the study by Guralnik et al. (3) the relationship of income to loss of mobility was independent of age or chronic conditions in both sexes. The same applied to the relationship between mobility loss and education in men. Social class has been considered to affect functional ability more than gender (17), which further indicates the importance of socioeconomic factors in relation to mobility.

Environmental factors are not the cause of mobility problems, but elderly people with such problems will be more vulnerable to environmental demands. For example, older people with mobility limitations more often report the need for modifications in dwellings, such as extra handrails, ramps or stair lifts, than others (18). In addition, environmental factors,

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e.g., the lack (4) or inaccessibility (19) of transportation, often limit the outdoor mobility of elderly people.

When difficulties in mobility appear, older people have several ways of dealing with them. They can try to adapt by altering how they act (e.g., acting more slowly, doing things in a different way or giving up difficult tasks), which often happens gradually and unconsciously (20, 21). Alternatively, people can try to improve their capabilities through medical or rehabilitative interventions (21). When inabilities appear, people can further compensate for such losses by increasing their informal or formal use of services, or by making the dwelling environment more suitable either by improving their existing home environment or moving into a more appropriately equipped dwelling (18, 20-22). When considering the ability of older disabled people to continue living at home, the condition and standard of the equipment in the dwelling environment not only are crucial, but also affect the family's willingness to take care of an older relative at home, as well as the possibilities for professional carers to render their services (23).

Previous research has shown that older people with mobility difficulties avail themselves of more health care services (24, 25) or home care (26-28) than those without. In addition, elderly people who move into another dwelling tend to have more disability or mobility problems than those who remain in their existing homes (29, 30). Special modifications are also made more often in the homes of older people who have mobility difficulties than in the homes of other older people (18, 31).

Mobility problems are common among elderly people, but to date few epidemiologic studies addressing representative populations have been carried out to clarify the factors associated with these problems. In particular, non medical factors (e.g., demands of the physical environment, use of external support) and their multivariate relations to mobility problems have not been addressed. The aim of the present study is, first, to clarify the extent of difficulties that people in the 65- to 84-year age group have in their mobility in the city of Jyväskylä, central Finland, and, second, to determine the relationship between mobility difficulties and socioeconomic factors, dwelling environment and use of services.

SUBJECTS AND METHODS

The study is part of the EVERGREEN-project, an extensive research and development project focusing on the elderly population of the city of Jyväskylä, central Finland. The aims of the project are to describe the health and functional capacity of the elderly people, and improve them with interventions at the population level. Jyväskylä has about 68 000 inhabitants of whom 12.6% in 1992 were 65 years or older, a figure slightly below the national average (13.8%). The material for this study was collected through home interviews with non-institutionalized people in 1988. The sample consisted of 1000 people from each of two decennial age groups (people born in 1904-1913 and 1914-1923), and it was further randomly decreased to 800 persons for financial reasons; 589 persons in the older age group were interviewed (179 men and 410 women), and 635 in the younger age group (240 men and 395 women). The participation rate was 80.2%. Proxy interviews were carried out in 60 cases (4.9% of the interviews). The interviews were carried out by 28 female students of the University of Jyväskylä, who received 40 hours of special training.

The dependent variables in this report were the mobility variables chosen from the Physical Activities of Daily Living (PADL) scale (transferring from/to bed, getting about indoors, getting about outdoors, where the alternatives were 1 = able without difficulty, 2 = able, but slowly, 3 = able with great difficulty or gets tired, 4 = able with technical aids, 5 = not able without personal assistance), and the Instrumental Activities of Daily Living (IADL) scale (using public transport; alternatives 1 = able without difficulty, 2 = able with difficulty, 3 = not able). The scales were constructed on the basis of previous experiences and the literature (32-34). The test-retest reliability of getting about outdoors was measured by a second interview (N=36) after two weeks, and the correlation between the answers was 0.82. The validity of mobility function assessment was not examined, but previous studies have shown that self-assessments of mobility (walking, for example) give valid information when compared to performance tests (agreement about 90%) (35, 36). In addition, difficulties in managing various tasks demanding physical exertion were studied (climbing up one flight of stairs without rest, running 100 m, walking in the woods, biking at least 2 km, skiing at least 2 km, swimming at least 25 m; alternatives 1 = able without difficulty, 2 = able with difficulty, 3 = not able). The response alternatives were dichotomized to 1 = able without difficulties, and 2 = able with difficulties/slowly/gets tired or not able.

Four variables were selected as independent variables. Length of full-time education in years, and personal monthly net income were chosen to represent socioeconomic status. The interviewer's answer to an open-ended question was chosen to describe the defects in the home environment that make functioning difficult, because an outsider's view was regarded more objective than the subject's own assessment. Towards the end of the interview, the interviewers observed the standard of equipment and functionality of the dwelling (e.g., existence of high thresholds, stairs, elevator, bathtub). Interviewers were then asked to record the factors that made the respondent's independent functioning difficult, on the basis of their observations and the questions asked earlier concerning the Activities of Daily Living. Modifications made in dwellings to facilitate functioning were explored by both structured and open-ended questions. Whether or not the subject received home help was selected to represent the use of services.

Age, sex, marital status, living alone and health status were included as confounding variables, whose influence was evaluated by multifactorial analyses. The number of chronic diseases was chosen to indicate health status. By means of an open-ended question, the respondents were asked to report all the chronic diseases or injuries (lasting more than 3 months) that had been diagnosed by their physician. The diagnoses were coded according to the ICD-9 and summed. The number of chronic diseases was significantly ($p<0.001$) associated with self-rated health in both age groups and in both sexes. In recent studies, self-report of medical conditions was found to be a sufficiently reliable source of information in epidemiologic studies (37, 38).

The statistical methods used were cross-tabulation and χ^2 test in the case of discrete variables, and Student's t test in the case of continuous variables to analyze associations between single variables. Multivariate correlations were used to investigate the interdependences of the mobility variables. Logistic regression was used to create multivariate models for two purposes: firstly, to investigate the associations of background and explanatory factors with difficulties in getting about outdoors; secondly, to determine the association of difficulties in getting about outdoors with the use of home help after controlling for the background and explanatory factors (39). Because of the sampling technique used (overrepresentation of subjects in the older age group), the data were weighed when dealing with both age groups together; the coefficient for the younger age group was 1.245, and for the older age group 0.736.

RESULTS

The majority of the men were married (74% in the older and 78% in the younger age group), while most of the women were widowed (62% in the older and 40% in the younger age group). Education was longer in the younger age group (7.5 years for men and 7.2 years for women) than in the older age group (5.9 years for men and 5.7 years for women, $p<0.001$ for both sexes). The men more often had vocational education than the women (53-60% compared with 39-46%, $p<0.001$). The commonest occupation reported was skilled worker (almost one half of the men and one third of the women). The net income of the men was greater than that of the women (3957 FIM *vs* 2841 FIM, $p<0.001$). About 45% of the subjects lived alone.

Table 1 reveals the proportions of persons who had difficulties or inabilities in performing the various mobility tasks. The women in the older age group had significantly more difficulties than the others in the performance of almost every task. The difference between the sexes was significant in almost every task in the older age group. In the younger age group, the results of the men and women were closer to each other. The easiest tasks were transferring from/to bed or getting about indoors, and the most difficult was running 100 m, in which only 15% of the women of the older age group reported no difficulties. Many subjects (1-40%) could not provide answers to questions concerning their performance in tasks requiring physical exertion.

About 25% of the subjects in the older age group, and 9% in the younger age group used a walking stick ($p<0.001$). Other technical aids to improve mobility were not commonly used; only a few persons used crutches, walker or wheelchair.

About 18-28% of the subjects rated their health as poor or very poor. This was most common among the women in the older age group ($p<0.001$). Between 22% and 35% of the subjects reported three or more chronic diseases; again these were most often the women in the older age group ($p=0.015$). The most frequent disease groups were those of cardiovascular and musculoskeletal diseases.

