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Predictive Value of Health-Related Fitness Tests on Mobility Difficulties in High-Functioning Older Adults

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ACADEMIC DISSERTATION
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To my parents

Contents

List of original publications

The dissertation is based on the following original articles, which are referred to in the text by their Roman numerals:

I Hämäläinen P, Suni J, Pasanen M, Malmberg J, Miilunpalo S (2006): Changes in physical performance among high-functioning older adults: a 6-year follow-up study. European Journal of Ageing 3:3-14.

II Husu P, Suni J, Pasanen M, Miilunpalo S (2008): Does physical activity affect the predictive value of health-related fitness tests on walking difficulty? Journal of Physical Activity and Health, in press.

III Hämäläinen HP, Suni JH, Pasanen ME, Malmberg JJ, Miilunpalo SI (2006): Predictive value of health-related fitness tests for self-reported mobility difficulties among high-functioning elderly men and women. Aging Clinical and Experimental Research 18:218-226.

IV Husu P, Suni J, Pasanen M, Miilunpalo S (2007): Health-related fitness tests as predictors of difficulties in long-distance walking among high-functioning older adults. Aging Clinical and Experimental Research 19:444-450.

Abbreviations

ADL	Activities of daily living
AUC	Area under the curve
BMI	Body mass index
CI	Confidence interval
EVTK	Health Behaviour and Health among Finnish Elderly Study
HR	Hazard ratio
HRF	Health-related fitness
IADL	Instrumental activities of daily living
ICF	International classification of functioning, disability and health
ICIDH	International classification of impairments, disabilities and handicaps
OR	Odds ratio
PA	Physical activity
PAR-Q	Physical activity readiness questionnaire
ROC	Receiver operating characteristics
RR	Relative risk
SCD	Stair climbing difficulty
VO_2max	Maximal oxygen uptake
WD	Walking difficulty
WHO	World Health Organization

Abstract

The purpose of this prospective study was to analyze the value of health-related fitness (HRF) tests in predicting the occurrence of mobility difficulties among high-functioning older adults. In addition, the study described six-year changes in HRF test performance and associations between test performance and physical activity. The safety and feasibility of the tests were also considered.

The study was based on the Kainuu Study on Living Habits and Health, which is a longitudinal cohort study conducted by the UKK Institute for Health Promotion Research. The study started as a postal questionnaire survey in 1980. In 1996 and 2002 the assessment of HRF targeted at persons aged 55 years and older was included into the study. The sample of the present study consisted of 55 to 79-year-old men and women who participated in the assessment of HRF in 1996. The assessment included seven field-based tests that were considered to represent the most important fitness factors for mobility function. Balance was assessed by one-leg stand and backwards walk, functional muscle strength of the lower extremities by one-leg squat, trunk extensor muscle strength by dynamic back extension, flexibility by trunk side-bending and walking ability by 6.1-m walking speed and 1-km walking time. Additionally, body mass index was used as a relative indicator of body composition. Mobility difficulties and participants' level of physical activity were assessed by self-reported questionnaires. Participants were regarded as having mobility difficulties if they reported at least some difficulties in walking 2 km or climbing several flights of stairs without a rest.

During six-year follow-up the study sample was selected to younger, healthier and physically more active individuals who performed the baseline HRF assessment better than those who were lost to follow-up. Over six years performance in HRF tests deteriorated, especially among the older age groups and among women. Deteriorations were greatest in the 6.1-m walk, backwards walk and trunk side-bending tests.

Poor performance in the HRF tests, non-vigorous physical activity and overweight in terms of high body mass index were all independent predictors of new mobility difficulties. The least active people with the poorest HRF test

performance or with overweight had the highest risk of mobility difficulties. Backwards walk, dynamic back extension, one-leg squat and 1-km walk were the most powerful predictors. Optimal cut-off values predicting mobility difficulties were successfully identified for these tests.

The results suggest that the proposed HRF tests are valid, safe and feasible tools to assess mobility function among high-functioning older adults. The tests can be used to identify those at increased risk of declining mobility. The test results can also be utilized in physical activity counseling in order to target activity at those components of fitness that are not adequate for good mobility.

Tiivistelmä

Tämän seurantatutkimuksen tarkoituksena oli selvittää, miten itsenäisesti liikkumaan kykeneville ikääntyville henkilöille suunnatut terveyskuntotestit ennustavat itse ilmoitettujen liikkumisvaikeuksien ilmaantumista kuuden vuoden aikana. Lisäksi tutkimuksessa selvitettiin seurannan aikana terveyskuntotestituloksissa tapahtuneita muutoksia sekä kunnon ja liikunta-aktiivisuuden välisiä yhteyksiä. Huomiota kiinnitettiin myös testien turvallisuuteen ja soveltuvuuteen.

Tutkimuksen aineisto on osa Kainuun Elintavat ja Terveys -tutkimusta, joka on UKK-instituutin toteuttama kohorttitutkimus Kajaanin, Sotkamon ja Suomussalmen kuntien alueella. Tutkimus alkoi postikyselynä vuonna 1980, ja vuosina 1996 ja 2002 siihen sisältyi myös 55 vuotta täyttäneiden henkilöiden terveyskunnon arviointi. Tämän tutkimuksen aineisto muodostui 55–79-vuotiaista henkilöistä, jotka osallistuivat ensimmäisiin terveyskuntomittauksiin vuonna 1996. Testit valittiin siten, että ne arvioivat liikkumiskyvyn kannalta keskeisimpiä kuntotekijöitä. Tasapainoa arvioitiin yhden jalan seisonta- ja takaperinkävelytesteillä, alaraajojen toiminnallista lihasvoimaa askelkyykkistystestillä, vartalon lihasvoimaa vartalon ojentajalihasten dynaamisella toistotestillä, liikkuvuutta selän sivutaivutuksella ja kävelykykyä 6,1 metrin kävelynopeudella sekä yhden kilometrin kävelyajalla. Kehon koostumus arvioitiin painoindeksin avulla. Tutkimushenkilöiden liikunta-aktiivisuutta ja liikkumisvaikeuksien ilmaantumista selvitettiin kyselyn avulla. Henkilöillä katsottiin olevan liikkumisvaikeuksia, mikäli he ilmoittivat vähintään jonkin verran vaikeuksia kahden kilometrin kävelyssä tai useamman kerrosvälin porrasnousussa levähtämättä.

Kuuden seurantavuoden aikana tutkimusjoukkoon valikoituivat nuoremmat, terveemmät ja liikunnallisesti aktiivisemmat henkilöt. Myös terveyskuntotesteistä suoriutuminen oli yhteydessä valikoitumiseen: alkumittauksissa paremmin suoriutuneet henkilöt osallistuivat seurantamittauksiin todennäköisemmin kuin alkutilanteessa huonommin suoriutuneet. Seurantajakson aikana erityisesti vanhimpien tutkimushenkilöiden ja naisten testisuoritukset heikentyivät alkutilanteeseen verrattuna. Eniten

suoriutuminen heikentyi 6,1 metrin kävelynopeudessa, takaperin kävelyssä ja selän sivutaivutustestissä.

Huono kunto, vähäinen liikunta-aktiivisuus ja ylipaino ennustivat toisistaan riippumatta liikkumisvaikeuksien ilmaantumista. Liikkumisvaikeuksien ilmaantumisen riski oli suurin vähän liikkuvilla henkilöillä, joiden alkutilanteen testisuoritus kuului huonoimpaan kolmannekseen tai jotka olivat ylipainoisia. Uusia liikkumisvaikeuksia parhaiten ennustavat testit olivat takaperin kävely, vartalon ojentajalihasten dynaaminen toistotesti, askelkyykistys ja yhden kilometrin kävely: mitä huonompi testitulos oli, sitä suurempi oli liikkumisvaikeuksien ilmaantumisen riski. Näille testeille pystyttiin määrittämään myös kynnysarvot, joita huonompi testitulos lisäsi merkittävästi liikkumisvaikeuksien riskiä.

Tulosten perusteella voidaan todeta, että ikääntyville suunnatut terveyskuntotestit ovat turvallinen, soveltuva ja pätevä menetelmä liikkumisvaikeuksien riskin arviointiin. Testejä voidaan käyttää tunnistamaan sellaisia ikääntyviä henkilöitä, joiden liikkumiskyky on vaarassa heikentyä. Niitä voidaan hyödyntää myös liikuntaneuvonnassa ja yksilöllisen liikuntaharjoittelun suunnittelussa. Harjoittelu tulisi kohdistaa erityisesti niihin kunnon osa-alueisiin, joita edustavat testisuoritukset ovat kynnysarvoja heikompia.

1. Introduction

According to population projections the proportion of older adults will increase dramatically in the coming decades. Statistics Finland (2007) predicts that the proportion of those aged 65 years or older will increase from 17% to 27% between 2007 and 2040. Increasing age is associated with impaired physical functioning and dependence, although there is evidence that older adults have better health status and mobility function today than a couple of decades ago.

Mobility function is an essential part of functional independence. Deterioration in mobility is the first identifiable indicator of further decline in physical functioning. Many older adults function close to their maximum ability level during normal activities of daily living. Any further decline or setback may drive them below the threshold that is needed for functional independence. Loss of independence in later life is costly both in terms of money spent on medical care and impaired quality of life. (Rikli and Jones 1997.) The National public health program of Finland has emphasized the importance of physical functioning and functional independence among the aging population (Ministry of Social Affairs and Health 2001), and target levels for the quality of guided health-enhancing physical activity (PA) for older people have been defined (Ministry of Social Affairs and Health 2004). Physical functioning has also received increasing attention internationally. The European Union has made efforts to improve the monitoring of physical functioning, fitness and PA among aging populations (ALPHA, EUNAAPA[1]) and the World Health Organization (WHO) has provided policy frameworks to promote active aging (WHO 2002).

Age-related decline in physical functioning and mobility is only partly due to the aging process as such. Studies have reported that both intensity and variability of PA tend to decrease with increasing age. Rikli and Jones (1997) suggested that besides health problems and diseases inactivity may also be an

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[1] *ALPHA: Instruments for Assessing Levels of Physical Activity and Fitness, European Commission*
EUNAAPA: European Network for Action on Ageing and Physical Activity, European Commission

important cause of dysfunction among older people. PA is a modifiable and self-dependent factor, and several randomized controlled trials have indicated that PA, especially strength training, is beneficial for physical functioning among older persons (e.g. Fiatarone et al. 1994, Latham et al. 2004).

There is evidence that a substantial part of age-related decline in functioning can be postponed through early detection. In recent decades studies have presented several methods to assess physical performance and functioning among older adults. Both self-reported (e.g. Rosow and Breslau 1966, Nagi 1976, Branch and Meyers 1987, Fried et al. 1991, Avlund et al. 1993) and performance-based assessments (e.g. Berg et al. 1989, Guralnik et al. 1994a, Guralnik et al. 1994b, Cress et al. 1996, Simonsick et al. 2001a, Lan et al. 2002, Pohjola 2006) have been developed, and many of them have been aimed at the early detection of functional deterioration. However, only few assessment tools have been targeted at high-functioning older adults with no mobility difficulties, and even fewer have been validated for mobility function with both cross-sectional and longitudinal studies. The present study aimed at analyzing prospective associations between fitness, PA and mobility difficulties among high-functioning older adults. The target of the study was to provide validated and practical assessment tools to identify individuals with early signs of increased risk of mobility difficulties.

2. Review of the literature

2.1 Mobility function in older adults

2.1.1 Conceptual models of functioning

Physical functioning is a prerequisite for independent life, health and well-being and it can be described in several terms, e.g. functional status, functional capacity and functional ability. Regardless of the term used, deteriorations in physical functioning precede functional disabilities and dependence. Thus, disability is a negative aspect of functioning referring to a person's inability or limitations in performing social roles and activities (Nagi 1965, Nagi 1976). Disability can be seen as the gap between a person's abilities and environmental demands (Nagi 1976, Verbrugge and Jette 1994). Basic self-care activities, commonly called activities of daily living (ADL) (Katz et al. 1963), are the most frequently assessed indicators of disability.

The mobility function can be seen as one stage of physical functioning. It covers an area of functioning higher than ADL (Avlund et al. 1998) and refers to a person's ability to move around in his/her environment (Tinetti 1986). Mobility is fundamental to overall functioning and independence (Avlund et al. 1998), and it forms the basis for the ability to perform more specific activities (Avlund et al. 2001), like the instrumental activities of daily living (IADL) (Lawton and Brody 1969, Hoeymans et al. 1996).

Many older adults, often due to their sedentary lifestyles, function close to their maximum performance level while performing ADL. Any further decline might easily cause additional limitations leading to disability and dependency. Physical disability in later life is costly both in terms of impaired quality of life and money spent on medical care. Detecting and treating physical impairments (declines in muscle strength, endurance, motor control etc.) as early as possible is a critical step in preventing or delaying functional deterioration. (Rikli and Jones 1997.) At this early stage, interventions may be less costly, less intensive and more effective (Brach et al. 2002), and they can include more intensive exercises.

Several conceptual models describing the progression of functional decline have been proposed. The first versions of conceptual models of functioning were presented by Nagi (1965, 1976, 1991). *The disablement process* described progression from pathology to disability through impairment and functional limitation. Impairments were defined as anatomical and/or physiological abnormalities and losses. Functional limitation referred to limitations in basic physical and mental actions on level of the whole person that impaired his/her ability to perform the tasks and obligations of his/her usual roles and normal daily activities. The degree of limitation was not dependent only on the type of impairment but also on the nature and requirements of social roles and activities. (Nagi 1965, Nagi 1976, Nagi 1991.)

Verbrugge and Jette (1994) presented an *extended model of the disablement process* (Figure 1) that described how chronic and acute conditions affect functioning in specific body systems, fundamental physical and mental actions and daily activities. Functional limitation referred to generic, situation-free features of functioning, while disability was a situational feature referring to experienced difficulty in doing activities in the domains of life that are typical for one's peer-group. New aspects in the disablement process presented by Verbrugge and Jette (1994) were predisposing risk factors, such as demographic, social, lifestyle, behavioral, psychological, environmental and biological characteristics that may affect the presence and severity of impairments, limitations and disability. In addition, the authors presented intra-individual factors (including lifestyle and behavioral changes, psychological attributes, coping and activity accommodations) and extra-individual factors (such as medical care, rehabilitation, medications, other therapeutic regimens, external supports and built physical and social environment) that may either speed up or slow down the disablement process.

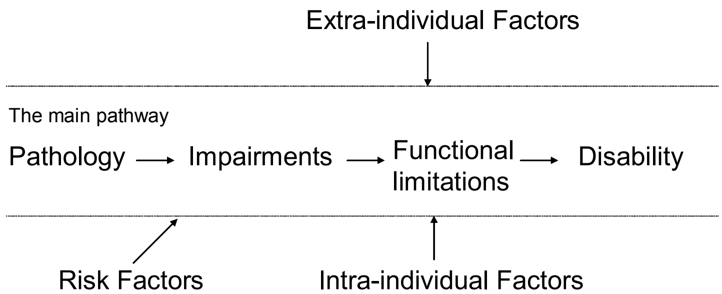


Figure 1. A model of the disablement process (Verbrugge and Jette 1994).

In 1980 the WHO presented the first version of the *International Classification of Impairments, Disabilities and Handicaps (ICIDH)* that was much like the disablement process presented by Nagi (WHO 1980). Twenty years later the WHO presented a revised version of the ICIDH model, ICIDH-2, the latest version of which, entitled *International Classification of Functioning, Disability and Health (ICF)* was presented in 2001 (WHO 2001) (Figure 2). The final model provided a multi-perspective approach to the classification of functioning and disability as an interactive and evolutionary process between body functions and structures, activities, participation, health conditions and both environmental and personal components. Interactions between these entities are specific and not predictable one-to-one relations. The interactions may work in both directions and interventions targeted at one entity may modify one or more of the other entities. (WHO 2001.)

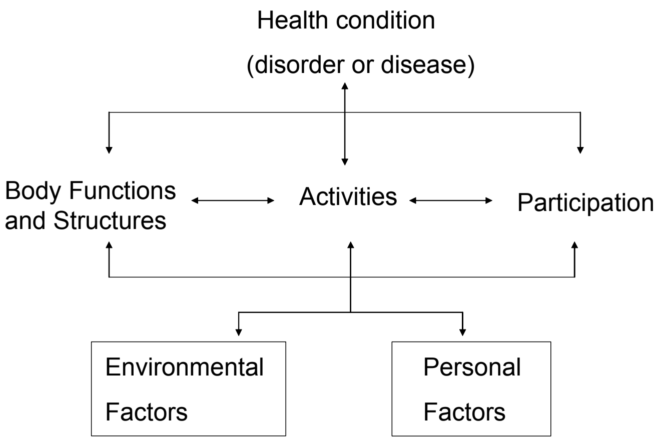


Figure 2. International Classification of Functioning, Disability and Health, ICF (WHO 2001).