Most of the subjects owned their own homes, and most lived in blocks of flats. The interviewer observed and recorded the defects in the dwelling that hampered the subject's functioning. Such defects were found least frequently among the men in the younger age group (13% had one or more defects), and most frequently among the women in the older age group (24% had one or more defects, $p=0.002$). The most usual defects were problems in the bathroom, such as a poorly accessible bathtub, and stairs with no lift. Among the persons living on the second floor or higher, 28% had no lift in their building. Several modifications to facilitate functioning had been made in the residences of 8-18% of the subjects; the most

Table 1 - *Difficulties in mobility in men and women born 1904-1913 and 1914-1923. Proportions and numbers of persons unable to perform mobility tasks without difficulty, proportions of missing data and statistical significances of differences between sexes and age groups (χ^2 test).*

Mobility task	75-84-year olds Men (N=179) % (n) missing data (%)	75-84-year olds Women (N=410) % (n) missing data (%)	p	65-74-year olds Men (N=240) % (n) missing data (%)	65-74-year olds Women (N=395) % (n) missing data (%)	p	Significance of age group Men p	Significance of age group Women p
Transferring from/to bed	13.6 (23) 6.7	20.2 (76) 8.3	0.084	6.1 (14) 4.2	8.4 (32) 3.5	0.373	0.017	<0.001
Getting about indoors	16.0 (27) 5.6	22.5 (85) 7.8	0.103	7.8 (18) 4.2	5.2 (20) 3.5	0.269	0.017	<0.001
Getting about outdoors	31.1 (52) 6.7	52.0 (196) 8.0	<0.001	24.8 (57) 4.2	23.1 (88) 3.5	0.707	0.192	<0.001
Using public transport	17.9 (30) 6.1	31.0 (117) 8.0	0.002	10.0 (23) 4.2	10.8 (41) 3.5	0.872	0.033	<0.001
Climbing stairs (one flight)	23.3 (41) 1.7	33.8 (133) 4.1	0.015	13.6 (32) 2.1	17.9 (70) 0.8	0.200	0.016	<0.001
Running (100 m)	71.4 (105) 17.9	85.2 (265) 24.1	0.001	54.5 (115) 12.1	62.9 (193) 22.3	0.070	0.002	<0.001
Walking in the woods	37.4 (61) 8.9	63.9 (228) 12.9	<0.001	29.4 (67) 5.0	35.2 (132) 5.1	0.167	0.119	<0.001
Biking (2 km)	33.3 (45) 24.6	78.5 (193) 40.0	<0.001	16.9 (35) 13.8	36.7 (105) 27.6	<0.001	0.001	<0.001
Skiing (2 km)	41.2 (49) 33.5	78.7 (199) 38.3	<0.001	29.6 (58) 18.3	46.2 (116) 36.5	0.001	0.048	<0.001
Swimming (25 m)	32.3 (43) 25.7	63.5 (176) 32.4	<0.001	25.7 (53) 14.2	34.8 (101) 26.6	0.039	0.233	<0.001

common were improvements in the bathroom, and the installation of support handles.

During the past 12 months, about 90% of the subjects had used the services of a physician. Only a few men in the younger age group received home help (5%), while it was received most frequently by the women in the older age group (38%, $p<0.001$). About 4% of the subjects received home health care.

Two logistic regression models were constructed to reveal the relations between mobility difficulties and socioeconomic factors, defects in the dwelling and the use of home help. The variable "getting about outdoors" was chosen to represent mobility, because it is essential for independent living and correlated well with the other mobility variables. The effects of age group, length of education, chronic diseases and defects in the home environment on difficulties in getting about outdoors are presented in Table 2. The odds ratios show that short education and defects in the home environment increase the probability of difficulties in

Table 2 - *Logistic regression model for difficulties in getting about outdoors*.*

Variable	Odds Ratio	95% Confidence Interval
Age group (75-84-year olds *vs* 65-74-year olds)	2.39	1.77-3.24
Length of education (0-5 years *vs* 6 or more years)	1.56	1.15-2.12
Number of chronic diseases (2 or more *vs* 0-1)	3.62	2.65-4.95
Defects in the dwelling environment (yes *vs* no)	3.68	2.57-5.27

* Sex, marital status and income were not significant and are not shown in the Table.

getting about outdoors, after controlling for age, sex, marital status, income and health status.

In Table 3 we can see that difficulties in getting about outdoors increase the probability of using home help after controlling for age, sex, marital status, living alone, length of education, income, chronic diseases, and defects in the dwelling environment.

Among the men in both age groups, modifications in dwellings had not been made more frequently for subjects with difficulties in getting about outdoors than for the others. On the other hand, among the women in both age groups, modifications had been made more often in the dwellings of subjects who had difficulties in getting about outdoors.

DISCUSSION

The aim of this study was to investigate difficulties in mobility among older people, and their association with socioeconomic factors, dwelling environment, and use of services in a cross-sectional procedure. Associations were revealed by logistic regression models in which the background factors (age, sex, marital status) and health status were considered as confounding factors.

The subjects had slightly more difficulties in mobility than found in previous Nordic studies (12, 40). This was probably due to the design of the questions concerning the PADL-items in this study, which also revealed the initial stages of mobility problems (slowness and tiredness in performance were regarded as difficulties). In general, women and subjects in the older age group had more difficulties, as also found in previous studies (11-13). The results concerning the amount of reported difficulties in taking physical exercise (e.g., walking in the woods, skiing) merit attention. Surprisingly, many subjects even in the younger age group had difficulties with these tasks, and many did not even know whether they could perform them or not. Moreover, the extent of the difficulties reported is probably an underestimate. It can be presumed that many people who were unable to answer these questions had not practised the physical exercise activities studied for several years, with the consequent difficulties in carrying them out. Obviously, many elderly people gradually give up effective physical activities, even though they might be expected to have lots of time for such activities after retirement, and, as indicated by several studies (14, 41, 42), physical exercise would help them maintain mobility.

Another striking feature was the poor performance in the mobility tasks of the women in the older age group. It is known that gender differences emerge in the health of the elderly; for example, in the fact that men suffer more often from fatal diseases, and women from disabling diseases (43, 44). Men have higher mortality than women, while among women disability not only continues for a longer time, but also increases in severity (13, 45). The problematic situation of older women is emphasized by the frequency of becoming widowed, which means losing a close relationship, as well as diminished possibilities of receiving practical help in problems of every day living. An additional factor is the low level of income, the effects of which become more prominent when there are no other persons to bring money into the household (46). In addition, the women in the older age group had the most chronic diseases. On the other

Table 3 - *Logistic regression model for the use of home help*.*

Variable	Odds Ratio	95% Confidence Interval
Age group (75-84-year olds *vs* 65-74-year olds)	3.19	2.21-4.59
Living alone (yes *vs* no)	2.03	1.21-3.42
Number of chronic diseases (2 or more *vs* 0-1)	1.80	1.21-2.66
Difficulties in getting about outdoors (yes *vs* no)	3.12	2.14-4.55

*Sex, marital status, length of education, income and defects in the dwelling environment were not significant and are not shown in the Table.

hand, they most frequently received home help, and modifications to facilitate functioning had been made slightly more often in their residences than in those of the others. These compensatory means do not seem sufficient to reduce the differences; for example, defects in the home environment that make functioning difficult were still most frequently observed in the homes of the women in the older age group. Reschovsky and Newman (18) also established that unmet needs for modifications in dwellings were more likely to be found in older frail households with female heads.

Multivariate analysis disclosed that short education and defects in the home that make functioning difficult increase the probability of difficulties in getting about outdoors. Further, the difficulties in getting about outdoors increase the probability of using home help. These findings are similar to those of previous studies carried out elsewhere (7, 15, 18, 28, 47). The associations did not seem referable to poorer health or background factors like age, sex or marital status. This indicates that, despite underlying chronic diseases, intervention addressing at least some of the factors connected with mobility problems would be possible, and is essential in regard to prevention. The bivariate association of being female with difficulties in mobility was evident only in the older age group, while in the logistic regression model the influence of sex was obviously masked by the influence of age. The association between defects in the home environment and difficulties in getting about outdoors presumably cannot be understood as a causal relationship. On one hand, it is likely that difficulties in mobility become more explicit when the physical environment is more demanding, e.g., defects in the dwelling are present. On the other hand, defects in the dwelling may indicate the less advantaged situation of the subjects in the same way as certain other variables (low education, great number of chronic conditions). The mobility variables correlated strongly with each other, and the answers to them were consistent, which makes it understandable why defects that were mostly inside the dwellings were also associated with outdoor mobility. The significant association between difficulties in getting about outdoors and use of home help indicates that home help is directed meaningfully according to disabilities and not merely through health status or economic situation (income). The associations between difficulties in mobility and use of home help seems to be a neglected research area.

Only a minor number of the subjects had made modifications in their homes to facilitate functioning. Defects in dwellings were found more frequently than modifications in dwellings. The small amount of these modifications can be at least partially explained by the findings of Wister (31), who concluded that elderly people tend to adapt to these difficulties by psychological processes rather than by adjusting the physical or social characteristics of the dwelling environment.

When trying to ameliorate the disabilities of elderly people, secondary and tertiary prevention are essential starting points in addition to the primary prevention of diseases. If the situations preceding disabilities could be identified, it would be possible to target prevention to the groups most likely to benefit (48). For example, difficulties in mobility have been found to predict other future disabilities (49). It would be important that public health planners consider difficulties in mobility a sufficient reason for preventive actions. For example, physiotherapists have traditionally focused on the treatment of diseases, and not on the promotion of health (50). Moreover, prescribing physiotherapy is generally linked to the expected response of the disease to rehabilitation (51). Thus, a great number of people with mobility problems are left without preventive services, even though many of them would benefit considerably from them. Previous studies have shown encouraging results in improving the mobility and functional capacities of elderly people by means of physiotherapy (52, 53) or physical exercise (54, 55).

One goal of Finnish health policy has been to diminish health differentials between population groups in Finland by directing measures at those groups where problems and risks are the greatest (56). The longitudinal studies of Valkonen et al. (57) and Martelin (58) show that this strategy has not been successful; the differences between social groups in life expectancy and mortality have not diminished. The results of the present study on socioeconomic factors and mobility-disability point in the same direction. This fact should be taken into account when planning preventive strategies.

The results of this study indicate that older women in particular experience a great deal of difficulties in mobility. We should try to reduce these difficulties more actively, either by improving the physical abilities of elderly people or by developing compensation strategies for their own use or in regard to the environment, where appropriate, through the help of gerontechnology. For example, enhancing the possibilities for physical activity despite frailty and environmental restrictions (such as lack of transportation or stair lifts) would be challenging. Paying attention and, if possible, eliminating defects in and outside dwellings would facilitate mobility, and make it more secure.

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III

HEALTH STATUS AS PREDICTOR OF MOBILITY DECLINE AMONG OLDER PEOPLE: A FIVE-YEAR FOLLOW-UP

by

Sakari R, Rantanen T, Laukkanen P, Suutama T, Heikkinen E.

Submitted for publication

IV

ASSOCIATIONS OF SENSORY-MOTOR FACTORS WITH POOR MOBILITY IN 75- AND 80-YEAR-OLD PEOPLE

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ASSOCIATIONS OF SENSORY–MOTOR FUNCTIONS WITH POOR MOBILITY IN 75- AND 80-YEAR-OLD PEOPLE

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ABSTRACT. This study investigated the associations of sensory–motor functions with mobility in elderly people. All 75- and 80-year-old residents of the city of Jyväskylä, Finland, were invited to take part in the study. A total of 617 (93%) persons were interviewed, and 500 (75%) took part in laboratory examinations. Self-reported mobility was recorded during the interview. Basic mobility functions (maximal walking speed and stair-mounting ability) and sensory–motor functions (maximal isometric muscle strength, standing balance, reaction time and visual acuity) were measured in the laboratory. Multivariate analyses showed that poor sensory–motor functions were significantly associated with poor performance in basic mobility functions and that poor performance in basic mobility functions was associated with self-reported disability in mobility. The associations discovered were consistent with models of the disablement process. Muscle strength, balance, reaction time and vision all have individual significance for mobility, underlining the need for multifactorial approaches in prevention and rehabilitation.

Key words: disability; elderly; functional limitation; impairment; mobility; sensory–motor function.

INTRODUCTION

Mobility is determined and coordinated by musculoskeletal, cardiorespiratory, sensory and neural systems. For example, without sufficient knee extensor strength it is not possible to climb stairs (25, 35). The maintenance of postural stability is a crucial requirement in walking because the body is actually in a continual state of dynamic imbalance (22). During locomotion, vision is needed for monitoring and analysing the location and movement of the body as well as the environmental conditions to which the motor system should respond (18, 28). The ability to react quickly is needed for the avoidance of obstacles in the gait path (5).

The sensory–motor background factors of mobility are impaired by aging, chronic diseases and inactivity. The decline of mobility that typically follows with old age can be described with models of the disablement process (24, 32). Nagi (24) and Verbrugge & Jette (32) suggest that different kinds of *pathologies* cause different *impairments* at the organ system level (for example, dysfunctions and abnormalities in musculoskeletal and cardiovascular systems). These impairments usually lead to basic *functional limitations* (for example, restrictions in basic physical actions such as ambulation, reach, stoop), which often cause *disability* in everyday life (for example, difficulties in activities of daily living in the person's own living environment).

This cross-sectional study set out to investigate the associations of sensory–motor functions that are essential for locomotion, such as muscle strength, balance, reaction time and vision, with the mobility of elderly people. At the same time the purpose was to establish whether the associations uncovered are consistent with the assumed pathway of the disablement process. The model of the disablement process (24, 32) was modified to consider mobility and its sensory–motor background factors at the three last levels (impairments, functional limitations and disability). To date, only a few studies have analysed more than two consecutive levels of the model simultaneously (e.g. 14, 17), and none of these have focused exclusively on the mobility of elderly people.

METHODS

Subjects

This study is part of the EVERGREEN project, a major research programme focusing on the health and functional capacity of the elderly population of the city of Jyväskylä, central Finland (13). The study groups comprised all people born in 1910 and 1914. In 1989, 119 (95.2%) men and 236 (91.8%) women from the younger age group (75-year-olds) took part in interviews carried out in their homes. Of the invited and eligible persons, 104 (83.2%) men and 191 (74.3%) women came to laboratory examinations about 2 weeks later. In 80-year-old men and women in 1990, the corresponding figures were 74 (96.1%) and 188 (90.4%) for the interviews and 60 (77.9%) and 145 (69.7%) for the laboratory examinations. Poor health was one of the major reasons why some people were unable to participate in the laboratory examinations. A significantly greater proportion of those who could not attend the laboratory examinations needed help in their mobility ($p < 0.05$ in every subgroup). Although the majority of the participants lived in the community (only 9 lived in institutions), there was considerable variation among the subjects in terms of chronic morbidity. For example, the study population included persons with several chronic diseases (maximum 8) and those without any diagnosed disease.

Assessment procedures

The interview comprised issues on sociodemographic factors, Activities of Daily Living (ADL) and living conditions. In addition, the subjects completed a health questionnaire at home. The laboratory examinations included a medical examination, measurement of height and weight, performance tests of mobility, measurements of sensory and psychomotor functions and muscle strength tests.

Mobility index. The disability level in the disablement process (24, 32) was represented by a mobility index, which indicated how mobility problems were manifested in the subject's everyday life. The index was formed on the basis of the subject's self-reported ability to get about indoors and outdoors and to negotiate stairs. These questions were part of the ADL Scale (2). The subjects were asked whether they are able to do the task, whether they get tired when doing the task, whether the task takes more time than before and whether they need help (alternatives yes and no). The index consisted of three categories. The subjects who reported need of help in any of the three tasks were allocated to the first category, the subjects who reported slowness or tiredness in at least one task but no need of help to the second category, and those participants who were able to perform the tasks without difficulty to the third category. The inter-rater and intra-rater reliability of the original three questions has been evaluated and found to be high in a Danish sample (4).

In order to validate the mobility index, information about 5-year mortality was obtained from the register of the province of Central Finland. Self-rated health was asked in the health questionnaire (scaling: 1 = very good, 2 = good, 3 = satisfactory, 4 = poor, 5 = very poor) and the prevalence of chronic diseases (lasting more than 3 months) was obtained at the medical examination. In logistic regression, adjusted for age and sex, the probability of dying was seven times greater among those who reported need of help [odds ratio (OR) 7.07, confidence interval (CI) 3.21 – 15.62] and two times greater among those who reported slowness or tiredness (OR 1.97, CI 1.04–3.73) when compared to those who had no difficulties. Similarly, the OR for rating one's health poor was 6.94 in the "need of help" group (CI 1.99–24.17) and 4.39 in the "slowness/tiredness" group (CI 2.44–7.90). The OR for having three or more chronic diseases was 5.91 in the "need of help" group (CI 2.86–12.18) and 3.00 in the "slowness/tiredness" group (CI 1.83–4.91).