Fried et al. (1991) presented the concept of *preclinical disability* that referred to an intermediate functional stage in which impairments may have an impact on general functioning without having a task-specific effect that an individual would recognize as a disability. Preclinical disability diminishes or alters function prior to obvious disability. There is evidence that in the early stages of functional decline, some individuals are able to compensate for underlying disease and maintain their function without a perception of difficulty. These individuals may change the method, speed or frequency of performance either consciously or unconsciously. Use of compensatory strategies may minimize the impact of impairment and prevent it from causing clinical disability. (Fried et al.

1991.) Self-reported tiredness in daily activities has also been used as an indication of preclinical disability (Avlund et al. 1993).

Traditional conceptual models of functioning presented by Nagi (1965, 1976, 1991), Verbrugge and Jette (1994) and WHO (1980) are disease-specific and concentrate on the development of functional disabilities. According to Rikli and Jones (1997) not only pathology, but also physically inactive lifestyle can be a primary cause of dysfunction. They suggested that physical inactivity (disuse) and pathology each have independent and interrelated effects on the processes leading to disability. (Rikli and Jones 1997.)

Based on the disablement process Rikli and Jones (1997) developed a *Functional performance framework* indicating progressive relationships between physiological performance, functional performance and activity goals (Figure 3). To be able to perform everyday activities a person needs the ability to perform functional movements (functions) and these movements in turn are dependent on having sufficient physiological reserve (physical parameters) (Rikli and Jones 1997, Rikli and Jones 1999a, Rikli and Jones 2001, Rikli and Jones 2002).

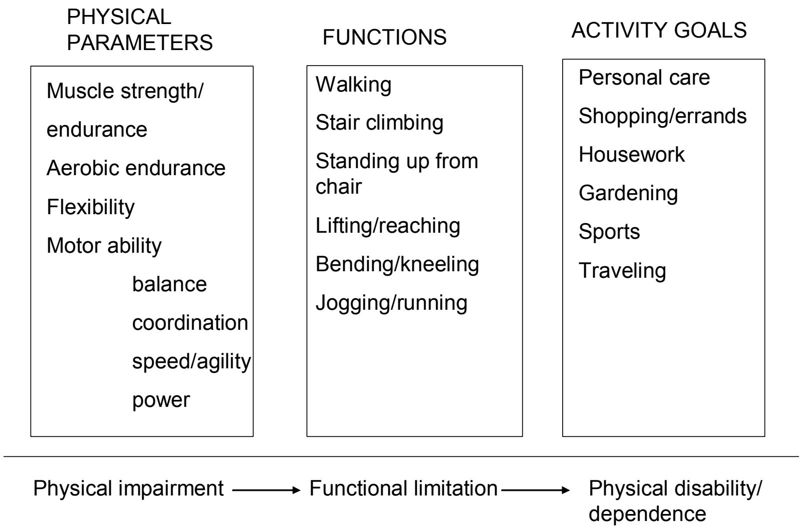


Figure 3. A Functional performance framework (Rikli and Jones 1997).

Fitness represents a higher level of functional hierarchy than physical functioning. Most definitions of physical and/or physiological fitness view it as a multifactorial construct including several components (Caspersen et al. 1985), although there is no agreement upon definitions. Fitness can be divided into performance and *health-related fitness (HRF)*. Performance-related fitness refers to an individual’s abilities needed for optimal work and sports performance. The concept of HRF is relatively new. It refers to those fitness components that are related to health status and that can be affected by PA (Bouchard and Shephard 1994). In line with the definition of functional fitness (Rikli and Jones 1999a) HRF has been defined as a state characterized by an ability to perform daily activities with vigor and demonstration of traits and capacities associated with a low risk of premature development of hypokinetic diseases and conditions. The five main components of HRF are morphological, muscular, motor, cardiorespiratory and metabolic fitness, and each component includes several factors (Table 1). HRF is best understood in terms of those components that should be taken into consideration when operationalizing the concept, and when talking about fitness assessments. (Bouchard and Shephard 1994.) The construct of HRF is based on current scientific evidence, and it is continually developing.

Table 1. Components and factors of health-related fitness (Bouchard and Shephard 1994).

Components	Factors
Morphological	Body mass for height Body composition Subcutaneuous fat distribution Abdominal visceral fat Bone density Flexibility
Muscular	Power Strength Endurance
Motor	Agility Balance Coordination Speed of movement
Cardiorespiratory	Submaximal exercise capacity Maximal aerobic power Heart functions Lung functions Blood pressure
Metabolic	Glucose tolerance Insulin sensitivity Lipid and lipoprotein metabolism Substrate oxidation characteristics

The Toronto model on PA, fitness and health specifies the relationships between activity, fitness and health from HRF point of view (Figure 4) (Bouchard et al. 1990, Bouchard and Shephard 1994). PA can influence fitness, which in turn may modify the level of activity. Fitness is also related to health in a reciprocal manner: fitness can influence health and health status may influence both PA and fitness levels. The relationships between the three main components of the model are modified by other life-style behaviors, physical and social environments, personal attributes and genetic characteristics. (Bouchard and Shephard 1994.)

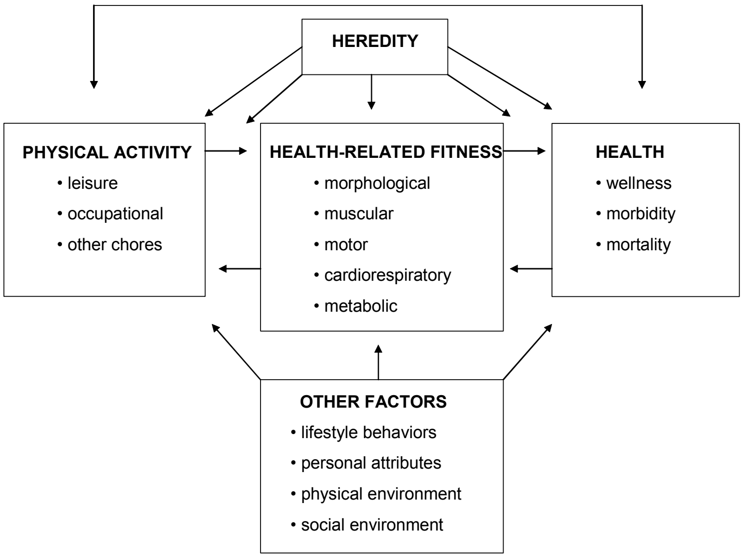


Figure 4. Toronto model on physical activity, fitness and health (Bouchard and Shephard 1994).

In the Toronto model PA and health are broadly defined. PA refers to any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure over the basal level. It covers all daily physical activities, including occupational activities, household chores, transportation, leisure time activities and exercise that can be characterized by type, mode, frequency, duration, intensity and purpose of activity. (Bouchard et al. 1990.) In recent years the terms *health-enhancing physical activity* or *health-related physical activity* have been used when the health effects of PA are emphasized (Fogelholm et al. 2005).

Health is defined as a human condition that includes physical, social and psychological dimensions. Each of these dimensions is characterized on a continuum with positive and negative poles. Positive health refers to the capacity to enjoy life and withstand challenges; it is more than the absence of disease. Negative health in turn refers to morbidity and, in the extreme, premature mortality. (Bouchard et al. 1990, Bouchard and Shephard 1994.)

The framework of the present study combines elements of the Functional Performance Framework and ICF to the Toronto model (Figure 5). HRF, as an indicator of impairment stage, is seen as a prerequisite for mobility function that indicates the stage of functional limitation. Mobility is neither purely a component of fitness nor a pure indicator of health. It covers the functioning of the fitness components on the whole body level and forms a prerequisite for functional independence and health. Poor HRF is seen both as a risk factor for functional limitation and disability and as an outcome of physical inactivity (disuse). PA is seen as a modifying factor that can affect both the etiology and manifestation of disability and health status. Regarding the ICF framework, HRF factors of the present study represent the entity of body functions and structures. Mobility, especially self-reported walking, can be located in the entity of activities and PA can be categorized into the participation-entity.

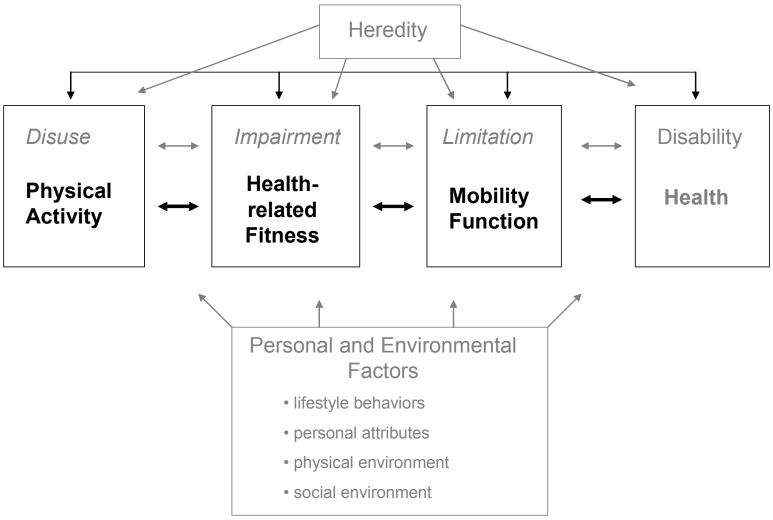


Figure 5. Framework of the present study. Words in bold face indicate the main aspects of the study.

2.1.2 Aging, mobility function and fitness

Functional decline and dependency are pronounced especially in the oldest members of populations. In recent decades the proportion of older adults has increased dramatically in Western societies. The life expectancy of the Finnish population has increased gradually since the 1960s. For example, the life expectancy of a 60-year-old man increased by 6.2 years from 1966 to 2006. Women outlive men and in recent decades the life expectancy of older women has increased even more than that of men. Between 1966 and 2006, the life expectancy of a 60-year-old woman increased by 7.2 years. According to population projections from 2007 to 2040 both the number and proportion of older adults will increase markedly. For example, the proportion of people aged 65 years or older is expected to rise from the present 16.5% to 27.0% by 2040.

(Statistics Finland 2007.) With the increasing number and proportion of older people, physical functioning and changes in functioning have become important research issues.

There is irrefutable evidence that physical functioning (Hoeymans et al. 1996, Rikli and Jones 1999b, Leveille et al. 2000, Forrest et al. 2006) and recovery from disability deteriorates (Leveille et al. 2000) with increasing age. Earlier studies have identified a hierarchical pattern in the progression of physical disability among older adults. Disability starts with difficulties in IADL and mobility function, and culminates in ADL problems (Guralnik et al. 1995, Hoeymans et al. 1996, Weiss et al. 2007).

A nationally representative Finnish survey, the Health 2000 Survey, indicated that older adults report gradually more mobility-related difficulties and disability than younger adults (Koskinen et al. 2004). The percentage of subjects who perceived no difficulties in walking half a kilometer decreased from 96% among 45 to 54-year-olds to 92% among 55 to 64-year-olds, and further to 79% among 65 to 74-year-olds and to 53% among 75 to 84-year-olds. The corresponding percentages of those who were able to climb one flight of stairs without difficulties decreased from 97% to 90%, 80% and 56% respectively, and the ability to carry a 5 kg shopping bag for 100 meters decreased from 93% to 85%, 74% and 45%. (Koskinen et al. 2004.)

According to the Health Behaviour and Health among Finnish Elderly (EVTK) Study 88% of 65 to 69-year-olds were able to use stairs without difficulties in 2005. The proportion decreased with age being 83% among 70 to 74-year-olds, 74% among 75 to 79-year-olds and 59% among the 80 to 84-year-olds. Self-reported ability to walk outside and carry heavy things decreased with age as well. Among 65 to 69-year-olds 94% were able to walk outside without difficulty. The corresponding percentages among the older age groups were 90%, 82% and 67% respectively. Regarding carrying the respective percentages were 88%, 78%, 67% and 49%. (Sulander et al. 2006.) In both the Health 2000 Survey and the EVTK Study functional deficits were more pronounced among aging women compared to men, especially in the older age groups (Koskinen et al. 2004, Sulander et al. 2006).

A regionally more restricted population study, Ikihyvä Päijät-Häme, showed corresponding trends, although neither the formulations of the questions nor the age groups were exactly the same in these three studies. In the Ikihyvä Päijät-Häme Study the proportion of subjects reporting that health status did not restrict their ability to walk half a kilometer decreased from 90% among 52 to 56-year-olds to 80% among 62 to 66-year-olds and to 59% among 72 to 76-year-olds.

The corresponding percentages of those who did not report any restrictions in ability to walk two kilometers decreased from 82% to 66% and 44%, in ability to climb one flight of stairs from 90% to 77% and to 62% and in ability to climb several flights of stairs from 72% to 48% and to 30% respectively. (Valve et al. 2003.)

These phenomena are partly due to decreased PA among older adults (see 2.1.3) and partly due to physiological changes associated with the normal aging process. There is a loss of size, number or both of functional units within every system of the body with increasing age. The functions of those units that remain also deteriorate. As a result aging can be characterized by a decreased ability to adapt to and recover from physiological displacing stimuli. (Skinner 2005.)

Longitudinal studies with varying follow-up periods (from three to 25 years) have reported age-related decline in muscle strength (Aniansson et al. 1983, Bassey and Harries 1993, Winegard et al. 1996, Metter et al. 1997, Rantanen et al. 1997, Bassey 1998, Hughes et al. 2001) and muscle power (Metter et al. 1997). Aniansson et al. (1983) reported a decline in strength especially in the lower extremities and slightly more in isokinetic measurements than in isometric measurements. Studies have shown that strength decline may vary in different muscle groups (Winegard et al. 1996, Rantanen et al. 1997) and strength plateaus may exist (Rantanen et al. 1997). Muscle power (velocity x force) has been reported to decline with age to a greater extent than muscle strength, especially among men (Metter et al. 1997), and power has been reported to be more strongly associated with physical functioning than muscle strength (Bean et al. 2002, Bean et al. 2003).

There is contradictory evidence regarding gender differences in age-related deterioration of muscle parameters. Bassey and Harries (1993) and Rantanen et al. (1997) reported that loss of muscle strength measured as a percentage of the baseline strength is more pronounced among older women than among older men. Hughes et al. (2001) in turn found that proportional strength decline is equal among both genders, but absolute decline is greater among men. They also reported that among men muscle strength deteriorates equally in the lower and upper extremities, but among women the strength of lower extremities deteriorates more than that of the upper extremities.

Age-related loss of muscle mass, strength and power together with changes in nervous system and motor units have substantial effects on the mobility and physical functioning of older adults. Many everyday activities are dependent on the level of muscle strength, power and motor abilities. Hortobagyi et al. (2003) reported that many older adults need their maximal capabilities in performing

ADL. Poor muscle strength and balance have been found to form a coimpairment that increases the risk of mobility problems (Rantanen et al. 1999a, Rantanen et al. 2001). Good muscle strength in midlife may provide a reserve capacity above the threshold of disability. With increasing age this reserve capacity can serve as a safety margin that helps to prevent functional limitations and disability from developing. (Rantanen et al. 1999b.)

Cartilage, tendons and ligaments become stiffer with increasing age (Skinner 2005). As a result, flexibility and range of motion in different joints seem to deteriorate. However, there is only limited longitudinal information about age-related changes in flexibility. Bassey (1998) reported only little or no change in shoulder range of motion during 8-year follow-up, whereas Winegard et al. (1996) reported increased passive tension in ankle dorsi and plantarflexors and declined passive range of motion in dorsiflexor direction during 12-year follow-up. According to Skinner (2005) the loss of flexibility is more pronounced in those areas of the body that are not used regularly. This indicates that both disuse and aging affect flexibility, but more research with longitudinal study designs is warranted.

Age-related changes also affect the cardiovascular and respiratory systems. At the same submaximal power output aging person is characterized by higher ventilation, higher blood pressure, greater arteriovenous oxygen difference, higher blood lactic acid concentration and greater oxygen debt than a younger person. In addition, an aging person has lower stroke volume and lower rate of adaptation to and recovery from exercise than a younger counterpart. These aging effects are most evident at maximal levels of exercise. Maximal oxygen uptake (VO_2max) and maximum heart rate decrease with increasing age leading to relatively more strenuous exercise tasks. (Skinner 2005.) According to Paterson et al. (2004) low cardiorespiratory fitness seems to be a significant determinant of becoming dependent among older adults.

Body composition also seems to change with advancing age. The amount of muscle mass tends to decrease while body fat increases. Bone mass also decreases, especially among older women. (Skinner 2005.) Longitudinal studies have shown systematic decline in body height with advancing age (Winegard et al. 1996, Suominen 1997). For body weight a slight age-related decrease has been reported (Winegard et al. 1996, Bassey 1998), especially among women (Suominen 1997).

Despite the previously described age-related deterioration in fitness factors and parameters of physical performance, on population level the mobility function of older adults has improved in recent decades. Malmberg et al. (2002a) reported a declining trend in mobility difficulties with succeeding birth cohorts during 16-year (1980-96) follow-up. According to the Health 2000 Survey the proportion of middle-aged and elderly people without mobility difficulties was higher in 2000 than in the Mini-Finland Health Survey in 1978-80 (Aromaa and Koskinen 2004). The EVTK Study showed a corresponding trend from 1993 to 2005 (Sulander et al. 2006). The Evergreen project among 65 to 69-year-olds also indicated that self-reported functional capacity, especially in strenuous mobility tasks, improved between the years 1988, 1996 and 2004 (Leinonen et al. 2006). These studies indicate that older adults in Finland have better physical functioning and mobility today than similar aged adults a couple of decades ago.