Basic mobility functions. The functional limitations level in the disablement process (24, 32) was interpreted as basic mobility functions at the whole body level, such as stair-mounting ability and maximal walking speed. In the stair-mounting test, the highest step that the subject could mount without support in a single step was recorded (step heights of 0, 10, 20, 30, 40, and 50 cm) (1,25). Because taller persons have greater leg length and thus more favourable working conditions for the lower extremity joints and muscles during stair-mounting, the result was adjusted for height. After dividing the original value by the subject's height, it was multiplied by the mean height of all participants. The new values were then reclassified as 0, 10, 20, 30, 40 and 50 cm, with cut points in the middle of the class intervals. The reclassified values were used in the multivariate models. Maximal walking speed over 10 metres was measured by a stopwatch in the laboratory corridor. Walking aids were allowed if the subject normally used them when walking. The corridor was illuminated by standard fluorescent lamps.

Sensory–motor functions. Sensory–motor functions were assumed to represent the impairments at body system level in the disablement process (24, 32). These functions do not indicate the impairments *per se,* but rather the functional consequences of impairments of separate organ systems. *Maximal isometric muscle strength* was measured for knee and trunk extensors by dynamometers (12). Knee extension strength was measured in a sitting position, knee fixed 60° from full extension, and trunk extension in a standing position. The strength/weight ratio was calculated and used in the analyses. *Standing balance* was measured by a computerized force platform system (8). The subject stood as still as possible on the platform for 40 seconds, feet comfortably apart and hands on hips, the first test with eyes open and the second with eyes closed. The speeds of antero-posterior and mediolateral movement of the centre of forces were used in the analyses, adjusted according to the subject's height. The balance variables in the final multivariate models differed according to the age group. *Simple reaction time* for visual stimuli was measured for the dominant hand (7). The subject was seated in front of the timing device, with the index finger on the rest button. After noticing the light, the subject moved the finger as quickly as possible from the rest button and switched the light off from a nearby button. *Visual acuity* with lens correction (if needed) was measured by a computerized refractometer (Topcon RMA2300). Because of technical problems, the reaction time and balance results could not be obtained for all subjects in the younger age group. However, this had no systematic effect on the results (8).

Statistical methods

The model of the disablement process (24, 32) guided the selection of the variables and the analytical methods. Cross-tabulation with χ^2 testing was used in bivariate analyses of discrete variables; Student's t-test was used in the case of continuous variables. Logistic regression was used for the validation study of the mobility index. Polychoric (between discrete variables), polyserial (between discrete and continuous variables) and Pearson's product moment correlation coefficients were calculated by PRELIS (29) (tables not shown). On the basis of these correlations, LISREL models (15) were created separately for each age and sex group. The sensory–motor variables indicated the independent variables (*x*-variables), and the mobility variables indicated the dependent variables (*y*-variables). Because of the skewness of the results in the stair-mounting test among men, the three lowest categories were combined. To achieve normally distributed values for further analyses, a few extreme cases were excluded from the balance and reaction time results (2 men and 9 women).

RESULTS

The mobility index indicated that there were some minor differences in self-reported mobility between age and sex groups (Table I). The women in the older age group needed help in their mobility functions more often than their counterparts in the younger age group ($p = 0.006$). Walking aids were used by 34 persons (12%) in the 75-year-olds and by 39 persons (23%) in the 80-year-olds.

About 6–9% of the participants were unable to mount even the 10 cm high step; their result was therefore zero (Table II). In men, a ceiling effect was evident and the distributions were skewed. About 75% of the 75-year-old men and about 60% of the 80-year-old men were able to mount the highest step. In women, the corresponding figures were 28% and 20%. The differences between men and women were statistically significant ($p < 0.001$). After adjusting the results according to the subject's height, the difference between the sexes was slightly reduced.

Table I. *Mobility index in 75- and 80-year-old men and women (the variables were: getting about indoors, getting about outdoors and negotiating stairs)*

	75-year-olds		80-year-olds	
Mobility	Men *n* (%)	Women *n* (%)	Men *n* (%)	Women *n* (%)
Needs help*	8 (8.0)	14 (7.6)	8 (16.7)	22 (18.3)
Slowly/tired†	55 (55.0)	121 (65.8)	26 (54.2)	78 (65.0)
Without difficulties‡	37 (37.0)	49 (26.6)	14 (29.2)	20 (16.7)
Total	100	184	48	120

* Needs help in at least one task;
† reported slowness or tiredness in at least one task;
‡ did not report slowness/tiredness/need of help in any task.

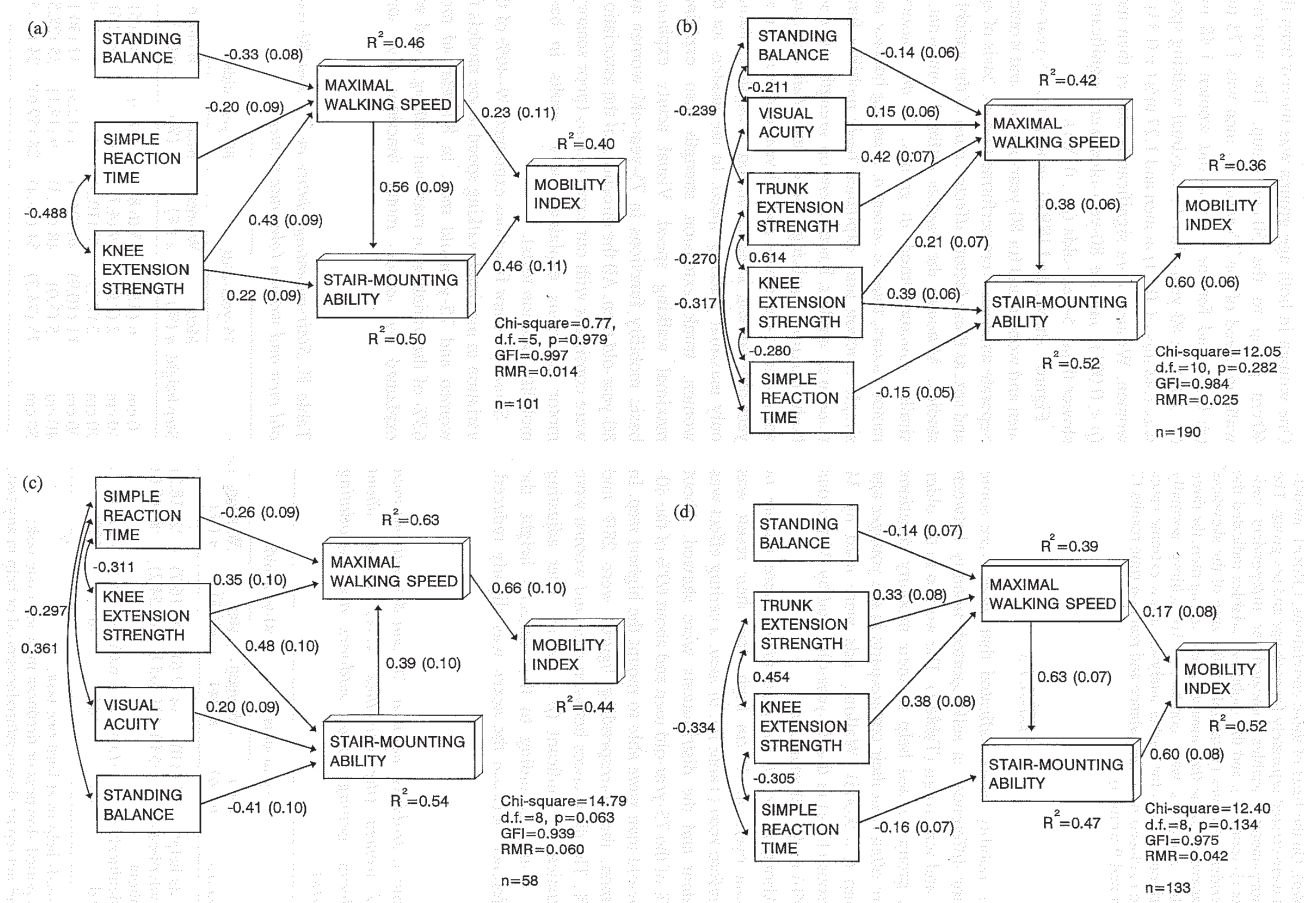
Six men born in 1914 and 2 men born in 1910 were reallocated from the 50 cm group to the 40 cm group. One woman in both age groups was moved from the 40 cm group to the 50 cm group. The maximal walking speed of the 75-year-old men was 1.78 m/s ($\pm$ 0.51) and for the 75-year-old women 1.48 m/s ($\pm$ 0.36). In 80-year-olds the maximal walking speed was 1.48 m/s ($\pm$ 0.54) in men and 1.27 m/s ($\pm$ 0.33) in women. Women were significantly slower than men ($p < 0.001$), and the 80-year-olds were significantly slower than 75-year-olds ($p < 0.001$).