2.1.3 Aging and physical activity

The previously presented age-related physiological changes are very similar to the changes associated with physical inactivity. In many cases age-related changes in functioning are reversible with activity (Bean et al. 2004). There is strong scientific evidence that PA can promote health and physical functioning throughout life, even among the oldest (e.g. Mazzeo et al. 1998, Spirduso and Cronin 2001, Bean et al. 2004, Nelson et al. 2007) and mobility-impaired people (Hirvensalo et al. 2000). Sedentary lifestyle in turn increases the risk of mobility difficulties and functional disabilities (Visser et al. 2005a, Malmberg et al. 2006).

Trainability is well maintained with increasing age. The training effect is more dependent on the intensity of exercise than age and other individual characteristics (Mazzeo et al. 1998). Randomized controlled trials have shown that exercise, especially resistance training, is effective in improving muscle strength, physical performance and functioning among older adults (e.g. Fiatarone et al. 1994, Latham et al. 2004). According to the latest recommendations (Nelson et al. 2007) PA should be one of the highest priorities for preventing and treating disease and disablement among older adults. The recommended activity should include moderate-intensity aerobic activity for at least 30 minutes on five days each week or vigorous-intensity activity at least 20 minutes on three days each week. In addition, muscle strengthening activities at least twice a week, activities maintaining or improving flexibility on at least two days each week for at least 10 minutes each day, and activities maintaining or improving balance are recommended for older adults. (Nelson et al. 2007.)

According to the Health 2000 Survey, the proportion of those reporting health-enhancing PA (activity causing at least some breathlessness and perspiration at least 4 times/week, at least 30 min/time) increased from 20% among 45 to 54-year-old men to 34% among 55 to 64-year-old men and to 43% among 65 to 74-year-old men. The corresponding percentages among women were 27%, 30% and 38%. In the very old ages (85+) the proportion of health-enhancing PA decreased in both genders (to 24% among men and 15% among women). (Uutela 2004.)

In the Ikihyvä Päijät-Häme Study 19% of men aged 52 to 56 years reported leisure-time PA causing breathlessness and perspiration, lasting at least 30 minutes at time, at least four times per week. Among the 62 to 66-year-old men the percentage was 33 and among 72 to 76-year-olds 34%. The corresponding percentages among women were 26%, 42% and 33%. (Valve et al. 2003.)

The EVTK Study separated walking from other forms of PA. Among the 65 to 69-year-old men 67% reported walking outdoors and 27% reported other PA at least half an hour at a time at least four times a week. Among the older age groups the corresponding percentages were 65% and 27% (70 to 74-year-olds), 66% and 25% (75 to 79-year-olds) and 55% and 25% (80 to 84-year-olds). Women showed a corresponding trend. Among the 65 to 69-year-olds 66% reported walking outdoors and 30% reported other PA. In the other age groups percentages were 61% and 26% (70 to 74-year-olds), 63% and 23% (75 to 79-year-olds) and 52% and 22% (80 to 84-year-olds). (Sulander et al. 2006.)

Pohjolainen et al. (1997) reported that intensity of PA among Finnish older adults increased and attitudes towards activity became more positive from 1972 to 1992. The Evergreen project also indicated that both frequency and intensity of PA among 65 to 69-year-olds increased from 1988 to 1996 and 2004 (Hirvensalo et al. 2006). Variability of activity types seemed to increase with succeeding birth cohorts. Fitness exercises increased their popularity, and particularly women adopted new activity types. The most popular types of physical exercise among elderly people were walking and calisthenics. (Pohjolainen et al. 1997, Hirvensalo et al. 2006.)

Finnish adults, like Swedish adults, seem to be physically more active than adults in other European Union countries. The lowest percentage of any leisure-time PA has been reported in Portugal. The percentage of Europeans reporting any leisure-time PA has been shown to decrease slightly with age, being 72% among 45 to 54-year-olds, 70% among 55 to 64-year-olds and 65% among 65-year-olds and older individuals. (Martinez-Gonzalez et al. 2001.) An American study showed that although 40% of the population was regularly active, less than 10% was active at a level thought to promote or maintain cardiorespiratory fitness. Most of the population (60%) was physically inactive or irregularly active. (Caspersen and Merritt 1995.) Comparison of activity rates across studies is difficult since the types of measurement and activity scoring protocols vary.

2.2 Assessment of mobility and health-related fitness

Assessment tools for physical functioning were originally developed to assess functions that are necessary for independent living in home and community settings. The first assessments were conducted through self or proxy-reports (Guralnik et al. 1989), but later more physically oriented methods have been developed, especially in order to assess higher levels of functioning, mobility and fitness.

2.2.1 Self-report measurements of mobility function

Traditional self-report measures of physical functioning were developed to assess the physical capabilities of older people in long-term care and rehabilitation settings (Katz et al. 1963, Mahoney and Barthel 1965, Lawton and Brody 1969). Branch and Meyers (1987) listed a summary of functional assessment scales and indices. Many of these measures were originally designed for professional use in order to assess physical functioning among elderly patients. Originally measures focused on inability, need for assistance or difficulty in performing a variety of functions. They were not designed to distinguish the entire range of function. Later various modes and applications of these measures have been developed and they have been applied in survey studies also among community-dwelling populations. (Guralnik and Simonsick 1993.) There are three standard forms to rate individual's physical functioning:

1) degree of difficulty in performing certain activities
2) degree of assistance or dependency and
3) whether or not an activity is performed.

The scaling method can have a major impact on the prevalence estimates of disability and cross-study comparisons should be drawn with caution. (Jette 1994.)

Need for help to perform ADL is an indicator of frailty and inability to live independently. ADL items can identify the most severely disabled individuals (Guralnik and Simonsick 1993), but they are not valid indicators for early signs of functional deficits. The focus of the present study is in high-functioning older adults among whom the prevalence of difficulty or need for help in ADL is relatively low. Indicators of IADL and mobility function, in turn, have been reported to be the first identifiable marks of deterioration in physical functioning (e.g. Guralnik and Simonsick 1993, Hoeymans et al. 1996, Wang et al. 2006, Weiss et al. 2007). The most widely referenced self-reported scales assessing mobility were developed by Rosow and Breslau (1966) and Nagi (1976). Walking on a flat surface and walking up and down stairs are most typically used items from these scales. Table 2 presents examples of definitions for walking and stair climbing that have been used as indicators of self-reported mobility function in population studies among community-dwelling older adults. Phrasings of the questions and response alternatives have not been uniform, which makes comparison between studies difficult.

Table 2. Examples of definitions for walking and stair climbing that have been used as indicators of self-reported mobility function in population studies among community-dwelling older adults.

Mobility item		References e.g.
Walking	¼ a mile (0.4 km)	Hoeymans et al. 1996, Rantanen et al. 2001, Simonsick et al. 2001a, Lan et al. 2002, Lan et al. 2003, Visser et al. 2005a, Visser et al. 2005b, Newman et al. 2006
	0.5 km	Valve et al. 2003, Koskinen et al. 2004, Sainio et al. 2006, Mänty et al. 2007
	½ a mile (0.8 km)	LaCroix et al. 1993, Guralnik et al. 1994a, Guralnik et al. 1995, Ostir et al. 1998, Rantanen et al. 1999b, Leveille et al. 2000, Fried et al. 2001, Reuben et al. 2004, Weiss et al. 2007
	one mile (1.6 km)	Simonsick et al. 2001a
	2 km	Hirvensalo et al. 2000, Malmberg et al. 2002a, Malmberg et al. 2002b, Malmberg et al. 2006, Sainio et al. 2006, Mänty et al. 2007
	several blocks	Lang et al. 2007
	outdoors on nice/ poor weather	Avlund et al. 1993
Stair climbing	one flight of stairs	Rantanen et al. 1999b, Hirvensalo et al. 2000, Valve et al. 2003, Koskinen et al. 2004, Newman et al. 2006, Sainio et. al. 2006, Mänty et al 2007, Lang et al. 2007
	several flights of stairs	Malmberg et al. 2002a, Malmberg et al. 2002b, Valve et al. 2003, Malmberg et al. 2006, Sainio et al. 2006, Lang et al. 2007
	walk up and down stairs to the 2nd floor	Guralnik et al. 1994a. Leveille et al. 2000, Reuben et al. 2004
	climbing 10 steps	Fried et al. 2001, Simonsick et al. 2001a, Visser et al. 2005a, Visser et al. 2005b
	climbing 20 steps	Simonsick et al. 2001a
	ability to manage stairs	Avlund et al. 1993, Ostir et al. 1998, Sulander et al. 2006

Like ADL items, most questions of mobility function also concern need for help or level of difficulty in task performance. For example, Newman et al. (2006) divided level of difficulty into two categories: those reporting any persistent difficulty in mobility tasks were regarded as having a mobility limitation and those reporting severe difficulty or inability to perform the tasks were regarded as having a mobility disability. There is a difference between whether the respondents are asked to judge their capacity to do a certain task (e.g. are you able to climb one flight of stairs) or to report their actual performance (e.g. do you use stairs during the course of a typical week). The accuracy of the responses will depend on the respondents' opportunities and desire to perform the requested activities. Both capacity and performance approach can add appropriate information to self-reported assessment of mobility function. (Branch and Meyers 1987.)

Self-reports have also been used to identify preclinical mobility disabilities (Fried et al. 1991). Avlund et al. (1993) presented a functional ability scale assessing mobility, and lower and upper limb functions in terms of reduced speed and tiredness when performing daily activities. Tiredness may be caused by multiple factors, such as a general vulnerability due to chronic disease, concurrent conditions or physiological decline with a loss of reserve capacity, that have not yet caused obvious disability (Avlund et al. 1998). Tiredness has been identified as an early sign of later disability (Avlund et al. 2001), even when adjusted for walking limitations (Avlund et al. 2006). It has been shown to predict hospitalization, home help use (Avlund et al. 2001) and mortality (Avlund et al. 1998). Task modification is another indicator of preclinical mobility disability. A recent report by Mänty et al. (2007) indicated that self-reported modification of task performance without perceived difficulty is associated with performance-based measurements of walking speed and muscle power and is also able to predict future manifest mobility difficulty.

2.2.2 Performance-based measurements of mobility and health-related fitness

Concerns about the reproducibility, ability to capture the full spectrum of disability, precision and sensitivity to change of self-reported scales have led to the development of more functionally oriented performance-based instruments (Reuben et al. 1995). Several measurement tools have been used to assess physical functioning and performance among older adults. Like the first self-reported measures, many performance-based measures were originally developed for frail individuals or for specific patient groups. Later they have also been applied in community settings. For example, the timed up-and-go test was originally developed to assess basic mobility functions of the frail elderly patients in a geriatric day hospital, but later the test has also been applied to community-dwelling people (Podsiadlo and Richardson 1991). Test batteries assessing mobility function and fitness among older adults have combined several single tests with varying purposes and target groups. Most of them include test items assessing walking ability/speed, lower extremity strength/function and balance, the three most important prerequisites for mobility function.

Walking

Walking ability has been assessed over various distances and with varying protocols. Short distances assessing walking speed have varied between 1-m and 30-m (e.g. Aniansson et al. 1980, Bassey et al. 1992, Guralnik et al. 1994a, Guralnik et al. 1994b, Nagasaki et al. 1995, Era and Rantanen 1997, Langlois et al. 1997, Chaves et al. 2000, Simonsick et al. 2001a, Forrest et al. 2006, Mänty et al. 2007, Weiss et al. 2007). Guralnik et al. (2000) suggested that 4-m would be the distance of choice because it has demonstrated feasibility in both home and clinical settings. Compared to the shortest distances longer distance may improve measurement accuracy (Guralnik et al. 2000) and may be less influenced by initial start-up time.

Longer walking distances also assess walking ability in terms of aerobic capacity and endurance. The 6-min walk test was first introduced to measure exercise capacity in patients with chronic heart failure (Guyatt et al. 1985), and the 5-min walk was developed to assess aerobic fitness in people with arthritis (Price et al. 1988, Peloquin et al. 1998). Later these tests and the 9-min version have also been applied among community-dwelling older adults (Rikli and Jones 1998, Miotto et al. 1999, Rikli and Jones 1999a, Kervio et al. 2003, Wang et al. 2005, Wang et al. 2006). A long distance corridor walk assesses time needed to walk 400 m (Simonsick et al. 2001a, Simonsick et al. 2001b). Simonsick et al. (2001b) compared performance on the long distance corridor walk and 6-min walk and concluded that the use of a target distance (400 m) instead of time (6 min) encouraged participants to work closer to their maximum capacity. The 1-km walk test (Malmberg et al. 2002b) was developed on the basis of the UKK 2-km Walk Test (Oja et al. 1991) to assess walking ability and endurance especially among high-functioning older adults.

Both standing (e.g. Bassey et al. 1992, Langlois et al. 1997, Forrest et al. 2006, Weiss et al. 2007) and “flying” starts for walking have been reported for short distance walks (e.g. Nagasaki et al. 1995, Era and Rantanen 1997, Steffen et al. 2002, Mänty et al. 2007). Participants have been instructed to walk at their usual pace (e.g. Aniansson et al. 1980, Guralnik et al. 1994a, Langlois et al.

1997, Simonsick et al. 2001a, Forrest et al. 2006, Weiss et al. 2007), as fast as possible (e.g. Guralnik et al. 1994b, Era and Rantanen 1997, Mänty et al. 2007) or at both (usual and maximal) speeds (e.g. Bassey et al. 1992, Nagasaki et al. 1995, Chaves et al. 2000, Shinkai et al. 2000, Bean et al. 2002, Malmberg et al. 2002b, Steffen et al. 2002).

Lower-extremity strength and function

Various forms of sit-to-stand test and stair climb have been used to assess lower extremity strength and function in field circumstances. In addition, participants' ability to squat has been assessed by two (Sievers et al. 1985, Sainio et al. 2006) and one-leg squat tests (Suni et al. 1996, Malmberg et al. 2002b). Most typical applications of the sit-to-stand test are timed five times (Guralnik et al. 1994a, Guralnik et al. 1994b, Seeman et al. 1994, McCarthy et al. 2004, Forrest et al. 2006, Sainio et al. 2006), ten times (Bean et al. 2002, Curb et al. 2006) and one-time sit-to-stand tests (Aniansson et al. 1980, Bassey et al. 1992, Ritchie et al. 2005). Number of chair stands performed in 30 seconds (Rikli and Jones 1999a, Jones et al. 1999, McCarthy et al. 2004, Macfarlane et al. 2006) and in 1 minute (Ritchie et al. 2005) has also been used. Ability to climb and descend one flight of stairs (Bassey et al. 1992), time to ascend a 10-stair flight (Bean et al. 2002), time to climb and descend one flight of stairs three times (Malmberg et al. 2002b) and time to ascend and descend a flight of 15 stairs (McAuley et al. 2005) are examples of the stair climb protocols. Additionally, stair climb has been simulated by climbing two steps up and down (Sievers et al. 1985, Sainio et al. 2006) and by box step tests (Aniansson et al. 1980, Rantanen et al. 1994, Era and Rantanen 1997, Ritchie et al. 2005).

Balance

Both dynamic and static methods have been used to assess balance. Dynamic balance and agility have been measured e.g. by a figure of eight run (Tegner et al. 1986, Uusi-Rasi et al. 1999, Karinkanta et al. 2007), narrow walk (Simonsick et al. 2001a), slalom walk (Netz and Argov 1997) and tandem walk both backwards (Nelson et al. 1994, Bean et al. 2002) and forwards (Bean et al. 2002). Duncan et al. (1990) presented a functional reach test as an indicator of dynamic postural control which reflects the margin of stability. One-leg standing balance test with different target times (5-60s) and protocols has been used as an indicator of static balance (e.g. Tinetti, 1986 Guralnik et al. 1994b, Nagasaki et al. 1995, Suni et al. 1996, Netz and Argov 1997, Uusi-Rasi et al. 1999, Simonsick et al. 2001a, Malmberg et al. 2002b). A less challenging test to assess static balance is tandem-stand including three standing positions (parallel, semi-tandem and tandem) (Guralnik et al. 1994a). The order of positions and target time in each position has varied between studies.

Other fitness factors

Additionally, test items assessing upper extremity strength and function as well as flexibility are often included in studies. These fitness factors are needed in many daily activities such as personal grooming, household chores, carrying and lifting tasks. Measurement of hand grip strength is a widely used indicator of upper extremity strength (e.g. Era and Rantanen 1997, Rantanen et al. 1999b, Uusi-Rasi et al. 1999, Koskinen et al. 2004). Clark (1989) presented arm curl test to indicate overall upper body strength and to reflect physical functioning, and Rikli and Jones (1999a) have used a modified version of it. Flexibility has been assessed e.g. by trunk side-bending (Suni et al. 1996, Malmberg et al. 2002b), sit-and-reach (Clark 1989), back scratch, "hand glide with leg crossed" (Netz and Argov 1997), shoulder rotation (Hoeymans et al. 1996), and lift and reach tests (Aniansson et al. 1980).