Figure 1 shows the LISREL models for 75-year-old men and women and for 80-year-old men and women. Separate analyses were performed on the basis of age and sex, as these factors affected most of the variables studies. Although the models differed somewhat, a similar structure fitted all groups. Of the sensory–motor factors, muscle strength, standing balance and simple reaction time explained basic mobility functions in all models. Knee extension strength explained both maximal walking speed and stair-mounting ability in 75-year-olds and 80-year-old men. In 80-year-old women, knee extension strength explained only maximal walking speed. In the models for the women, trunk extension strength also explained maximal walking speed. Visual acuity explained basic mobility functions in 75-year-old women and 80-year-old men. All the directions of the associations were consistent with our expectations (poor sensory–motor functions explained poor results in basic mobility function tests).

Sensory–motor functions explained 39–46% of the variation in maximal walking speed in the models for women and 75-year-old men. In 80-year-old men, 63% of the variation in maximal walking speed was explained by sensory–motor functions and stair-

Table II. *Stair-mounting ability in 75- and 80-year-old men and women (absolute values)*

	75-year-olds		80-year-olds	
Step height	Men *n* (%)	Women *n* (%)	Men *n* (%)	Women *n* (%)
0 cm	6 (5.9)	13 (6.8)	4 (8.5)	8 (6.5)
10 cm	2 (2.0)	9 (4.7)	0	3 (2.4)
20 cm	2 (2.0)	20 (10.5)	0	16 (13.0)
30 cm	11 (10.9)	46 (24.2)	6 (12.8)	37 (30.1)
40 cm	5 (5.0)	48 (25.3)	9 (19.1)	35 (28.5)
50 cm	75 (74.3)	54 (28.4)	28 (59.6)	24 (19.5)



(a)
STANDING BALANCE
SIMPLE REACTION TIME
KNEE EXTENSION STRENGTH
-0.488
-0.33 (0.08)
-0.20 (0.09)
0.43 (0.09)
0.22 (0.09)
R^2=0.46
MAXIMAL WALKING SPEED
0.56 (0.09)
STAIR-MOUNTING ABILITY
R^2=0.50
0.23 (0.11)
0.46 (0.11)
R^2=0.40
MOBILITY INDEX
Chi-square=0.77,
d.f.=5, p=0.979
GFI=0.997
RMR=0.014
n=101
(b)
STANDING BALANCE
VISUAL ACUITY
TRUNK EXTENSION STRENGTH
KNEE EXTENSION STRENGTH
SIMPLE REACTION TIME
-0.211
-0.239
0.614
-0.270
-0.317
-0.280
-0.14 (0.06)
0.15 (0.06)
0.42 (0.07)
0.21 (0.07)
0.39 (0.06)
-0.15 (0.05)
R^2=0.42
MAXIMAL WALKING SPEED
0.38 (0.06)
STAIR-MOUNTING ABILITY
R^2=0.52
0.60 (0.06)
R^2=0.36
MOBILITY INDEX
Chi-square=12.05
d.f.=10, p=0.282
GFI=0.984
RMR=0.025
n=190
(c)
SIMPLE REACTION TIME
KNEE EXTENSION STRENGTH
VISUAL ACUITY
STANDING BALANCE
-0.311
-0.297
0.361
-0.26 (0.09)
0.35 (0.10)
0.48 (0.10)
0.20 (0.09)
-0.41 (0.10)
R^2=0.63
MAXIMAL WALKING SPEED
0.39 (0.10)
STAIR-MOUNTING ABILITY
R^2=0.54
0.66 (0.10)
MOBILITY INDEX
R^2=0.44
Chi-square=14.79
d.f.=8, p=0.063
GFI=0.939
RMR=0.060
n=58
(d)
STANDING BALANCE
TRUNK EXTENSION STRENGTH
KNEE EXTENSION STRENGTH
SIMPLE REACTION TIME
0.454
-0.334
-0.305
-0.14 (0.07)
0.33 (0.08)
0.38 (0.08)
-0.16 (0.07)
R^2=0.39
MAXIMAL WALKING SPEED
0.63 (0.07)
STAIR-MOUNTING ABILITY
R^2=0.47
0.17 (0.08)
0.60 (0.08)
MOBILITY INDEX
R^2=0.52
Chi-square=12.40
d.f.=8, p=0.134
GFI=0.975
RMR=0.042
n=133

mounting ability. In the models for women and 75-year-old men, sensory–motor functions and maximal walking speed explained 47–52% of the variation in stair-mounting ability. In 80-year-old men, sensory–motor functions explained 54% of the variation in stair-mounting ability.

Basic mobility functions were associated with the mobility index in all models. Stair-mounting ability and maximal walking speed correlated strongly with each other, which was probably the reason that the effects of these variables on the mobility index were mediated through one or the other in 75-year-old women and 80-year-old men. The direction of the associations was as expected: poor stair-mounting ability and slow walking speed explained the poor result in the mobility index. Of the variation in the mobility index, 36–52% was explained in the models. In addition, maximal walking speed had a significant indirect effect on the mobility index (not shown in Fig. 1): in 75-year-old men the coefficient was 0.26 and the standard error 0.07, in 75-year-old women 0.23 and 0.04 and in 80-year-old women 0.38 and 0.07, respectively. In 80-year-old men, stair-mounting ability had a significant indirect effect on the mobility index (coefficient 0.26, standard error 0.08). According to the χ^2 tests as well as other fit measures, all the models fitted well to the data.

DISCUSSION

The results of this study indicate that sensory–motor impairments are significantly associated with basic functional limitations and, further, that basic functional limitations are significantly associated with poor mobility in 75- and 80-year-old men and women. The associations discovered are consistent with our framework, which was modified from the model of the disablement process (24, 32). This was ascertained by multivariate analyses, which showed similar structures across age and sex groups. However, given the limitations of the cross-sectional research design, the results must be interpreted with caution. Further studies applying longitudinal procedures are needed.

The rates of participation in both the interviews and the laboratory examinations were very high, which makes the generalizability of the results exceptionally good. However, the subjects with the highest level of impairment were unable to take part in every phase of the study, which is common in mobility studies that include performance tests.

The explanative strength of the models was good. However, there was still some unexplained variation which may be due, among other things, to our failure to capture in the framework used all the possible impairments caused by aging processes, inactivity and chronic conditions. For example, no evaluations were made of pain or range of motion in the joints of the lower extremities.

The mobility index used in this study indicated roughly the same level of disability in mobility as have previous, comparable population studies (3, 30). The results for stair-mounting ability and maximal walking speed correspond to previous results for persons of approximately the same age (3, 10). These performance tests have been found to correlate with poor self-reported mobility (3, 11), as was the case in the present study.

Poor knee extension strength was a strong determinant of poor mobility in this study. Similar results have been obtained in previous studies concerning both walking speed (20, 27) and stair-mounting ability (25, 27). When climbing stairs, the climber has to place the foot onto the elevated surface of the stair and bring the centre of mass over the new base of support (16). In our analyses, the contribution of anthropometric properties in this task was taken into account by adjusting stair-mounting ability for height and muscle strength for body mass. Among women in this study, the strength of trunk extensors also explained maximal walking speed in the models. It is obvious that control of the movements of the upper body (head, arms and trunk) during the stride cycle

Fig. 1. The sensory–motor determinants of mobility functions by LISREL models in (a) 75-year-old men, (b) 75-year-old women, (c) 80-year-old men and (d) 80-year-old women. The straight arrows indicate significant associations and their directions between variables. The coefficients and their standard errors (in brackets) are shown. In reaction time and balance variables higher values mean poorer performance, which causes negative coefficients. The curved arrows represent significant correlations between independent variables. The R^2 values indicate the amount of variation in the dependent variables explained by the background factors in the model. GFI = goodness of fit index, RMR = root mean square residual. In (a) and (b), standing balance is the speed of antero-posterior movement of the centre of forces, eyes closed. In (c) and (d), standing balance is the speed of antero-posterior movement of the centre of forces, eyes open.

requires significant involvement of the trunk musculature.

Previous researchers have found mainly moderate but significant associations between standing balance measured by force platform and mobility in elderly people (19, 23), although there are some exceptions (10). In the present study, the associations of standing balance with stair-climbing capacity (in 80-year-old men) and maximal walking speed (in women and in 75-year-old men) were significant. The slower walking speed in old age results from shorter stride length and longer duration of the double support phase (9). These changes in the gait pattern seem to be caused by poorer balancing abilities and reduced muscle strength (34).