Test batteries

There is wide intra-individual variation in the changes of different functions with increasing age. Thus, no single measure can be regarded as a reliable indicator of overall functioning (Era and Rantanen 1997). Test batteries consisting of several test items have been developed and validated for assessing overall physical functioning among older adults. Berg et al. (1989) introduced the Balance Scale consisting of 14 movements of everyday life. Performance-oriented Assessment of Mobility Problems (Tinetti 1986), the Continuous-scale Physical Functional Performance test (Cress et al. 1996), its modified version the Assessment of Daily Activity Performance (de Vreede et al. 2004, de Vreede et al. 2006) and the Physical Performance Test (Reuben and Siu 1990) include 7 to 16 every-day tasks, ranging from easy to demanding. These batteries focus primarily on assessing physical functioning and mobility of older adults at behavioral level. The functional limitations detected by these measurements are indicators of a relatively late stage of the disability process. Thus they may not be able to discriminate across the full range of individual functioning (Rikli and Jones 1997).

In Finland the physical functioning of older people has been widely assessed with the TOIMIVA test battery developed by the State Treasury of Finland (Pohjola 2006). Battery includes measurements of one-leg stand, chair stand, hand grip strength, walking speed on a 10-m course, peak expiratory flow and the visual analogue scale to assess pain, and it was specifically targeted at assessing mobility function among those aged over 75 years. Thus, it may not be an optimal tool to apply among younger older adults.

The Short Physical Performance Battery (Guralnik et al. 1994a) and the test batteries used in the MacArthur Study (Guralnik et al. 1994b, Seeman et al. 1994, Seeman et al. 1995) and the Health ABC Study (Simonsick et al. 2001a) all assess walking ability, lower extremity function and balance. The Short Physical Performance Battery has been applied among different populations aged over 65 years (Guralnik et al. 1995, Ostir et al. 1998, Guralnik et al. 2000, Penninx et al. 2000). MacArthur and Health ABC studies in turn were targeted at non-disabled people aged 70 to 79 years. The Index of mobility-related physical limitations (Lan et al. 2002) was targeted at a wider age range (55-85), but its later form (Lan et al. 2003, Melzer et al. 2004) did not include a test item for balance. However, all these batteries have been reported to indicate level of physical functioning among the target populations.

Only a few test batteries have been developed to detect functional decline before it proceeds to functional limitations or disability. Fitness assessments may serve as an early indicator of impending functional limitation. A comprehensive fitness test provides specific information on a person's physical strengths and weaknesses associated with functional tasks and activity goals that are important for everyday life. This information is needed to design individualized PA programs for older adults. Fitness assessment may serve as a precursor in helping a person to set personal goals for daily activities. Assessment can also be utilized in making proper adjustments to activity programs, in tracking the process during programs, in evaluating the effectiveness of programs and in providing personalized feedback. (Jones and Rikli 2000, Rikli and Jones 2002.) Several fitness factors have been assessed in laboratory conditions (e.g. Rantanen et al. 1994, Era and Rantanen 1997, Rantanen and Avela 1997, Paterson et al. 1999, Paterson et al. 2004, Visser et al. 2005b). In the past twenty years more functionally oriented methods of fitness assessment have been developed. Table 3 presents fitness test batteries targeted at community-dwelling older adults.

One of the first reported fitness test batteries was the AAHPERD Functional Fitness Test. The preliminary testing of the battery provided information on the feasibility of the tests (Clark 1989) as well as responsiveness of the test performance to change with exercise intervention (Hopkins et al. 1990). On the basis of the AAHPERD battery Netz and Argov (1997) developed their Functional Fitness Tests that represent activities of daily functioning among community-dwelling older adults. They added measurements of static balance and lower extremity strength to the AAHPERD battery. Additionally, they replaced the sit-and-reach test with separate flexibility tests for lower and upper extremities and chair stand and walk test was replaced by slalom walk. The reliability and health and functioning-related validity of these batteries have been reported (Bravo et al. 1994, Shaulis et al. 1994, Mobily and Mobily 1997, Netz and Argov 1997).

The other functional fitness test batteries including measurements for several fitness components have been developed for community-residing older adults aged over 55 [Groningen Fitness Test (Voorrips et al. 1993, van Heuvelen et al. 1994, van Heuvelen et al. 1997, Lemmink et al. 2001) and Physical Fitness Field Test (Ritchie et al. 2005)] and 60 years [Fullerton /Senior Fitness Test (Miotto et al. 1999, Rikli and Jones 1999a, Rikli and Jones 1999b, Jones and Rikli 2000, Rikli and Jones 2001)]. The reliability, PA and physical functioning-related validity have been reported for these batteries (Voorrips et al. 1993, van Heuvelen et al. 1994, van Heuvelen et al. 1997, van Heuvelen et al. 1998, Lemmink et al. 2001, Miotto et al. 1999, Rikli and Jones 1999a), which enables them to be applied as part of a strategy to stimulate PA in sedentary older adults.

The validity and reliability of these fitness test batteries targeted at community-dwelling older adults have been established in cross-sectional study designs. According to Ritchie et al. (2005) future studies should aim at developing appropriate field-based measurements for use with well-functioning older adults aged 55 to 70 years of age. Measurements should have quantitative outcomes that enable them to distinguish individuals on all levels of performance from low to high function (Curb et al. 2006). Tests designed for high-functioning older adults should be validated for larger populations with prospective study designs. The mobility and PA-related validity of the tests especially should be further examined.

Table 3. Functionally-oriented fitness test batteries for community-dwelling older adults.

Reference	Battery	Country	Population
Clark 1989	AAHPERD Functional Fitness Test	USA	60+
Netz and Argov 1997	Functional Fitness Tests	Israel	60-89
Rikli and Jones 1999a Rikli and Jones 2001	Senior Fitness Test	USA	60-90+
Ritchie et al. 2005	Physical Fitness Field Test	Australia	55-70
Voorrips et al. 1993 van Heuvelen et al. 1994	Groningen Fitness Test	Netherlands	55+

Components	Factors	Items
morphological fitness	spine and hip flexibility	sit and reach
	body composition	body weight and height
muscular fitness	upper extremity strength	arm curl
motor fitness	agility/dynamic balance	walk around two cones
	coordination	soda pop
cardiorespiratory fitness	walking speed	½ mile walk
morphological fitness	upper extremity flexibility	back scratch
	lower extremity flexibility	hand glide with leg crossed
muscular fitness	upper extremity strength	arm curl
	lower extremity strength	10-times chair stand
motor fitness	balance	one-leg stand
	agility	slalom walk
	coordination	soda pop
cardiorespiratory fitness	walking speed and ability	½ mile walk
morphological fitness	body composition	body mass index
	upper extremity flexibility	back scratch
	lower body flexibility	sit and reach
muscular fitness	upper extremity strength	arm curl
	lower extremity strength	30-s chair stand
motor fitness	agility/dynamic balance	8-ft up and go
cardiorespiratory fitness	aerobic endurance	6-min walk
		2-min step test
morphological fitness	body composition	body weight and height
		waist and hip circumference
muscular fitness	upper extremity strength	lift and reach
	lower extremity strength	1-min chair stand
	rate of force development	single time chair rise
motor fitness	balance	tandem stand
	functional capacity	step test
cardiorespiratory fitness	circulation	blood pressure
		resting heart rate
morphological fitness	body composition	body weight and height
	upper extremity flexibility	circumduction
	spine and hip flexibility	sit and reach
muscular fitness	upper extremity strength	hand grip
	lower extremity strength	leg extension
motor fitness	manual dexterity	block transfer
	reaction power	light response
	balance	balance board
cardiorespiratory fitness	endurance	walking at increasing velocity
	pulmonary function	peak expiratory flow
	circulation	blood pressure

2.2.3 Advantages and disadvantages of self-report and performance-based measurements

Self-reports reflect adaptations that older people have made to facilitate routine day-to-day performance. They are easy to perform since they do not require a lot of time, space or special equipment. Thus they can be used to assess physical functioning and mobility among large groups of people. However, traditional self-reports may fail to capture small changes in physical functioning (Hoeymans et al. 1996), especially among high-functioning older adults. Regarding fitness assessment, self-reported measures fail to reproduce multidimensional structure of fitness. Older persons especially tend not to estimate individual fitness components when asked to do so, but instead assess overall fitness, in which cardiovascular fitness is a dominant factor. (van Heuvelen et al. 1997.)

Performance-based measurements assess actual performance of standardized tasks at a particular point of time. Thus they may not fully reflect activities performed in daily life. However, performance-based measurements may contribute information beyond that obtained from self-report (Nagasaki et al. 1995) and provide information across the entire spectrum of functioning (Seeman et al. 1994). People with similar self-reported physical functioning may perform differently in performance-based measures (Guralnik et al. 1994a, Lan et al. 2003, Reuben et al. 2004). Use of a series of graded and timed performance tests provides greater ability to identify differences in abilities, especially at higher levels of ability (Seeman et al. 1994). Duncan et al. (1990) reported that continuous measurement systems provide greater sensitivity than categorical or ordinal measures. Poor performance may reveal a preclinical state of decreased function for which the individual has made adequate adaptations to maintain daily activities (Guralnik et al. 1995, Penninx et al. 2000) and does not recognize it him/herself. Performance measures are also less influenced by cognitive function, culture, language and education than self-reported measures (Guralnik et al. 1989).

Performance has been shown to be more strongly associated with age than self-report. Older people may tolerate more functional limitations and adapt to a certain amount of declining function believing that it is part of aging rather than a consequence of impaired health. (Hoeymans et al. 1996.) Performance-based measures have been shown to identify more limitations in physical functioning (Brach et al. 2002) and predict mortality better (Markides et al. 2001) than self-reports. They also seem to have greater sensitivity to change than self-reports, especially in the early stage of functional decline (Guralnik et al. 1989). According to Rikli and Jones (1997) personal performance assessment may empower older adults by providing them with information about their physical ability and activities they can undertake to improve functioning. Many older people also enjoy the attention and feedback associated with personal assessment.

Performance-based measurements require more staff time and effort to perform than self-report measurements. Those administering the tests need to be adequately trained for testing. Safety concerns need to be taken into account. Adequate space and equipment are also needed, which makes performance-based measurements more costly compared with self-report measurements. Application of performance-based measurements for different settings may need modifications. Since performance-based measurements are administered in standardized circumstances they may not reveal whether the identified functional limitations or disability have any relevance to the actual activities or needs of an individual. (Guralnik et al. 1989.)

Studies have reported weak to strong associations between self-reports and performance-based measurements (Guralnik et al. 1994a, Hoeymans et al. 1996, Simonsick et al. 2001a). These two types of measurements measure different aspects of the same construct and complement each other (Guralnik et al. 1994a, Hoeymans et al. 1996). A combination of self-report and performance-based items may provide an optimal assessment of physical functioning (Reuben et al. 1995, Sainio et al. 2006), especially among people with high self-reported functioning (Reuben et al. 2004). The choice of instrument should depend on the physical and cognitive capabilities of the person to be assessed, the components of physical performance to be measured and the purpose for which the results of the assessment will be used.

2.2.4 Safety and feasibility of performance-based measurements

Safety and feasibility are major concerns in assessing the physical performance of older adults by performance-based measurements. Safe assessment should be conducted without extensive referrals for medical evaluation and without excluding a large number of subjects. Feasibility has to do with the suitability of an assessment tool for its use and the probability of it being used in a particular testing environment. The costs and inconvenience of many laboratory tests prohibit transporting large numbers of older adults for laboratory assessments. Tests suitable for use in field conditions should be relatively easy to administer and score, and they should require minimum equipment, time and space. Most importantly, the tests should be safe for participants without medical supervision. (Rikli and Jones 1997.)

Knowledge of current and former health status and PA level of the subjects, as well as the physiological exertion of the tests, are important factors affecting the safety and feasibility of performance-based assessment. The health status of elderly people should be screened in advance in order to ensure safety of assessment. Screening should identify those with medical contraindications for assessment as well as those with other medical concerns possibly affecting test results. The PA readiness questionnaire (PAR-Q) has been successfully administered as a screening instrument (Chrisholm et al. 1975). It was originally designed to screen individuals from participating in physical activities that might be too strenuous for them. Knowing the physical exertion of performance-based assessment PAR-Q can also be used as a screening tool for testing. Additionally, information about present and past PA can be utilized in the interpretation of the test results and in determining individual PA counseling. Careful control of both environmental conditions and the state of the participant are also imperative for safety. Trained examiners are the best way of improving the safety of assessments.

Safety concerns have been reported for only few fitness tests targeted at older adults. The Senior Fitness Test has been reported to be safe for the majority of community-dwelling older adults. No injuries or complications were reported among the 7,000 participants tested (Rikli and Jones 1999a). Lemmink et al. (2001) reported safety procedures with minor test-specific exclusions for the Groningen Fitness Test. A systematic health-screening has been a part of HRF assessment both among middle-aged (Suni et al. 1998a) and older adults (Malmberg et al. 2002b) and assessments have been reported to be safe and feasible for the target populations (Suni et al. 1998a, Malmberg et al. 2002b).

2.2.5 Mobility-related validity of performance-based measurements

Concepts of validity

The most widely used indicators of validity of performance-based measurements are content validity and criterion validity. *Content validity* refers to the degree to which a test measures the capacity that it is intended to measure. A first step to analyze the content validity of a test is to identify important components of the construct of interest through a literature review, an expert panel and /or factor analysis. (Rikli and Jones 1997.) When analyzing the mobility-related validity of performance-based measures a new instrument is often compared to an established construct and other measures that might be related to it, but are not identical (Reuben et al. 1992). *Criterion validity* represents the degree to which a test correlates with a criterion measure that is already known to be valid (Rikli and Jones 1999a). *Concurrent validity*, as a part of criterion validity, indicates the degree to which a test result is related to clinical judgment and laboratory measurements. Ideally a new instrument is compared to a “gold standard”, but for many domains of physical performance no such gold standard exists. *Predictive validity* indicates the ability of a measure to predict health outcomes. It helps to clarify causative pathways that link the assessment to the particular outcome. If performance on a measurement scale is closely associated with some long-term outcome e.g. institutionalization, then deterioration in performance might be expected to result in a poorer outcome. (Reuben et al. 1992.)

Careful control of aspects affecting the reliability of test performance, such as environmental aspects, equipment used and instructions given, are imperative for valid test results. Repeated testing should be conducted at the same time of day, the temperature of the testing area should be constant, dietary guidelines should be adhered to, the use of stimulants such as coffee, tea, nicotine and alcohol should be avoided and the subjects must not participate in assessment while under the influence of drug interventions. (Bouchard et al. 1990.)

Content validity

Cross-sectional studies among elderly populations have reported mobility-related content validity for several performance-based measurements. Performance in walking speed (Wang et al. 2005, Wang et al. 2006, Mänty et al. 2007), 6-min (Rikli and Jones 1998) and 5-min-walks (Wang et al. 2005), timed up-and-go (Wang et al. 2006), functional reach (Wang et al. 2005, Wang et al. 2006), hand grip strength, chair stand (Wang et al. 2006), step test and timed floor transfer (Wang et al. 2005) have been reported to be associated with self-reported mobility function. In a study by Mänty et al. (2007) maximal walking speed was also able to discriminate participants with preclinical mobility limitation from those with no limitation and those with manifest limitation.

Several test batteries have also been shown to be associated with physical functioning (e.g. Cress et al. 1996, Netz and Argov 1997, van Heuvelen et al. 2000, Collins et al. 2004, Pohjola 2006). Mobility-related cross-sectional content validity has been reported for the Berg Balance Scale (Wang et al. 2006), the

Short Physical Performance Battery (Guralnik et al. 1994a), the Index of mobility-related physical limitation (Lan et al. 2002), measurements of the Health ABC Study (Simonsick et al. 2001a), and HRF tests for older adults (Malmberg et al. 2002b). Although PA is closely related to the mobility function among older adults, only few test batteries targeted at older adults have been studied in relation to PA (van Heuvelen et al. 1994, Seeman et al. 1995, van Heuvelen et al. 1998, Miotto et al. 1999, Rikli and Jones 1999a, Malmberg et al. 2006).

Criterion validity

Criterion validity has not been studied as much as content validity since there is a lack of gold standards available to be used as criteria. The one existing gold standard, VO_2max, has been used to analyze the criterion validity of cardiorespiratory fitness tests, e.g. 2-km walk (Oja et al. 1991, Rance et al. 2005), 5-min walk (Peloquin et al. 1998), Rockport 1-mile walking test (Fenstermaker et al. 1992) and long distance corridor walk (Simonsick et al. 2006) among older adults. Paterson et al. (1999) reported that the minimum level of aerobic power for an independent life at the age of 85 would be approximately 18 ml/kg/min among men and 15 ml/kg/min among women.

For other fitness components there are no gold standards available to identify criterion validity for the mobility function. Performance in test items assessing factors of muscular and motor fitness has been compared with performance in laboratory tests. Walking speed on tandem walk (Bean et al. 2002) and on different distances (Aniansson et al. 1980, Rantanen and Avela 1997, Bassey et al. 1992, Bean et al. 2002), ability to rise from a chair for 30 seconds (Jones et al. 1999, McCarthy et al. 2004, Macfarlane et al. 2006), performance in one time (Bassey et al. 1992), five times (McCarthy et al. 2004) and ten times chair stand tests (Bean et al. 2002), step test performance (Aniansson et al. 1980) and ability to climb stairs (Bassey et al. 1992, Bean et al. 2002) have been reported to be moderately associated with laboratory measurements of leg power, strength or balance. In addition, performances in the sit-and-reach test and in its modified version seem to correlate moderately with laboratory-based measurement of hamstring flexibility (Lemmink et al. 2003).

Regarding test batteries, performance in the Berg Balance Scale has been reported to correlate with laboratory measures of postural sway (Berg et al. 1992) and performance in the Continuous-scale Physical Functional Performance has been shown to correlate with laboratory-based measurements of biceps strength, knee extensor strength, shoulder flexion, step reaction time and VO_2max (Cress et al. 1996). The test items of the Groningen Fitness Test (van Heuvelen et al. 1997), the Senior Fitness Test (Rikli and Jones 1999a) and selected tests of the Physical Fitness Field Test (Ritchie et al. 2005) have been reported also to correlate with laboratory-based criterion measurements.

Predictive validity

Prospective study designs have been used to analyze the value of performance-based tests to predict mobility-related outcomes. Hoeymans et al. (1996) and Weiss et al. (2007) have indicated that deterioration of mobility function follows a hierarchical pattern of difficulties occurring first in more demanding tasks and then in basic activities. Good test performance is thought to act as a reserve that protects against future losses in mobility function and prevents the onset of functional disabilities. Table 4 summarizes the mobility-related predictive value of performance-based measurements among community-dwelling, relatively healthy older adults. The studies have used different formulations for self-reported mobility-outcome and follow-up periods have varied from one to several years.

Walking speed over different distances is the most widely studied performance-based measurement among older adults. Slow walking speed on both short (Guralnik et al. 1995, Schroll et al. 1997, Ostir et al. 1998, Chaves et al. 2000, Guralnik et al. 2000, Lan et al. 2003, Onder et al. 2005) and long distances, as well as inability to walk long distances (Newman et al. 2006) have been reported to predict self-reported mobility difficulties during one to seven-year follow-up. Using ADL disability as the outcome, a six-year follow-up study by Shinkai et al. (2000) showed that especially maximal walking speed predicted functional dependence among 65 to 74-year-olds, while usual walking speed was most sensitive in predicting dependence among older people. A three-year follow-up study by Woo et al. (1999) reported that both walking speed and stride length were predictive of physical functioning among people of 70 and older. Besides mobility and physical functioning-related outcomes, poor walking ability seems also to have predictive value for fractures (Stel et al. 2004), hospitalization and even mortality (Woo et al. 1999).

Balance and muscle strength have been much studied in laboratory conditions. Regarding field-based measurements, earlier prospective studies have shown that poor standing balance in both tandem (Guralnik et al. 1995, Ostir et al. 1998, Rantanen et al. 2001) and one-leg stands (Chaves et al. 2000), poor hand grip strength (Rantanen et al. 1999b) and poor performance in chair stand (Guralnik et al. 1995, Ostir et al. 1998, Onder et al. 2005, Weiss et al. 2007) and stair climbing tests (Schroll et al. 1997, Weiss et al. 2007) seem to increase the risk of incident mobility difficulties.

According to Onder et al. (2005) progressive and catastrophic disabilities are not similarly predicted. Performance-based measurements seem to have higher predictive value for progressive disability, referring to a steady downward trend in functioning, than for catastrophic disability. During a three-year follow-up period measurements of lower extremity function tended to predict the onset of disability, while upper extremity measurements were less consistently associated with the mobility outcomes. (Onder et al. 2005.)

In addition to single tests, mobility-related predictive validity has also been reported for summary scores of performance-based measurements. The Short Physical Performance Battery score is the most widely studied summary score and its predictive value has been reported for both mobility and ADL-related disability (Guralnik et al. 1995, Hoeymans et al. 1996, Ostir et al. 1998, Guralnik et al. 2000). According to Guralnik et al. (2000) and Onder et al. (2005) assessment of walking speed seems to have nearly as good predictive value for incident disability as batteries consisting of several test items. This indicates that assessment of walking speed may be an efficient tool for use as the first step in screening large numbers of older adults (Guralnik et al. 2000). On the other hand, Lan et al. (2003) showed that the Index of mobility-related physical limitations consisting of several measurements (gait speed, 5 times chair stand and peak expiratory flow) had greater responsiveness to change and better predictive value for difficulties than gait speed alone. A hierarchical pattern in mobility function identified by Weiss et al. (2007) also reflects that walking speed alone may not be an optimal way to identify mild deficits in mobility among high-functioning older adults. Among this sub-population more demanding test items should be used. Assessment of several fitness factors may also increase measurement accuracy (Guralnik et al. 2000) and add value of assessments to be utilized in PA counseling.

Since there are many ways to assess physical functioning, mobility and fitness among older adults, an instructor should pay attention to several factors when selecting an appropriate assessment tool for a certain person. Rikli and Jones (2002) stated that at first an instructor should consider what the purpose of assessment is in general. The health status and general functioning of a person should be taken into account when selecting assessment tools. Tools designed for use with frail and disabled older adults should not be used with high-functioning individuals and vica versa. An ideal choice would be test items that can be used with a wide range of functional abilities. More than one physical parameter of the body should be measured, and the reliability and validity of assessment tools should be analyzed among the target population. The safety and feasibility of an assessment tool should be considered, and the equipment, space, time, personnel and costs needed for assessment should be carefully evaluated. A test instructor should be appropriately trained for testing and the availability of performance standards (normative or criterion-referenced) for the assessment tool should be checked. (Rikli and Jones 2002.)

Table 4. Table summarizing studies indicating predictive value of performance-based measurements on self-reported mobility function among community-dwelling older adults.

Reference	Population	Follow-up (years)	Test(s)	Outcome(s)	Main results (95% CI)
Chaves et al. 2000	n= 266 women 70-80 years	1.5	1-m walk 5 chair stands one-leg stand side-by-side stand semi-tandem stand tandem stand hip flexor strength grip strength	self-reported difficulty to walk 0.8 km, climb 10 steps, or transfer from or into a car or bus	1-m walk, usual pace OR=4.39 (1.86-10.37) 1-m walk, rapid pace OR=4.25 (1.25-14.50) 5 chair stands OR=2.28 (1.38-3.77) one-leg stand, 10-30 s OR=0.51 (0.26-0.99) one-leg stand, 30s OR=0.09 (0.02-0.39)
Guralnik et al. 1995	n= 1122 71+ years	4	8-ft (2.4-m) walk 5 chair stands side-by-side stand semitandem stand tandem stand	self-reported ability to walk 0.5 mile or climb stairs without help	poorest vs. best quarter walk, RR=4.8 (2.4-9.6) chair stand, RR=4.1 (2.3-7.2) balance, RR=1.9 (1.2-2.9) summary score, 10-12 as reference 4-6, RR=4.9 (3.1-7.8) 7-9, RR=1.8 (1.3-2.5)
Guralnik et al. 2000	n=6534	1-6	8-ft (2.4-m) walk 5 chair stands side-by-side stand semitandem stand tandem stand	self-reported ability to walk 0.5 mile or climb stairs without help	summary score, 10-12 as reference 4-6, RR=2.9-4.9 (1.6-7.8) 7-9, RR=1.5-2.1 (1.0-3.2) in different study populations summary score AUC=0.69 gait speed AUC=0.65

Continued overleaf

Table 4 continued

Reference	Population	Follow-up (years)	Test(s)	Outcome(s)	Main results (95% CI)
Lan et al. 2003	n= 1034 55-85 years	3	3-m walk back and forth 5 chair stands peak expiratory flow	self-reported difficulty or inability to walk ¼ mile	mobility difficulty: summary score, OR=1.21 (1.06-1.37) AUC= 0.59 gait speed, OR=1.01 (0.90-1.13) AUC= 0.54 mobility inability: summary score, OR=1.61 (1.28-2.01) AUC=0.66 gait speed, OR=1.02 (0.87-1.20) AUC=0.59
Newman et al. 2006	n= 3075 70-79 years	mean 4.9 (0.9)	long-distance corridor walk (400-m on 20-m course)	self or proxy-reported limitation and disability to walk ¼ mile or climb stairs	mobility limitation inability to complete, HR=2.01 (1.72-2.36) poorer performance, HR=1.59 (1.50-1.69) mobility disability: inability to complete, HR=2.14 (1.72-2.66) poorer performance, HR=1.59 (1.46-1.73)
Onder et al. 2005	n= 844 women mean 78.7	3	4-m walk chair stand balance putting on blouse Purdue pegboard grip strength	self-reported disability to walk across a room	progressive mobility disability: balance, RR=0.43 (0.35-0.54) chair stand, RR=2.25 (1.82-2.78) walk, RR=0.27 (0.19-0.38) lower extremity, summary score, RR=0.29 (0.22-0.37) putting on blouse, RR=1.35 (1.10-1.76) upper extremity summary score, RR=0.77 (0.62-0.95) catastrophic mobility disability: chair stand, RR=1.39 (1.09-1.77) walk, RR=0.57 (0.41-0.80) lower extremity summary score, RR=0.58 (0.41-0.82)

Continued overleaf

Table 4 continued

Reference	Population	Follow-up (years)	Test(s)	Outcome(s)	Main results (95% CI)
Ostir et al. 1998	n= 1365 65-99 years	2	8-ft (2.4-m) walk 5 chair stands side-by-side stand semitandem stand tandem stand	self-reported inability to walk 0.5 mile or climb stairs without help	poorest vs. best quartile walk, OR=3.4 (1.8-6.5) chair stand, OR=2.7 (1.7-4.2) balance (middle vs. best) OR=1.6 (1.1-2.6) summary score, 9-11 as reference 1-4, OR=4.8 (2.6-8.7) 5-8, OR=2.4 (1.6-3.6)
Rantanen et al. 1999b	n= 3218 45-68 years	25	hand grip	self-reported difficulty in heavy housework, lifting, walking 0.8 km, climbing 1 flight of stairs	lowest vs. highest third housework OR=1.69 (1.69-2.27) lifting OR=1.94 (1.25-3.02) walking OR=1.25 (0.93-1.67) climbing OR=1.28 (0.93-1.78)
Rantanen et al. 2001	n= 758 women 65+ years	3	knee extensor strength side-by-side stand semitandem stand tandem stand	self-reported inability to walk ¼ mile or walking speed 0.4m/s or less	lowest vs. highest third knee extension RR=1.89 (1.26-2.84) poorest vs. best category balance, RR=3.29 (1.88-5.76) unable vs. best category balance, RR=4.94 (2.66-9.17) co-impairment: poor & poor vs. high & high RR=5.12 (2.68-9.80)
Schroll et al. 1997	n= 307 75 years	5	knee extension strength body extension strength stair mounting 10-m walk forced expiratory volume	self-reported Mobility-help and Mobility-tiredness scales	mobility-help (need of help): knee extension, RR=5.2 (4.6-5.9)/men RR=4.1 (3.6-4.5)/ women body extension, RR=6.9 (5.8-8.0)/men RR=4.4 (3.8-5.0)/women walk, RR=7.0 (6.4-7.6)/men RR= 7.5 (6.9-8.2)/women
Weiss et al. 2007	n= 261 women 70-79 years	3	4-m walk, usual speed 5 chair stands putting on oversized scrub pants climbing 10 steps	self-reported limitation to walk 0.5 mile	walk, OR=1.04 (0.93-1.17) chair stand, OR=1.14 (1.03-1.26) dressing, OR=1.15 (1.03-1.29) climbing, OR=1.22 (1.09-1.37)

AUC= area under the curve, CI= confidence interval, HR= hazard ratio, OR= odds ratio, RR= relative risk

3. Purpose of the study

The study aimed at evaluating the ability of the proposed HRF tests targeted at high-functioning older adults to detect early difficulties in mobility function. Mobility function refers to a person's perceived mobility and is assessed in terms of self-reported mobility difficulties. The practical target of the study was to establish appropriate HRF tests that could be used in the early screening of a large number of elderly people. The study includes test items for all the main components of HRF, which enlarges its scope to PA counseling targeting exercise individually at the poorest components of fitness.

The specific aims of the study were:

1 to describe and analyze the selection process of an aging study population during six-year follow-up

2 to describe age and gender-specific changes in mobility-related components of HRF during six-year follow-up

3 to describe associations between PA and performance in HRF tests

4 to analyze the validity of the proposed HRF tests in predicting self-reported mobility difficulties

5 to analyze interaction between HRF and PA in predicting self-reported walking difficulties

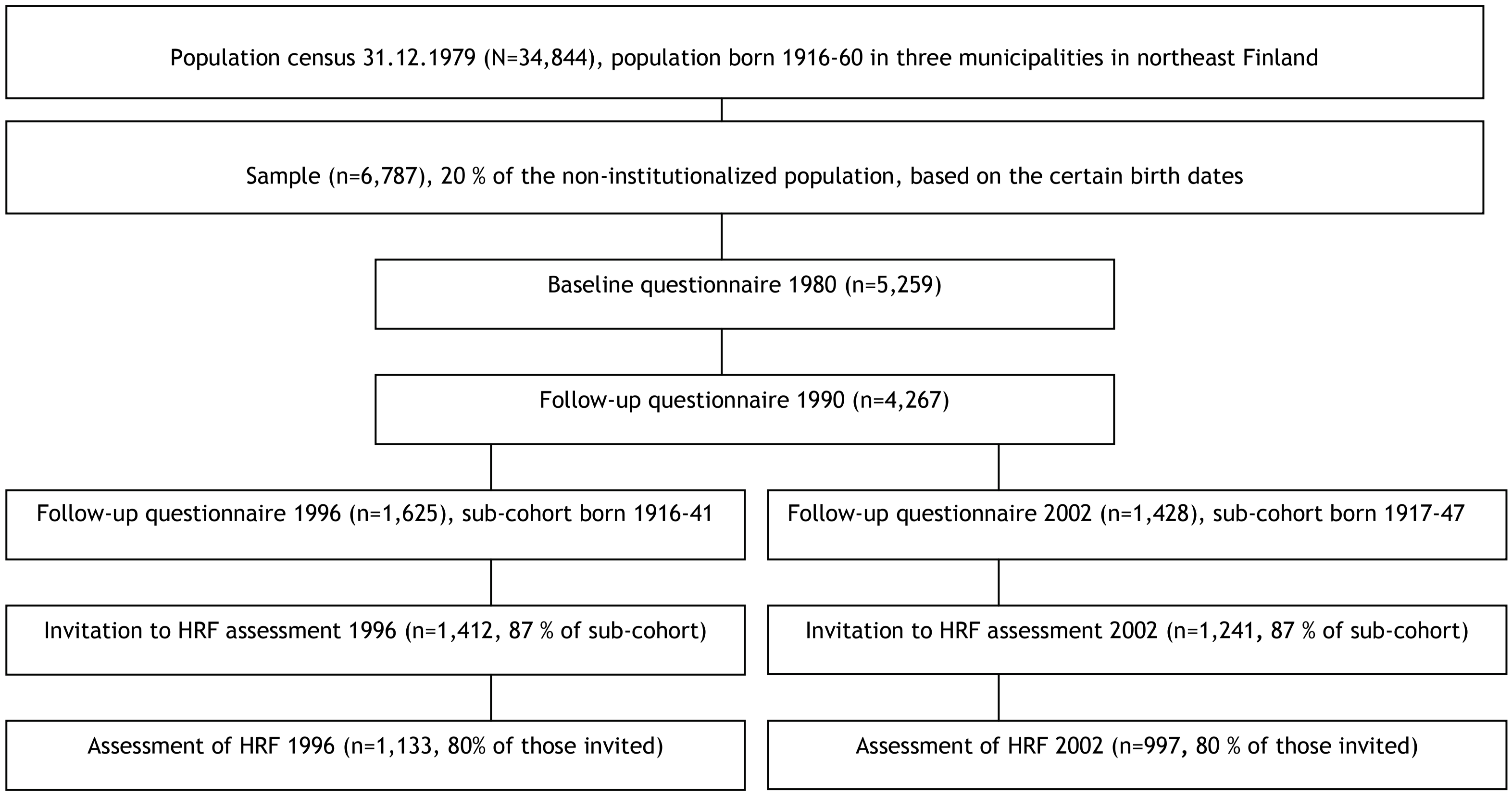
6 to establish optimal cut-off values for the tests predicting mobility difficulties.