Simple reaction time, which requires relatively low-level central nervous system processing, has been found to be an important determinant of postural balance (7, 21). In this study, both standing balance and simple reaction time remained in the models as significant determinants of mobility functions. Similarly, Lord et al. (20) found that simple reaction time was associated with walking speed in multivariate analyses.

Visual acuity significantly explained mobility functions in 75-year-old women and in 80-year-old men. Similar results have been reported previously (20, 26). The importance of visual acuity during walking is readily apparent. For instance, in the middle of the swing phase of the stride cycle the toes are not raised more than about 1 cm off the ground (33). Thus, even minor ruggedness of the terrain needs to be seen properly to prevent stumbling.

The results of this study indicate that both stair-mounting ability and maximal walking speed are important dimensions behind mobility problems in everyday life. The measurement of these functions helps to identify persons with mobility problems, even in an early stage (11). The assessment of sensory–motor background factors gives an insight into the probable effectors and modifiers of mobility problems and, consequently, provides valuable clues for planning treatment.

The levels of most sensory–motor and basic mobility functions differ between age and sex groups, which was why the analyses were carried out separately in each group. In spite of these basic differences, the roles of the background factors were very similar among the groups and essentially the same structure could be seen in all models. This suggests that both in elderly men and women the same factors should be examined when attempting to identify people at risk and prevent the deterioration of mobility.

It has been shown in two recent studies (6, 20) that age-related dysfunctions in mobility are associated with impairments in multiple physiological domains. As Vandervoort et al. (31) state, this multifactorial nature of mobility dysfunction in the elderly population requires comprehensive assessment and treatment approaches. The results of the present study suggest that the sensory–motor functions studied have individual importance for mobility and that they do not compensate each other. This means that not only muscle strength but also other aspects such as balance, reaction time and vision should be taken into account when planning and implementing interventions which aim to improve mobility. Many of these factors are modifiable by physical exercise or other means of prevention and rehabilitation.

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MOBILITY PERFORMANCE AND ITS SENSORY, PSYCHOMOTOR AND MUSCULOSKELETAL DETERMINANTS FROM AGE 75 TO AGE 80

by

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Mobility performance and its sensory, psychomotor and musculoskeletal determinants from age 75 to age 80

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ABSTRACT. ***Background and aims:*** *Prospective studies on the simultaneous effects of multiple determinants on objectively assessed mobility are few. The aim of this study was to analyse mobility performance, its stability and sensory, psychomotor and musculoskeletal determinants in an older population from age 75 to age 80.* ***Methods:*** *Sixty-three men and 121 women aged 75 participated at baseline and, five years later, in the follow-up phase of this population-based prospective study. Maximal walking speed and step-mounting height were assessed at baseline and follow-up. Maximal isometric knee extension strength, standing balance on force platform, reaction time, visual acuity and limitations in range of motion (ROM) of hips and knees were assessed at baseline. Structural equation modeling was used to analyse the associations.* ***Results:*** *The stability of mobility performance from baseline to the five-year follow-up was high (coefficient 0.80 in men, 0.78 in women). In men, knee extension strength, standing balance, ROM limitations and visual acuity explained 69% of the variation in mobility performance at baseline and, indirectly, 59% of that variation at follow-up. Among women, knee extension strength, standing balance, visual acuity and reaction time explained 52% of the variation of mobility performance at baseline and, indirectly, 30% at the five-year follow-up.* ***Conclusions:*** *Results indicate that the predictive effects of sensory, psychomotor and musculoskeletal functions on mobility performance extend over five years in older people. In seeking to prevent mobility limitations, vision, reaction time and lower extremity ROM need to be targeted, in addition to muscle strength and balance.*
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INTRODUCTION

Moving about in different environments requires, among other things, proper functioning of the sensory, central nervous and musculoskeletal systems. In old age, mobility often declines: for example, walking speed becomes slower (1) and difficulties begin to show in stair-climbing (2, 3).

The main muscle groups responsible for horizontal movement of the body in walking are the ankle plantar flexors; vertical stabilization of the body is mainly achieved by the knee extensors (4). However, in stair-climbing, the knee extensors generate most of the energy for vertical movement of the body (5). Difficulties in controlling balance result in changes in gait pattern, as the individual seeks to reduce the forces causing imbalance, which goal is also probably served by a reduction in the motions of the lower extremity joints (6). In old age, the range-of-motion (ROM) limitations of the joints in the lower extremities may approach the critical ROM levels that are required for normal walking or stair-climbing (5, 7). Vision is needed, especially for proactive balance control of locomotion, as it provides information about the environment and the motion and velocity of the body (8). The slowing of reaction times in old age (2) further challenges balance control. The supply of energy by oxidative mechanisms is essential to sustain the activity level required for locomotion (9). On average, in old age cardiorespiratory fitness declines to thresholds that may slow down mobility and limit daily activities (10).

Cross-sectional studies have shown that sensory, psychomotor and musculoskeletal impairments correlate with poor mobility in older people. According to multivariate analyses, weak muscle strength in the lower extremities (11-13), poor postural balance (11, 14, 15),

Key words: Aging, balance, mobility, muscle strength, prospective study, visual acuity.

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deficits in visual functions (12, 13, 16), slow reaction times (12, 13, 17, 18) and limited ROM in the lower extremities (12, 19) individually explain poor walking ability and other mobility performance. However, according to multivariate analyses by Hughes et al. (20), postural balance and ankle ROM are not significantly associated with walking speed and other mobility functions, whereas the isometric strength of lower extremities remains significant in regression models.

Only a few prospective analyses on the contributions of sensory and motor functions to naturally occurring changes in mobility performance have been published. It has been shown that weak quadriceps strength and joint impairments in the lower extremities explain the decline in walking speed over 2 and 4 years (1). Poor standing balance on a force platform was associated with a decline in a timed car transfer task over 2.5 years, but not with walking speed or stair-climbing time (14). Both knee extension strength and a clinical balance test predicted the onset of severe walking disability over 3 years in the study by Rantanen et al. (21), in which walking disability was defined as slow walking speed or inability to walk at least 400 m. Deterioration in visual acuity and hearing has been shown to predict deterioration in a combined measurement of gait and balance performance over 8-10 years (22), although in another study visual acuity did not explain the change in walking speed over 5 years (23).

In our earlier, baseline analysis of the present study, we found that, among 75-year-old men and women, poor muscle strength, standing balance, reaction time and visual acuity explained poor results in walking speed and stair-mounting ability and also self-reported mobility limitations (24). The aim of this study was to analyse the stability of mobility performance over five years among men and women aged 75 at baseline and to clarify how sensory, psychomotor and musculoskeletal functions measured at baseline predict mobility performance five years later, at the age of 80.

METHODS

Material

This study was part of the Evergreen project, the focus of which is on the health and functional capacity of the older population in the city of Jyväskylä, Finland (25). At baseline, all men and women born in 1914 (aged 75) were invited to participate in interviews, medical examinations and laboratory tests, which were repeated five years later. The subjects' personal data were elicited from the population register. In total, 293 persons (76.7% of the eligible population) participated in measurements of mobility performance at baseline (190 women, 103 men). Five years later, 121 women (63.7%) and 63 men (61.2%) participated in the follow-up mobility tests. During the follow-up period, 30 women and 20 men had died. The numbers of other drop-outs was 39 women and 20 men. The reasons for non-participation among survivors were very much the same as at baseline, i.e., poor health, lack of interest, and being too busy to participate. The measurement methods have been described in detail earlier (2, 26). The project was approved by the ethical committee of the University of Jyväskylä, Finland. Participants gave their informed consent in writing on entering the research laboratory.

Measurement of mobility performance

The mobility tests were carried out among subjects who entered the laboratory and were able to walk without personal assistance. *Maximal walking speed* over 10 m was measured in the laboratory corridor using a stopwatch (27). An additional two meters was allowed both for acceleration and deceleration. In the *step-mounting test*, the maximum height that subjects could mount unsupported with a single step was measured using 5 boxes of dimensions 60 cm (length) x 60 cm (width) x 10 cm (height) (27). Subjects were allowed to use either leg. The results were scored from 0 cm to 50 cm.