4. Material and methods

4.1 Subjects

The study is based on the Kainuu Study on Living Habits and Health (Kainuu Study). A sample of people born between 1916 and 1960 was drawn in January 1980 from the census data of a medium-sized industrial town (Kajaani) and two rural municipalities (Sotkamo, Suomussalmi) in northeast Finland (Oja et al. 1994) (Figure 6). Sampling was carried out by selecting people according to their birth dates, dates ending to the numbers 5 and 0 were selected for the sample. The sample (n=6,787) consisted of 20% of the non-institutionalized population, 77% (n=5,259) of which completed the baseline questionnaire in 1980 and formed the study cohort. A self-administrated follow-up questionnaire was sent to the study cohort in 1981, 1985, 1990 and 2002. The questionnaire included questions on socioeconomic status, health status, chronic conditions, functional ability, fall injuries, demographic background and health-related lifestyle (PA, smoking, alcohol consumption). In 1996 a follow-up questionnaire was sent only to cohort members born 1916-41. According to national census data from the Central Statistical Office of Finland, a total of 490 persons (9% of the study cohort) died between the baseline survey in 1980 and the follow-up survey in 1996 (Malmberg et al. 2002a).

In 1996 and 2002 assessment of HRF was conducted in the three target municipalities. The respondents' readiness to participate in the assessment was pre-screened on the basis of their self-reported functional ability. The exclusion criteria for the assessment were "living in an institution and/or severe difficulties or inability to walk independently outdoors and/or on stairs". Based on these criteria 213 subjects were excluded from the 1,625 respondents residing in the three target municipalities in 1996. (Malmberg et al. 2002b.) In 2002 the corresponding figure was 187 among the 1,428 respondents. A total of 1,412 people in 1996 and 1,241 people in 2002 met the eligibility criteria and were invited for HRF assessment. In 1996 a total of 1,133 (80%) people and in 2002 a total of 997 (80%) people participated in the fitness assessment.



Study population (I)
Subjects participating in HRF assessment both in 1996 and 2002

	Men		Women	
	n	%	n	%
1937-41	110	41	124	37
1932-36	70	26	100	30
1927-31	60	22	76	23
1917-26	31	11	35	10
Total	271	100	335	100

Study population (III)
Subjects participating in HRF assessment in 1996 and free of self-reported mobility difficulties

	Able to walk 2 km in 1996				Able to climb stairs in 1996			
	Men		Women		Men		Women	
	n	%	n	%	n	%	n	%
1937-41	126	35	149	35	127	38	118	38
1932-36	96	27	116	27	83	25	91	29
1927-31	80	22	105	24	77	23	68	22
1917-26	55	15	61	14	47	14	36	12
Total	357	100	431	100	334	100	313	100

Study population (II, IV)
Subjects born 1927-41, participating in HRF assessment in 1996 and free of self-reported walking difficulties

	Able to walk 2 km in 1996			
	Men		Women	
	n	%	n	%
1937-41	126	42	149	40
1932-36	96	32	116	31
1927-31	80	26	105	28
Total	302	100	370	100

Figure 6. Design of the study.

The study concentrated on community-dwelling high-functioning older adults. There seems to be no agreed standard for defining high-functioning. In the present study high-functioning was defined as not having difficulties in walking 2 km (walking difficulty=WD) or in climbing several flights of stairs (stair climbing difficulty=SCD) without a rest in 1996. Figure 6 presents the designs of Studies I-IV. The sample of Study I consisted of those born between 1917 and 1941 (subjects aged 55 to 79 years in 1996) who participated in the HRF assessment in both 1996 and 2002 (n=606). The sample of Study III consisted of correspondingly aged people who participated in the assessment in 1996 and were free of self-reported mobility difficulties at that time. Six years later 92 (12%) people of the 788 subjects reporting no WD, could not be contacted, had severe health restrictions or had died. The corresponding number among the 647 subjects without SCD was 76 (12%). Six hundred and four people who were free of WD and 501 free of SCD answered the corresponding mobility questions of the follow-up questionnaire in 2002. The sample of Studies II and IV consisted of those born between 1927 and 1941 (subjects aged 55 to 69 years in 1996), who participated in the HRF assessment in 1996 and who did not report WD at baseline (n=672). Six years later 68 (10%) people could not be contacted, had severe health restrictions or had died, and 537 (80%) responded to the WD question of the follow-up questionnaire.

4.2 Assessment of physical activity

Self-reported questionnaires were used to assess the respondents' level of PA. In 1990 and 1996 subjects were asked to report "Which of the following categories best describes your PA during the past 12 months? Consider all types of leisure-time PA, including walking and cycling, if activity takes at least 15-20 minutes at a time". The original response alternatives describing PA levels were 1) vigorous activity at least twice a week, 2) vigorous activity at least once a week and in addition other light activities, 3) some activity each week, but less than above, 4) no regular weekly activity (Oja et al. 1994). In the instructions vigorous activity was described as intense enough to cause perspiration and breathlessness. For the analysis PA levels in 1990 and 1996 were combined and categorized into two groups. Subjects reporting activity level 1 in both 1990 and 1996 and subjects reporting activity level 1 in one year and level 2 in the other year were regarded as vigorously active. All the other subjects were regarded as having no regular vigorous activity. Earlier studies among the Kainuu Study cohort have indicated validity for this single-item self-assessment of global PA (Haapanen-Niemi et al. 2000, Malmberg et al. 2006). In 1996 subjects were also asked to report the three most typical types of PA they had performed during the past 12 months.

4.3 Assessment of health-related fitness

Assessment of HRF was conducted by the HRF tests targeted at high-functioning older adults. The proposed tests were developed on the basis of the HRF concept (Bouchard and Shephard 1994) and the UKK Institute's HRF Test Battery for Middle-aged Adults, which has been systematically evaluated for its reliability (Suni et al. 1996, Rinne et al. 2001), safety and feasibility (Suni et al. 1998a) and health (Suni et al. 1998b) and PA-related content validity (Suni et al. 1999). In 1996 the proposed tests showed cross-sectional content validity for perceived health and self-reported mobility status. The tests were also reported to be safe and feasible in terms of minor health-related test exclusions. (Malmberg et al. 2002b.)

The participants' invitation to HRF testing included information about the purpose of the study and option to discontinue testing at any time. Each participant signed a statement of informed consent (two identical copies) before taking part in the tests. The participants were instructed to wear proper attire, to refrain from heavy exertion within the preceding 42 hours, to refrain from physical exercise on the testing day, to refrain from any heavy meal 3-5 hours before testing, to refrain from alcoholic beverages within the preceding 24 hours and to bring their glasses and hearing apparatus if needed. The study was approved by the ethics committee of the UKK Institute for Health Promotion Research in 1995 and by The Ethical Committee of Pirkanmaa Hospital District in 2002.

A team of six (1996) or four (2002) health and fitness professionals, all of whom had a degree in sport or health sciences, screened and tested the participants individually at a local gymnasium in each of the three target municipalities. The same places were used for testing in 1996 and 2002. Before the beginning of the study the teams were educated in testing procedures. They had a training period during which they practiced testing until they could demonstrate the proper skills in the procedures to the researchers responsible.

The pre-testing health screening was identical in 1996 and 2002. It included measurement of systolic and diastolic blood pressure (after 5 min rest in a sitting position) and tests of visual acuity (standard vision card, 0-2.0) and hearing accuracy (understanding of conversation over a distance of 5-m, able/not able). The use of spectacles and hearing aids was permitted. The health screening also included a modified PAR-Q (Suni et al. 1998a), a question on perceived health status (Miilunpalo et al. 1997) and a single-item self-assessment of global PA during the previous 12 months (Oja et al. 1994). Based on the screening information testers applied a safety procedure (Suni et al. 1998a, Malmberg et al. 2002b) to exclude non-eligible participants according to the test-specific rules. The participant was regarded as non-eligible for several tests if she/he had severe cardiorespiratory or musculoskeletal symptoms or diseases, risk factors for exercise induced cardiovascular complications, such as significant obesity with inactivity, as well as poor visual acuity hindering safe mobility or poor hearing accuracy causing difficulties in understanding test instructions.

The proposed tests include measures for all the main components of HRF (Bouchard and Shephard 1994). Motor fitness in terms of static balance was assessed by 60-sec one-leg stand (Suni et al. 1996). Backwards walk for 6.1-m (20-ft) (Nelson et al. 1994) was used as an indicator of dynamic balance. Muscular fitness in terms of functional muscle strength of lower extremities was assessed by one-leg squat with increasing weight load (Suni et al. 1996, Malmberg et al. 2002b) and trunk muscle endurance by 30-sec dynamic back extension (Mälkiä 1983). Cardiorespiratory fitness and mobility were assessed by 1-km walk time (Oja et al. 1991) indicating aerobic endurance and walking ability. In addition, maximal walking speed on 6.1-m course (Bassey et al. 1992, Fiatarone et al. 1994) was used as a mobility indicator. Flexibility was assessed by trunk side-bending (Suni et al. 1996). Body composition in terms of relative fatness was assessed by body mass index (BMI) by dividing weight in kilograms by the square of height in meters (kg/m^2). Measurements for body weight and height were conducted with light sports clothing without shoes.

Each subject was tested individually by one of the testers. The tests were administered in a standard order starting with weight and height measurements and balance assessments. The 1-km walk time was assessed last. Each test was explained both verbally and visually before subjects were asked to perform it. A description of testing procedures and the test-specific exclusion criteria are presented in Table 5.

Table 5. Description of health-related fitness testing procedures and test specific exclusion criteria.

Test: **One-leg standing balance**, to assess static postural control when area of support is reduced (Suni et al. 1996).
Method: Subject stands as still as possible on the preferred leg wearing sports shoes. The opposite foot is placed at knee level along the inner side of the supporting leg, with thigh and knee rotated outward and arms relaxed.
Outcome: Duration of balance task up to 60 seconds as measured by a stopwatch (s). Subject has two attempts to achieve maximum time. If maximum time is achieved on the first attempt, the second is not performed.
Exclusion criteria: Severe dizziness, severe symptoms of spine or lower extremities which may be aggravated by the test.

Test: **Backwards walking**, to measure postural control in movement (Nelson et al. 1994).
Method: Subject walks backwards along a marked 6.1-m (20-ft) line with tandem steps (toes touching heels at every step) as quickly as possible. After a 2-m practice trial, the subject performs three trials.
Outcome: Walking times of three trials as measured by a stopwatch (s) from standing position to the end of the line. Best time is final result.
Exclusion criteria: Severe dizziness, severe symptoms of spine or lower extremities which may be aggravated by the test.

Test: **6.1-m (20-ft) walk**, to assess ability to walk (Bassey et al. 1992, Fiatarone et al. 1994).
Method: Subject walks the course twice 1) at "usual" pace; 2) as fast as possible, starting from a stationary position.
Outcome: Performance time (s) of second attempt (as fast as possible) measured by a stopwatch.
Exclusion criteria: Severe dizziness, severe symptoms of spine, hip and knee which may be aggravated by test.

Test: **Trunk side-bending to right and left,** to measure average range of motion in lateral flexion of the thoracic and lumbar spine and pelvis (Suni et al. 1996).
Method: Subject stands on marked lines (15 cm apart) with back against wall and arms and fingers straight at the sides of the body (baseline). Subject slides the middle finger along lateral thigh to right and then to left as far as possible, keeping shoulders and buttocks in contact with the wall and heels in contact with the floor. The tester measures the distance between baseline and maximum slide of middle finger tip.
Outcome: Average distance (cm) between maximal right and left side-bending range of motion measured by a tape measure.
Exclusion criteria: Severe dizziness, severe spinal symptoms which may be aggravated by test movement.

Continued overleaf

Table 5 continued

Test: **One-leg squat with increasing weight load,** to assess functional strength of lower extremities (Suni et al. 1996, Malmberg et al. 2002b).
Method: Subject takes a short step forward, first with the right leg, squats down until knee of tracking leg lightly touches mat, then rises up, and steps back to starting position. Squat is repeated with left leg.
Outcome: Load limit for a successful squat task measured as maximum weight relative to subject's body weight, up to 125% (1-13 points). Test starts with the body weight (i.e. no added weight) and 5% increments of body weight are added at four successive steps of 10%, 15%, 20% and 25%, using a weight vest.
Exclusion criteria: Dizziness, severe diseases or symptoms of cardiovascular system, moderate or severe symptoms of spine, hip and knee which may be aggravated by test movement.

Test: **Dynamic back extension,** to assess trunk extensor muscle endurance (Mälkiä 1983).
Method: Subject lies in a semi-inclined body position (50 degrees) in a portable standing hyper extensor* with hips and lower legs supported, fingers crossed behind neck and upper body lying on table. Subject raises the upper body off table to a straight back level (45 degrees from table level) and returns to starting position as quickly as possible.
Outcome: Maximum number of repetitions in 30 seconds.
Exclusion criteria: Moderate to severe diseases or symptoms of cardiovascular system, severe spinal, hip and knee symptoms which may be aggravated by test movement.

Test: **1-km walk,** to assess sub-maximal aerobic capacity and walking ability (Oja et al. 1991).
Method: Subject walks as fast as possible on a flat surface using normal walking style.
Outcome: Walking time (min) measured by a stopwatch.
Exclusion criteria: Severe diseases or symptoms of cardiovascular system, severe dizziness, severe symptoms of spine, hip and knee which may be aggravated by test.

* Supplier: Standing Hyper Extensor, HUR Ltd., Kokkola, Finland

Photographs by MediaStage Ky

4.4 Assessment of mobility function

In the present study mobility function is understood to reflect a person's perceived mobility, and it is assessed in terms of self-reported mobility difficulties. The assessment was based on similar questionnaire information in both 1996 and 2002. The subjects were asked to report how well they were able to walk 2-km and climb several flights of stairs without a rest. The response alternatives for both questions were 4) able without difficulty, 3) able with some difficulty, 2) able with severe difficulty and 1) not able. Subjects who reported at least some difficulty (response alternatives 1-3) were regarded as having mobility difficulties. Responses to the 2002 questionnaire were used as outcome measures.

4.5 Statistical methods

General characteristics of the study samples were analyzed by cross-tabulations and chi-square test of independence. The selection process of the study population was analyzed by multinomial logistic regression analysis (I). Binary logistic regression analysis was used to estimate predictive value of HRF tests on mobility difficulties (III) and to analyze the effect of PA on predictive values of HRF test performance and BMI on WD (II).

In both multinomial and binary logistic regression analyses the results are presented as odds ratios (OR) with 95% confidence intervals (CI). OR in Studies I and III were expressed according to one unit difference in test results. When the 95% CI of OR did not include 1.00, the result was considered statistically significant at a level of $\alpha=0.05$.

Analysis of covariance was used to analyze the six-year changes in HRF among the subjects who could be tested in both 1996 and 2002 (I) and the cross-sectional association between HRF test performance and PA (II). Due to the skewed distributions of some variables six-year changes in HRF were analyzed with log-transformed test variables. Both interaction and main effects of age and gender were tested. Interactions with p-values less than 10% ($p<0.10$) and main effects less than 5% ($p<0.05$) were considered statistically significant. The anti-log transformation of mean differences in log-transformed variables gives an estimate of the ratio of group means.

Receiver operating characteristic (ROC) curves were generated for the most powerful predictors of mobility difficulties (IV). The ROC analysis evaluates the accuracy of the tests by summarizing the potential of the test to discriminate subjects into those who developed mobility difficulties and those who did not. The area under the curve (AUC) was used as a measure of the overall performance of the ROC curve, since it is equal to the probability that a random person with mobility difficulties will have a poorer test result than a random person without difficulties. The AUC can take values between 0 and 1, where AUC 1 indicates a perfect test for screening and AUC 0.5 indicates screening value equal to chance. Gender-specific cut-off values were calculated for all tests with their respective sensitivity and specificity. Sensitivity indicates the proportion of mobility difficulty cases that performed the test more poorly than the optimal cut-off value, and specificity indicates the proportion of those who maintained their mobility function and performed the test better than the cut-off. Agreement between dichotomized test performance variables (above or below the optimal cut-off value) was assessed by kappa-coefficients.

HRF test results were used as continuous variables in the original Studies III and IV. In Study II performance in HRF tests was categorized into age and gender-specific thirds. Those who were eligible to participate in the HRF assessment, but were unable to perform a specific test, were included in the poorest third. In addition, a summary score of the three tests (backwards walk, one-leg squat, 1-km walk) was created, and the sum was further categorized into three groups. In Study I both continuous and categorized test variables were used. The background characteristics of the subjects and PA information were collected by self-administered questionnaires. Gender, birth cohort, marital status, vocational education and smoking were regarded as potential confounders in all original publications. In addition, level of PA, perceived health status and BMI were adjusted for when describing selection of the study sample (I). In studying changes in HRF during six-year follow-up test results were also adjusted for baseline test performance (I). Level of PA, amount of daily walking, alcohol consumption and information on subject’s home municipality were adjusted for when analyzing the predictive value of HRF test performance on mobility difficulties (III).

The subjects were divided into four age groups according to their birth year: 1937-41 (subjects aged 55-59 years in 1996), 1932-36 (subjects aged 60-64 years in 1996), 1927-31 (subjects aged 65-69 years in 1996) and 1917-26 (subjects aged 70-79 years in 1996). The oldest subjects (subjects born 1917-26) were excluded from the ROC analyses (IV) and analysis for studying interactions between PA and HRF test performance (II). All the analyses were performed with SPSS statistical software, versions 12.0.1 and 14.0 (SPSS Inc, Chicago IL).

5. Results

5.1 Participation in the assessment of health-related fitness (I)

Of the 1,133 subjects who participated in the baseline (1996) HRF assessment 728 (64%) were eligible to be invited to re-testing six years later, and 606 (83%) of these actually participated. The selection of the study population over six years is described in Study I. The subjects who were lost to follow-up were on average four years older and less likely to be physically active than the subjects who participated in re-testing. The re-test (2002) non-participants were also less educated, perceived their health status to be poorer, were more likely to be smokers and had on average higher BMI than the participants. The subjects who performed poorly in the baseline HRF assessment (1996) were more likely to be lost to follow-up over six years than the better performing subjects.

Poorer performance in the baseline HRF assessment also predicted test-specific exclusions and discontinuations in re-testing (Table 6). Poor performance in the 1-km walk and dynamic back extension tests were associated with selection indicators (non-response, non-participation, test-specific exclusion and discontinuation).

In 2002 test-specific exclusion rate was highest (19%) in the dynamic back extension test. Discontinuation rate indicating inability to perform a specific test according to test instructions was highest for the backwards walk test (22%). Both exclusion and discontinuation rates increased with advancing age in all tests. The overall exclusion rate increased with age from 4% among 55 to 59-year-olds to 16% among the 70 to 79-year-olds. The corresponding percentages for discontinuation were 3% and 15% respectively. The 6.1-m walking speed was the most feasible test, having the lowest rates of exclusion and discontinuation (Figure 7).

Table 6. Selection of the study sample during six-year follow-up according to baseline health-related fitness test performance. Re-test participants were used as a reference group.

		Men			Women		
	Risk for	OR	95% CI	p-value	OR	95% CI	p-value
Backwards walk	Non-response	1.07	1.03 to 1.12	0.001	1.02	0.99 to 1.05	0.127
	Non-invited	1.04	0.98 to 1.10	0.214	1.00	0.97 to 1.04	0.926
	Exclusion	1.07	0.87 to 1.32	0.534	0.98	0.88 to 1.11	0.790
	Discontinuation	1.09	1.04 to 1.14	<0.001	1.02	0.99 to 1.04	0.250
6.1-m walk	Non-response	0.91	0.55 to 1.49	0.705	1.12	0.76 to 1.65	0.583
	Non-invited	2.00	1.22 to 3.27	0.006	1.33	0.91 to 0.96	0.146
	Exclusion	NA			NA		
	Discontinuation	NA			NA		
Trunk side-bending	Non-response	1.02	0.94 to 1.11	0.652	1.07	0.98 to 1.18	0.145
	Non-invited	1.08	0.96 to 1.20	0.189	1.05	0.96 to 1.16	0.290
	Exclusion	NA			1.59	1.04 to 2.42	0.031
	Discontinuation	NA			NA		
Dynamic back extension	Non-response	1.07	1.00 to 1.14	0.036	1.05	0.96 to 1.14	0.277
	Non-invited	1.19	1.07 to 1.32	0.002	1.14	1.03 to 1.26	0.014
	Exclusion	1.11	1.03 to 1.21	0.008	1.08	0.99 to 1.18	0.100
	Discontinuation	1.10	0.88 to 1.37	0.390	1.17	1.02 to 1.35	0.026
1-km walk	Non-response	1.32	1.02 to 1.71	0.038	1.32	1.02 to 1.70	0.033
	Non-invited	2.11	1.43 to 3.12	<0.001	1.78	1.37 to 2.32	<0.001
	Exclusion	2.10	1.49 to 2.97	<0.001	1.54	1.14 to 2.08	0.005
	Discontinuation	2.75	1.24 to 6.11	0.013	1.61	1.09 to 2.40	0.017

OR= odds ratio, CI= confidence interval, NA= not applicable

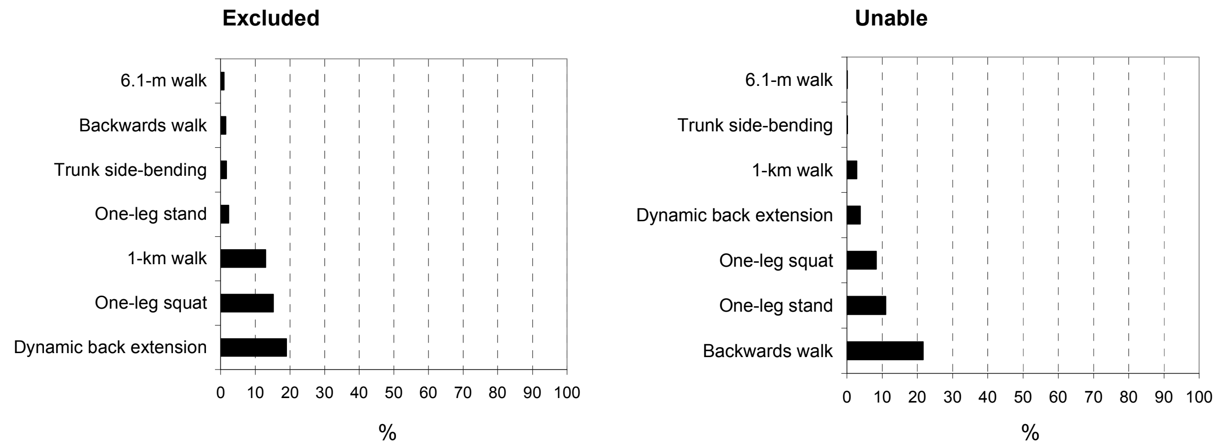


Figure 7. Percentages of test participants excluded from a specific test in 2002 and percentage of test participants unable to perform the tests according to test instructions (=discontinuations).

5.2 Six-year changes in health-related fitness test performance (I)

Performance in HRF tests in 1996 correlated with each other indicating content validity of the tests. The strongest correlations were identified between the dynamic back extension, one-leg squat and 1-km walk tests. Performance in dynamic back extension and 1-km walk also correlated strongly with performance in 6.1-m walk and backwards walk (Table 7).

The heterogeneity of the test results was greater among the older age groups than among the younger groups. In both 1996 and 2002 older age groups performed the HRF tests on average more poorly than the younger groups. There was a linear declining trend in the changes of HRF test results with increasing age: test performance of older people deteriorated on average more than that of younger people (Figure 8). In the backwards walk and dynamic back extension tests the mean performance of younger people even improved during follow-up. Older age groups showed the greatest deterioration in the 6.1-m walk and backwards walk and trunk side-bending tests.

In both 1996 and 2002 men performed the HRF tests on average better than women. During the follow-up period the mean performance of women deteriorated to a greater extent than the average performance of men. The mean performance of women in the backwards walk and dynamic back extension tests deteriorated during follow-up, while the mean performance of men did not change statistically significantly.

Table 7. Partial correlation coefficients for health-related fitness test results in 1996, adjusted for age group and gender (n=1,133).

	One-leg stand	Backwards walk	6.1-m walk	Trunk side-bending	One-leg squat	Dynamic back extension	1-km walk
One-leg stand (s)	1						
Backwards walk (s)	-0.19**	1					
6.1-m walk (s)	-0.22**	0.14**	1				
Trunk side-bending (cm)	0.04	-0.11*	-0.18**	1			
One-leg squat (points)	0.20**	-0.18**	-0.18**	0.15**	1		
Dynamic back extension (repetitions / 30s)	0.23**	-0.28**	-0.35**	0.21**	0.33**	1	
1-km walk (min:s)	-0.28**	0.27**	0.42**	-0.15**	-0.30**	-0.53**	1

* $p<0.05$ ** $p<0.001$

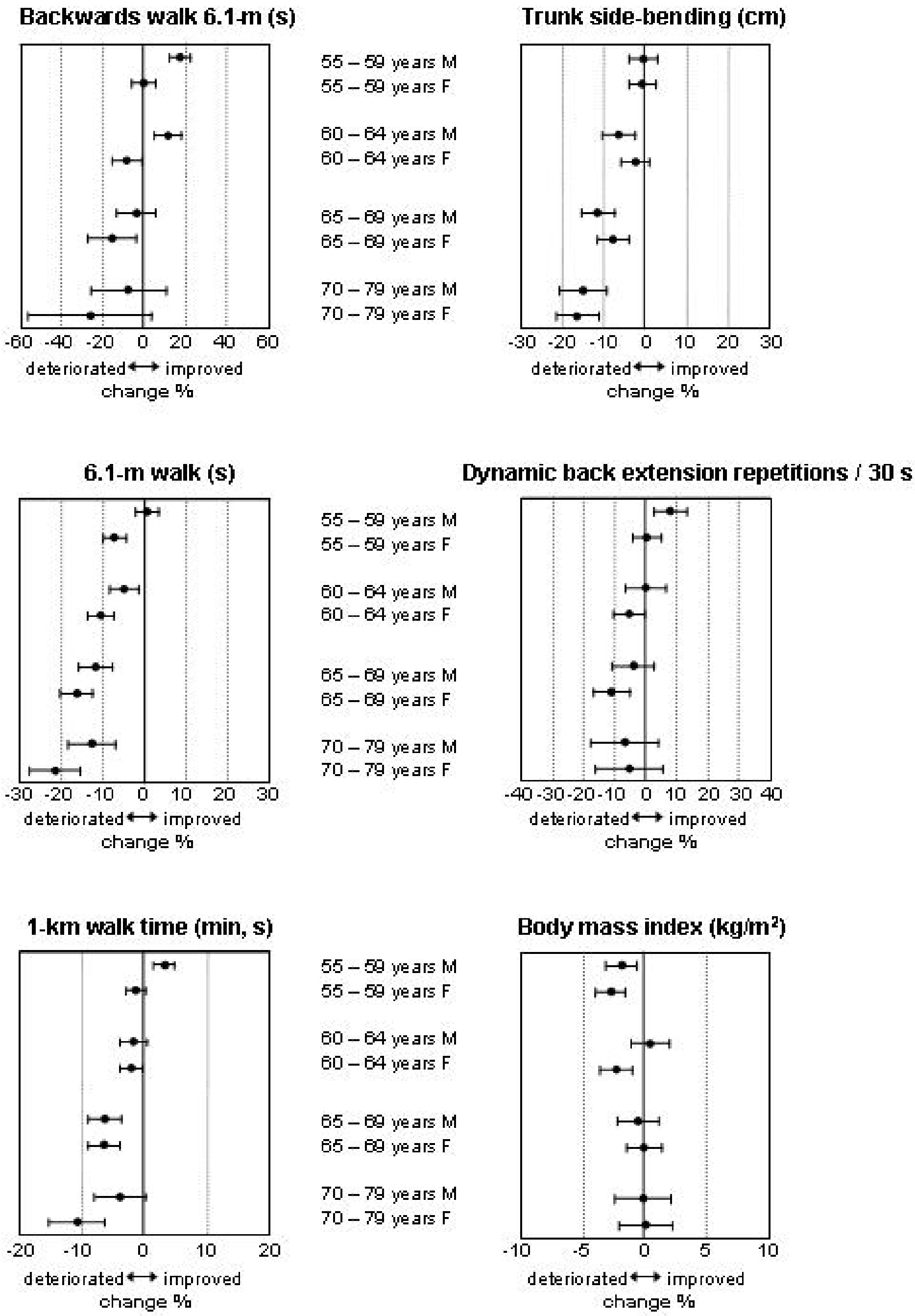


Figure 8. Changes (%) in health-related fitness test performance during six-year follow-up. Age group indicates subjects' ages in 1996. M refers to males and F to females.

The mean BMI increased in the two younger age groups during follow-up, while there were no statistically significant changes in the two older groups (subjects aged 65-79 years in 1996). The mean increase in BMI seemed to be slightly greater among women than among men (1.4% vs. 0.4%, p=0.075), although the difference did not reach the level of statistical significance.

Better baseline test performance was associated with greater deterioration of the results during follow-up. In all tests the mean performance of the subject in the best performing third deteriorated over six years. The mean performance of the poor performers remained unchanged or improved.

5.3 Cross-sectional associations between physical activity and health-related fitness test performance (II)

Among the subjects born in 1927-41 who did not report WD in 1996 over one fourth (28%, n=68) of men and one third (36%, n=108) of women reported vigorous PA (1990-96). Walking was the most typical type of activity in both genders: 75% of subjects reported walking to be their most typical type of activity. The next typical activities were jogging, cycling and skiing.

Subjects who reported vigorous PA performed the dynamic back extension test on average better and walked the 1-km distance on average faster than the non-vigorously active subjects (Table 8). Vigorously active women also performed the one-leg stand, 6.1-m walk, trunk side-bending and one-leg squat tests better than the non-vigorously active women. Additionally, the mean BMI of the vigorously active women was lower than the mean BMI of non-vigorously active women.

Table 8. Cross-sectional associations between physical activity and health-related fitness test performance in 1996. Age-adjusted analysis of covariance.

		Vigorously active		Non-vigorously active		Adjusted	
		n	adjusted mean	n	adjusted mean	mean difference (95% CI)	p-value
One-leg stand (s)	Men	67	42.9	172	42.3	0.6 (-4.9 to 6.1)	0.826
	Women	107	37.0	187	31.8	5.3 (0.6 to 9.9)	0.026
Backwards walk (s)	Men	61	23.8	155	25.1	-1.2 (-3.8 to 1.3)	0.339
	Women	91	32.6	157	32.8	-1.2 (-3.1 to 2.8)	0.909
6.1-m walk (s)	Men	68	3.1	173	3.3	-0.2 (-0.3 to 0.0)	0.071
	Women	108	3.5	188	3.7	-0.2 (-0.3 to 0.0)	0.016
Trunk side-bending (cm)	Men	68	16.1	171	15.4	0.7 (-0.3 to 1.7)	0.194
	Women	107	15.5	188	14.7	0.8 (0.0 to 1.6)	0.041
One-leg squat (points)	Men	68	11.2	171	10.6	0.6 (-0.5 to 1.7)	0.277
	Women	106	8.4	186	6.8	1.6 (0.7 to 2.6)	0.001
Dynamic back extension (repetitions / 30s)	Men	68	19.6	169	17.5	2.1 (0.4 to 3.7)	0.014
	Women	102	15.7	183	13.6	2.1 (1.0 to 3.2)	<0.001
1-km walk (min:s)	Men	68	9:24	167	9:48	-0:24 (-0:46 to -0:01)	0.037
	Women	108	10:06	188	10:37	-0:31 (-0:48 to -0:15)	<0.001
Body mass index (kg/m^2)	Men	68	26.7	173	27.0	-0.3 (-1.2 to 0.6)	0.528
	Women	108	26.8	188	28.0	-1.2 (-2.1 to -0.3)	0.009

CI= confidence interval

5.4 Predictive value of health-related fitness tests and physical activity on mobility difficulties (II, III)

The occurrence of new WD during the six-year follow-up period was 18% among the 55 to 79-year-old men and 23% among women. Among the younger part (55 to 69-year-olds) of the cohort the corresponding percentages were 17% and 18%. New SCD occurred respectively for 21% and 27% of the whole cohort and for 19% and 25% of the younger part. In the single test item analyses poorer performance in 6.1-m walk, dynamic back extension and 1-km walk increased the risk for both types of difficulties. In addition, the risk of WD was increased with poorer baseline performance in trunk side-bending, one-leg stand and backwards walk. Inability to perform backwards walk also increased the risk of WD. Poor performance in one-leg squat predicted SCD in all age groups, but WD only in the older age groups, subjects born 1917-31.

When all statistically significant single test items were entered as predictors into the final multivariable model, both inability to perform the backwards walk (OR=5.01, 95% CI 1.72-14.62) and poorer performance (s) in that test (OR=1.03, 95% CI 1.00-1.06) increased the risk of WD. The poorer the time (min) in the 1-km walk (OR=1.42, 95% CI 1.15-1.76) and the poorer the performance (points) in the one-leg squat test among the older age groups (OR=1.23, 95% CI 1.09-1.39 among 65 to 69-year-olds, OR=1.18, 95% CI 1.01-1.37 among 70 to 79-year-olds) also increased the risk. Regarding SCD poorer performance in the one-leg squat (OR=1.11, 95% CI 1.03-1.20), dynamic back extension (repetitions per 30 s) (OR=1.08, 95% CI 1.02-1.15) and 1-km walk (OR=1.38, 95% CI 1.10-1.73) tests increased the risk.

To analyze the predictive value of HRF tests on mobility difficulties in more detail the effect of PA was taken into account and also the value of BMI in predicting WD was assessed. The analysis included three test items representing the most important fitness factors for mobility function (backwards walk, one-leg squat, 1-km walk). The three HRF tests and PA were independently associated with the occurrence of new WD. In all three tests poor performance increased the risk of difficulties regardless of the activity level and low activity increased the risk regardless of the test performance. The non-vigorously active subjects with poor test performance had the highest risk. The summary score of HRF had higher OR for WD than the individual test items. BMI was also independently associated with difficulties. Overweight in terms of BMI equal to or over 27 kg/m^2 was predictive of difficulties regardless of PA level. Activity and BMI were predictive of difficulties when HRF summary score was not entered into the model (Table 9, model A). Correspondingly, activity and fitness summary score predicted difficulties when BMI was not entered (Table 9, model B). When all three predictors (HRF summary score, BMI and PA) were included in the same model, the predictive value of activity rose slightly over the used level of statistical significance (Table 9, model C).