Measurement of sensory, psychomotor and musculoskeletal functions

Maximal isometric knee extension strength was measured in a dynamometer chair with the knee of the dominant hand side at 60° flexion. The extension force applied against the ankle strap was measured by a strain gauge and adjusted to body mass (N/kg). The best of three trials was recorded as the result. *Standing balance* was measured on a force platform as the speed of the antero-posterior sway (movement of the center of forces, mm/s). Subjects were instructed to stand as still as possible during the measurement (40 seconds), feet comfortably apart (26). Sway was measured both with eyes open and with eyes closed. Higher speed indicated poorer balance. *Simple reaction time* for visual stimuli was measured in the dominant hand. Reaction time was the time from the onset of the light stimulus to the moment when the subject released the waiting button in order to switch the light off by pressing the adjacent button. Of 12 trials, the average of the last 5 successful trials was recorded as the result (ms). *Visual acuity* was measured with the illuminated Landolt ring chart (Oculus 4512). The best result for either eye with or without eyeglasses was recorded (range 0.125-2.0). The *range of motion (ROM)* limitations in hips and knees was assessed as part of a routine medical examination, without any equipment. With the subject lying supine, the physician assessed the passive ROM of hip flexion, inner and outer rotation, and knee flexion and extension. The number of clearly detectable limitations (about 20°, except in knee extension where the limitation criterion was less, about 10°) was recorded (range 0-10, higher score indicating more limitations). For technical reasons, balance, reaction time and visual acuity results were not obtained for all subjects, although this had no systematic effect on the results (26). According to *t*-tests, there were no significant differences between those who had a result in each test and those who had not. The proportions of missing data were 26% for visual acuity, 28% for balance, and 57% for reaction time.

Statistical analyses

The baseline missing data were handled with imputation using the EM algorithm (SPSS 15.0), and the procedure was acceptable according to Little's MCAR test, which showed that the values were missing completely at random (28). Gender differences in mobility variables and baseline characteristics were analysed by *t*-test. Baseline differences between those who participated at follow-up and those who had died were analysed with the *t*-test.

Structural equation models were constructed by LISREL 8.72 (e.g., 29). Structural equation modeling was chosen, as it makes possible complex structures between dependent and independent variables and the use of several dependent variables in the same model. In addition, confirmatory factor analysis can be used as part of structural equation modeling to build up latent variables that combine the information of several observed variables. In the present study, it was hypothesized that the combination of walking speed and step-mounting ability represents mobility performance better than either of them alone. Thus, two latent mobility performance variables (dependent variables) were constructed, one from the observed variables walking speed and step-mounting ability at baseline, and the other from the same variables at follow-up. First, the loading structures and stability of these dependent variables were analysed. The reliability of the loading structures was estimated with the reliability coefficients of observed variables in relation to latent variables. To analyse the stability of mobility performance over five years, the effect of the baseline latent variable on the follow-up latent variable was estimated. Next, recursive path models were constructed which included the above-mentioned models of mobility performance factors and baseline sensory, psychomotor and musculoskeletal functions as independent variables. As the latter had higher correlations with mobility variables at baseline than at follow-up, it was hypothesized that the determinants would have direct effects on baseline mobility and only indirect effects on mobility at follow-up. The models were based on sample covariance matrices.

RESULTS

Walking speed declined in about the same proportions between men and women during the 5-year period (Table 1). The decline in the step-mounting test was small among men, as more than 70% were able to climb the highest step at both baseline and follow-up. The baseline results for the sensory, psychomotor and musculoskeletal tests are shown in Table 1. The comparison between survivors and those who had died in five years showed that, among men, survivors had better results in walking speed (p=0.013), standing balance (eyes open, p=0.017) and visual acuity (p=0.045) and, among women, in walking speed (p<0.001), step-mounting ability (p=0.007), knee extension strength (p=0.006) and standing balance (eyes closed, p=0.046).

Table 1 - *Characteristics of 75-year-old men and women at baseline.*[*] *Means and standard deviations (in brackets) or, in case of physical activity, numbers (and proportions).*

	Men (n=63)	**Women (n=121)**	***p*-value**[†]
Background factors			
Years of education	6.1 (3.0)	6.1 (3.4)	0.893
Number of chronic diseases	2.0 (1.3)	2.2 (1.6)	0.453
Body Mass Index	25.9 (3.4)	27.7 (4.0)	0.003
At least moderate physical activity	49 (77.8%)	100 (83.3%)	0.359
Mobility performance			
Walking speed (m/s):			
Baseline	1.89 (0.46)	1.56 (0.29)	<0.001
Follow-up	1.57 (0.49)	1.28 (0.35)	<0.001
Step-mounting height (cm):			
Baseline	44.6 (12.0)	37.0 (13.1)	<0.001
Follow-up	43.8 (12.2)	31.5 (13.1)	<0.001
Sensory, psychomotor and musculoskeletal functions at baseline			
Knee extension strength (N/kg)	5.2 (1.3)	3.8 (1.0)	<0.001
Standing balance[‡], eyes open (mm/s)	23.5 (6.0)	21.8 (4.7)	0.038
Standing balance[‡], eyes closed (mm/s)	33.5 (7.2)	28.8 (5.8)	<0.001
Simple reaction time (ms)	343 (107)	367 (67)	0.104
Visual acuity (Landolt rings)	0.64 (0.28)	0.52 (0.24)	0.003
Number of ROM[§] limitations in hips or knees	1.1 (1.9)	1.3 (1.9)	0.561

[*]Imputed values: because of data missing at random, baseline values of those who survived and participated in mobility measurements at follow-up were imputed. [†]Difference between men and women. [‡]Speed of movement of center of forces in antero-posterior direction. [§]ROM=Range of Motion.

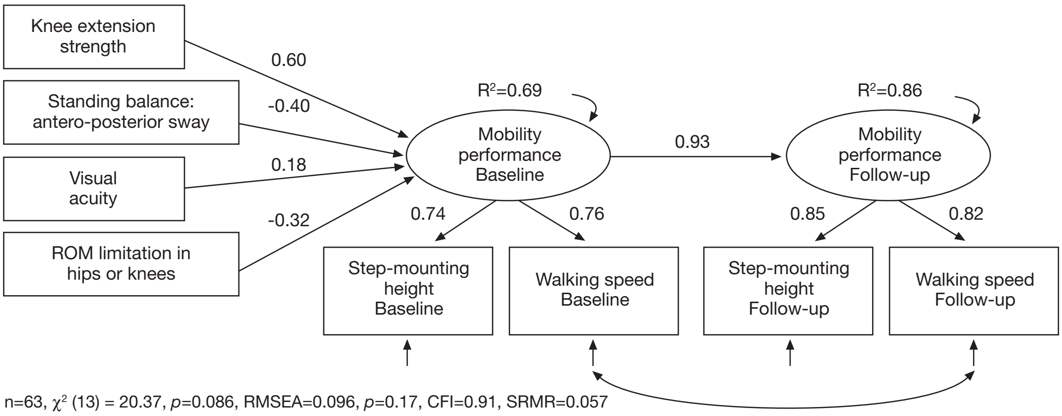

Fig. 1 - *Mobility performance at baseline and five-year follow-up, and its sensory, psychomotor and musculoskeletal determinants among men aged 75 at baseline in LISREL model (completely standardized solution). Standing balance= speed of antero-posterior movement of center of forces, eyes open; ROM= Range of motion. Model fit indices: RMSEA= Root mean square error of approximation; CFI= Comparative fit index; SRMR= Standardized root mean square residual. Loose arrows indicate residuals or measurement errors.*

All LISREL models were constructed separately for men and women. First, the stability of mobility was analysed with the latent variables mobility performance at baseline and at follow-up, which were constructed from the observed variables walking speed and step-mounting ability. According to goodness-of-fit statistics, both men's and women's models fitted the data well. The coefficient of stability between mobility performance measured at baseline and at follow-up was 0.80 for men and 0.78 for women. The reliability of observed variables in relation to latent variables was good, the reliability coefficients ranging from 0.48 to 0.68 among men and 0.55 to 0.96 among women.

Second, the sensory, psychomotor and musculoskeletal determinants were included in the models to analyse their effects on mobility performance over five years. The models fitted the data well (goodness-of-fit tests shown in Figs. 1 and 2). Among men, maximal isometric

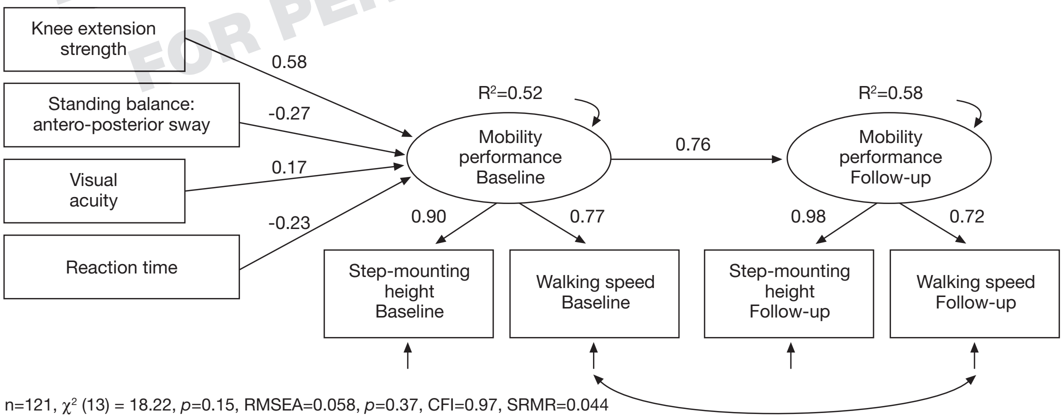

Fig. 2 - *Mobility performance at baseline and five-year follow-up and its sensory, psychomotor and musculoskeletal determinants among women aged 75 at baseline in LISREL model (completely standardized solution). Standing balance= speed of antero-posterior movement of center of forces, eyes open. Model fit indices: RMSEA= Root mean square error of approximation; CFI= Comparative fit index; SRMR= Standardized root mean square residual. Loose arrows indicate residuals or measurement errors.*

knee extension strength, standing balance, visual acuity, and the number of ROM limitations in hips and knees significantly explained mobility performance at baseline (R^2 0.69, Fig. 1). In addition, mobility performance at baseline explained 86% of the variation in mobility performance at follow-up (R^2=0.86). To evaluate how much of the mobility performance at follow-up was explained by sensory, psychomotor and musculoskeletal variables, their indirect effects through baseline mobility performance were estimated. Each of the variables had significant indirect effects on mobility performance at follow-up, the highest standardized coefficient being for knee extension strength (0.56), followed by standing balance (-0.37), ROM limitations (-0.30) and visual acuity (0.17) (negative signs due to different direction of scaling). Sensory, psychomotor and musculoskeletal variables indirectly explained altogether 59% of the variation in mobility performance at follow-up (data not shown).

Among women, the model with knee extension strength, standing balance, visual acuity and reaction time explained 52% of the variation in mobility performance at baseline (R^2=0.52, Fig. 2). Mobility performance at baseline explained 58% of the variance in follow-up mobility performance. In addition, knee extension strength, standing balance, visual acuity and reaction time indirectly explained 30% of the variation in mobility performance at follow-up, indicating effects beyond baseline mobility performance. The standardized coefficients of the statistically significant indirect effects were 0.44, -0.20, 0.13 and -0.18, respectively (negative signs due to different direction of scaling; data not shown).

DISCUSSION

In this longitudinal study, sensory, psychomotor and musculoskeletal functions explained a large amount of the variation in mobility performance at baseline, and their influence was still high five years later, as they explained 30% (among women) and 59% (among men) of the variation in mobility performance at follow-up. In addition, considerable decline was seen in mobility performance over the five-year period, although stability between baseline and follow-up was high. Poor muscle strength of knee extensors was the most important determinant of mobility and its decline.

Poor muscle strength and balance, limited ROM of the joints of lower extremities and poor visual acuity predicted poor mobility performance, as has been found in earlier studies with follow-up times ranging from 2 to 10 years (1, 21, 22). However, in earlier studies, the models included at most two of the above-mentioned functions. A new finding in the present study was that reaction time had an individual predictive value on mobility performance over 5 years in women.

In an earlier cross-sectional study within the same project (24), almost the same determinants as in the current analyses explained mobility in 75- and 80-year-old persons. The importance of knee extension strength in relation to mobility performance has also been emphasized in other cross-sectional, multivariate analyses, in which knee strength remained significant (12, 13, 18). The same applies to balance (15, 17, 18) as well as to coimpairments in strength and balance (11). The association between visual acuity and mobility found in the present study is in line with the results of an earlier, cross-sectional study, in which visual acuity explained the result of a step test (12). In several studies, other aspects in vision than visual acuity have been important for mobility performance, such as contrast sensitivity (13, 15, 18) and visual field (16). The significance of the lower extremity ROM limitations for mobility performance over five years found in the present study is also supported by earlier cross-sectional studies (12, 19), in which the models included strength and also other sensorimotor functions. The association between reaction time and poor mobility performance found in the present study is in line with several cross-sectional studies (12, 13, 15, 17).

Over a period of five years, old people generally undergo many events affecting their health and functioning. From a clinical point of view, it is noteworthy that the predictability of mobility functions and their decline may remain high for several years, as was found in the present study. The stability of the mobility measurements during follow-up indicates that the typically observed decline in mobility probably affects most older persons to a similar extent.

Structural equation modeling was a good choice for the analyses, as it enabled simultaneous analyses on the stability of mobility performance over five years as well as on the associations between mobility performance and its determinants. In addition, it was possible to analyse the indirect effects of these determinants on follow-up mobility performance, beyond the effects of mobility performance at baseline. The determinants represented separate aspects and, in the models, each of them had individual effect on mobility performance. The LISREL models for men and women showed minor differences, but their structure was essentially the same. Gender differences in physical performance (2) do not seem fundamentally to affect the structure of the longitudinal associations between mobility performance and its determinants, although the combination of the separate determinants may vary. Use of the imputation technique made it possible to preserve important characteristics of the whole data for more accurate estimates (28), in spite of random missing values in baseline data. There were no essential differences in the results when additional analyses were carried out without imputation (data not shown).

Many important factors from the point of view of mobility performance were not analysed in the present study. For example, chronic conditions and level of physical activity were not included in the models, as their effects were expected to be mediated through the sensory, psychomotor and musculoskeletal functions. Also, the small sample size somewhat limited the number of variables included in the models. Instead, measuring the strength and ROM of ankles would have been valuable, as has been shown in earlier studies (4, 12). However, knee extension strength is easy to measure reliably and may adequately represent overall leg strength, as the knee extensors are the largest muscle group in the lower extremity (30). The measurement of ROM limitations was a rough estimate and more accurate methods would be preferable. However, it is noteworthy that this quick method, which is easy to administer clinically as part of any medical examination, gave valuable information about the state of lower extremity joints relative to mobility. Aerobic capacity has also been shown to be associated with short-term mobility performance (31) but, unfortunately, feasible information about our subjects' aerobic capacity was not available.

The present results may be generalized to older, quite well-functioning persons, as the tests required independent mobility at both baseline and at five years follow-up. Comparison of baseline results between those who had died and those who participated in the five-year follow-up showed better functioning among survivors in some of the measured variables, which was expected, as poor functioning is related to poor health and is associated with mortality. The number of other drop-outs was also high, and was at least partially due to poor health. Earlier studies have shown that attrition may not always cause serious bias if the study focuses on the associations between variables and not on descriptive analyses, e.g., prevalence of disability (32). However, in a shorter follow-up time, the associations might have been even stronger than in the present study, as there would have been more persons left from the lower end of the continuum of functioning, leading to higher correlations as well as a larger sample size.

Earlier prospective studies did not include sensory, psychomotor and musculoskeletal functions simultaneously when analysing the contributors to decline in mobility performance. It seems that older people use individual compensation and adaptation strategies for age- and pathology-related decline in sensory, cognitive and motor processes (33). The interaction of separate sensory and motor functions determines the observable output of mobility performance which, consequently, does not linearly reflect the function of any single body system. This variety of possible contributors to mobility needs to be taken into account when planning preventive and rehabilitative strategies. For example, people with poor vision or inappropriate eyeglasses will probably continue to walk slowly in order to maintain balance until their visual problems are corrected. Limited ankle dorsiflexion may also prevent the taking of longer steps (34) and thus prevent the increase of walking speed, despite any increase in muscle strength or balance achieved by an exercise program.

CONCLUSIONS

The stability of mobility performance was high over 5 years, which indicates that, among the majority of the 75-year-old persons studied here, the decline in mobility may be predictable and follow a consistent pattern, at least up to the age of 80. Several sensory, psychomotor and musculoskeletal functions contribute simultaneously to mobility performance in older people, and their predictive effects seem to extend over five years. In seeking to prevent mobility limitations, vision, reaction time and lower extremity ROM need to be targeted, in addition to muscle strength and balance.

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