Table 9. Confounder-adjusted logistic regression analyses on physical activity (PA), health-related fitness summary score (HRF) and body mass index (BMI) to predict self-reported walking difficulties.*

		Risk of walking difficulties		
			OR (95%CI)	p-value
Model A	PA	Vigorous activity	ref.	0.021
		Non-vigorous activity	2.04 (1.11 to 3.75)	
	BMI	<27 kg/m^2	ref.	<0.001
		≥ 27 kg/m^2	2.75 (1.60 to 4.72)	
Model B	PA	Vigorous activity	ref.	0.028
		Non-vigorous activity	2.04 (1.08 to 3.85)	
	HRF	High fit	ref.	<0.001
		Fit	2.93 (1.30 to 6.61)	
		Low fit	7.12 (3.15 to 16.08)	
Model C	PA	Vigorous activity	ref.	0.053
		Non-vigorous activity	1.90 (1.00 to 3.56)	
	BMI	<27 kg/m^2	ref.	0.013
		≥27 kg/m^2	2.08 (1.17 to 3.71)	
	HRF	High fit	ref.	<0.001
		Fit	2.55 (1.12 to 5.81)	
		Low fit	5.79 (2.52 to 13.32)	

*adjusted for gender, age group, age-gender-interaction, smoking, marital status and vocational education

ref.= reference group
OR= odds ratio
CI= confidence interval

5.5 Optimal cut-off values for health-related fitness tests predicting mobility difficulties (IV)

The AUC values indicating the ability of HRF tests to identify risk of WD varied between 0.59 and 0.75 in men and between 0.65 and 0.77 in women (Table 10). In both genders 1-km walk, dynamic back extension and backwards walk showed the highest AUC values, indicating that these tests had the highest predictive value for difficulties. The lowest AUC values were identified for trunk side-bending among men and for one-leg stand among women.

Regarding the predictive value of HRF tests on SCD the AUC values varied between 0.51 and 0.71 in men and 0.59 and 0.71 in women (Table 10). Dynamic back extension and 1-km walk in both genders and one-leg squat in women were the best predictors of SCD. The lowest AUC values were identified for one-leg stand in men and for trunk side-bending in women.

The optimal cut-off values predicting mobility difficulties indicated poorer test performance among women when compared to men. For the proposed HRF tests sensitivity showed that 63% of men and 70% of women reporting WD at follow-up walked the 1-km distance more slowly than the optimal cut-off values. Accordingly, 67% of men and 82% of women who had WD in 2002 performed dynamic back extension more poorly than the cut-off values. However, according to specificity only 59% of women without WD performed the test better than the optimal cut-off. In backwards walk 65% of men and 74% of women with WD performed the test more slowly than the optimal cut-off values.

Regarding SCD, sensitivity showed that 62% of men and 73% of women reporting difficulties at follow-up walked the 1-km distance more slowly than the optimal cut-off values. Specificity in turn indicated that 76% of men and only 59% of women without SCD walked faster than the optimal cut-off values. The optimal cut-off values for one-leg squat (specificity 83%) and dynamic back extension (specificity 77%) were able to identify those men who remained free of difficulties, but the ability of the test to identify SCD risk was poor: sensitivity was 41% in one-leg squat and 54% in dynamic back extension. Among women the sensitivity of the optimal cut-off values in these tests showed that 61% (one-leg squat) and 74% (dynamic back extension) of women reporting SCD at follow-up performed the tests more poorly than the optimal cut-offs at baseline. Corresponding specificities indicated that 69% and 68% of women without SCD performed the test better than these cut-offs.

Table 10. Area under the curve (AUC) values and optimal cut-off values predicting self-reported mobility difficulties during six-year follow-up with corresponding sensitivity and specificity for health-related fitness tests.

		Test	n	AUC	95% CI	p-value*	cut-off	Sensitivity %	Specificity %
Walking difficulties	Men	One-leg stand (s)	239	0.67	0.57 to 0.76	0.001	32.3	58	71
		Backwards walk (s)	241	0.72	0.63 to 0.80	<0.001	27.7	65	69
		6.1-m walk (s)	241	0.68	0.60 to 0.77	<0.001	3.3	70	61
		Trunk side-bending (cm)	239	0.59	0.49 to 0.70	0.065	15.4	59	56
		One-leg squat (points)	239	0.66	0.56 to 0.76	0.001	11.5	55	77
		Dynamic back extension (rpt. /30 s)	237	0.72	0.64 to 0.81	<0.001	16.5	67	65
		1-km walk (min:s)	238	0.75	0.66 to 0.84	<0.001	10:15	63	75
	Women	One-leg stand (s)	295	0.65	0.57 to 0.73	0.001	24.4	62	60
		Backwards walk (s)	296	0.70	0.63 to 0.78	<0.001	35.0	74	61
		6.1-m walk (s)	296	0.67	0.58 to 0.76	<0.001	3.8	64	73
		Trunk side-bending (cm)	295	0.67	0.59 to 0.75	<0.001	13.4	57	76
		One-leg squat (points)	292	0.67	0.58 to 0.75	<0.001	6.5	64	64
		Dynamic back extension (rpt. /30 s)	289	0.69	0.62 to 0.76	<0.001	13.5	82	59
		1-km walk (min:s)	296	0.77	0.70 to 0.83	<0.001	10:47	70	71
Stair climbing difficulties	Men	One-leg stand (s)	229	0.51	0.42 to 0.61	0.764	41.4	47	59
		Backwards walk (s)	230	0.55	0.45 to 0.64	0.330	21.0	72	37
		6.1-m walk (s)	230	0.62	0.52 to 0.71	0.018	3.3	56	59
		Trunk side-bending (cm)	228	0.57	0.48 to 0.67	0.130	16.2	63	45
		One-leg squat (points)	210	0.61	0.51 to 0.72	0.030	11.5	41	83
		Dynamic back extension (rpt. /30 s)	225	0.70	0.62 to 0.79	<0.001	14.5	54	77
		1-km walk (min:s)	227	0.71	0.62 to 0.80	<0.001	10:14	62	76
	Women	One-leg stand (s)	225	0.61	0.52 to 0.70	0.016	23.4	52	69
		Backwards walk (s)	225	0.60	0.52 to 0.68	0.029	29.8	68	49
		6.1-m walk (s)	225	0.64	0.56 to 0.73	0.001	3.6	64	62
		Trunk side-bending (cm)	224	0.59	0.51 to 0.68	0.035	15.5	68	51
		One-leg squat (points)	193	0.71	0.63 to 0.79	<0.001	7.5	61	69
		Dynamic back extension (rpt. /30 s)	220	0.70	0.62 to 0.78	<0.001	13.5	74	68
		1-km walk (min:s)	224	0.71	0.64 to 0.78	<0.001	10:10	73	59

CI= confidence interval
* p-value for difference of AUC equal to change (0.5)

The greatest agreement between the dichotomized test performances was identified for 1-km walk and dynamic back extension in both genders. The proportion of agreement was 70% among men (kappa-coefficient 0.34) and 74% among women (kappa-coefficient 0.47).

Using dichotomized HRF test performance as independent variables, all test items remained statistically significant predictors of WD (Table 11). The OR for WD among the subjects who performed the HRF tests more poorly than the optimal cut-off values varied between 2.30 (95% CI 1.36-3.90) in one-leg stand and 4.82 (95% CI 2.81-8.26) in 1-km walk when compared to the subjects who performed the tests better than the cut-offs. Regarding SCD, poor performance in dynamic back extension, one-leg squat, 1-km walk and 6.1-m walk predicted difficulties. The OR was highest for the dynamic back extension test and lowest for the 6.1-m walk.

Table 11. Confounder-adjusted odds ratios for mobility difficulties according to cut-off-specific health-related fitness test performance. Subjects who performed the tests better than the optimal cut-off values were used as a reference group.*

Test item	Risk for walking difficulties		Risk for stair climbing difficulties	
poorer than the cut-off value	OR (95% CI)	p-value	OR (95% CI)	p-value
One-leg stand	2.30 (1.36 to 3.90)	0.002	1.45 (0.88 to 2.41)	0.145
Backwards walk	3.39 (2.00 to 5.70)	<0.001	1.52 (0.90 to 2.57)	0.120
6.1-m walk	3.48 (2.05 to 5.92)	<0.001	1.91 (1.15 to 3.17)	0.013
Trunk side-bending	2.32 (1.38 to 3.90)	0.001	1.48 (0.88 to 2.48)	0.142
One-leg squat	2.65 (1.54 to 4.56)	<0.001	3.75 (1.82 to 7.73)	<0.001
Dynamic back extension	3.87 (2.23 to 6.71)	<0.001	4.70 (2.75 to 8.04)	<0.001
1-km walk	4.82 (2.81 to 8.26)	<0.001	3.78 (2.20 to 6.51)	<0.001

*adjusted for gender, age group, age-gender-interaction, smoking, marital status and vocational education
OR= odds ratio
CI= confidence interval

6. Discussion

6.1 Methodological considerations

6.1.1 Selection of study sample

The study sample of the present study consisted of a regionally representative cohort of middle-aged and older adults whose living habits, health, physical functioning and mobility function were assessed by postal questionnaires several times between 1980 and 2002. Assessment of HRF targeted at high-functioning individuals aged 55 years and older was included in the study in 1996 and 2002. The feasibility of the proposed HRF tests was evaluated by describing the selection of the study sample during six-year follow-up. The response rates of the questionnaires were relatively high (85% in 1990 and 1996, 66% in 2002) indicating good external validity of the study. The lower response rate in 2002 may be due to new ethical guidelines requiring the respondents to give written permission with their personal signature to allow researchers to link new questionnaire data to the old data.

The subjects who responded to the questionnaires were on average younger, physically more active and they perceived their health status on average to be better than did the non-respondents. In 1996, 36% of the 55 to 79-year-old respondents reported their health status as good or fairly good. In the nationally representative cross-sectional Health 2000 Survey on average 40% of the 55 to 84-year-old respondents perceived their health status to be fairly good or good (Koskinen and Aromaa 2004). The closeness of these percentages in the two studies lends support to the external validity of the present study.

The respondents were invited to participate in HRF assessment if they fulfilled the inclusion criteria: lived in one of three target municipalities (Kajaani, Sotkamo, Suomussalmi), were 55 years old or older and did not report severe difficulties or inability in walking independently outdoors and/or on stairs. In both 1996 and 2002, 87% of the respondents were eligible to be invited to the HRF assessment. Since the respondents were selected to the healthier and physically more active part of the original cohort and since only people not reporting any mobility difficulties at baseline were included in the study, the observed changes in HRF test performance and associations between test performance and mobility difficulties may be underestimations of the true changes and associations in general population.

The study showed that the subjects who participated in the baseline assessment of HRF were younger and physically more active than those who did not participate. Correspondingly, younger and more active subjects were more likely to participate in re-testing six years later. This is in line with earlier studies reporting that subjects who did not attend follow-up measurements were older, frailer and less active at baseline than the re-test participants (Bassey and Harries 1993, Forrest et al. 2006). Furthermore, consistent with earlier studies (Rantanen et al. 1997, Paterson et al. 2004) the subjects with poorer baseline test results were less likely to participate in re-testing. Poorer baseline performance was also associated with more exclusions and discontinuations in re-testing.

In the present study the deterioration of HRF was greatest in the test items with the lowest exclusion rates (i.e. 6.1-m walk, backwards walk and trunk side-bending). These are also the physically least strenuous test items. The selection bias seemed to be greater in the physically more strenuous tests that had higher exclusion rates (i.e. dynamic back extension, one-leg squat and 1-km walk). Since the exclusion rates in general increased with age, the feasibility of these more strenuous tests may be limited in older age groups.

6.1.2 Study methods

Both self-report and performance-based methods were used to gather study data. The advantages and disadvantages of each are discussed in 2.2.3. HRF assessment of the present study included several test items representing the most important fitness factors for mobility function (Guralnik et al. 1994a, Guralnik et al. 1995, Rantanen et al. 2001). Assessment of several fitness factors may increase measurement accuracy (Guralnik et al. 2000) and add value of fitness assessment to be utilized in PA counseling. Performance in HRF test items was timed and continuous scorings were used. According to a review on balance measurements (Whitney et al. 1998) timed instruments or the ratio measurements seem to be more sensitive to change over time than instruments with ordinal measures. Continuous coding has also been reported to have better repeatability than categorical measurement scales and the results of continuous scales do not seem to be dependent on raters as much as those of categorical scales (Rinne et al. 2001). The longitudinal study design, relatively long (six years) follow-up period and reasonable sample size are strengths of the present study as well.

One of the limitations of the study is that only self-reports were used as an outcome measure of mobility function. Earlier studies (Sainio et al. 2006, Stenholm et al. 2007) have used measured walking speed ($\leq$ 1.2 m/s) or inability to finish a 6.1-m gait speed test as a primary indicator of walking limitation. Speed of 1.2 m/s has been reported to have the greatest diagnostic accuracy for self-reported walking difficulty (Stenholm 2007). The same speed has been used as a proxy for the ability to cross the street at light-controlled intersections (Langlois et al. 1997). Rantanen et al. (1999a, 2001) used both self-reported (inability to walk one quarter of a mile) and performance-based assessments (walking speed $\leq$ 0.4 m/s) to define severe walking disability. In the present study walking speed on 6.1-m distance was on average 1.8 m/s at baseline (1996) and 1.7 m/s at follow-up (2002). Only 2.4% (n=16) of the 55 to 79-year-old subjects walked the distance more slowly than 1.2 m/s at baseline. The corresponding percentage at follow-up was 3.9 (n=17). The slowest walking speed was 0.9 m/s both at baseline and at follow-up. Thus, the previously reported cutpoints for walking speed would not have been appropriate to be used as the outcome among high-functioning subjects of the present study. Additionally, use of self-reported mobility difficulties as the outcome indicates the respondents' perceived mobility function in their everyday environment, which reflects their actual level of functional independence. The effects of the selection process are also smaller for self-reports than for performance-based measurements, which leads to a more representative study sample.

The assessment of HRF was conducted at only two points of time. Moreover, information on self-reported mobility function was collected only twice during the six-year time period. More frequent assessments may have revealed more fluctuation and intra-individual variation in both fitness and mobility variables. It is also possible that those who were lost to follow-up may have had a period with mobility difficulties that was not captured. Paterson et al. (2004) reported a corresponding limitation in their study.

The present study was unable to estimate the genetic effects between HRF and mobility function or between PA and mobility. Tiainen et al. (2007) reported that maximal walking speed, muscle strength and power have a genetic effect in common which may lead some individuals to be more prone to functional limitations than others. According to Blair et al. (2001) genetics also affect the magnitude of response to exercise stimulus. However, genetics do not affect alone. Environmental and behavioral factors, like PA patterns, account for approximately half of the variation in fitness factors (Tiainen et al. 2007).

The PA assessment of the present study covered all activity and exercise that lasted at least 15-20 minutes at a time. Specific information about energy expenditure during activity was not available. Earlier studies categorizing PA on the basis of estimated energy expenditure have reported inconsistent findings. Visser et al. (2005a) reported an association between energy expenditure-based PA level and incident mobility limitations while Malmberg et al. (2006) did not. Since walking was clearly the most typical type of PA in the present study sample, it was not possible to analyze the effects of different types of activity on the occurrence of mobility difficulties. In a four-year follow-up study by LaCroix et al. (1993) regular PA was associated with decreased risk of losing mobility regardless of the type of activity. This supports the validity of the PA assessment of the present study. In addition, Ainsworth et al. (1994) reported that the reliability and validity of global leisure-time PA questions, like the PA question of the present study, are good when compared with physiological validation parameters. Using the present study population Haapanen-Niemi et al. (2000) suggested validity for the single-item global PA measurement of the study and Malmberg et al. (2006) reported that the question was associated with occurrence of mobility difficulties among middle-aged and older adults.

6.2 Longitudinal changes in health-related fitness test performance

The six-year changes in HRF test results showed a linear declining trend with increasing age. During the follow-up period the test performance of older people deteriorated on average more than that of younger people and the performance of women deteriorated on average more than that of men. The overall deterioration in test performance among the older age groups is in line with earlier studies (Aniansson et al. 1983, Era and Rantanen 1997, Rantanen et al. 1997, Hughes et al. 2001, Onder et al. 2002, Forrest et al. 2006), although the study designs and testing procedures differed. Rantanen et al. (1997) reported muscle group differences in age-related alterations, and according to Onder et al. (2002) lower-extremity performance seems to deteriorate during follow-up more than upper-extremity performance. In a Finnish study maximal walking speed of 75 to 80-year-old men and women deteriorated on average 17-20% over a five-year follow-up period (Era and Rantanen 1997). Forrest et al. (2006) reported on average a 17% decline in walking speed among older women over 10 years. These are in line with the present findings among the oldest age group (70-79 years) whose walking speed deteriorated on average 17%.

The younger age groups of the present study seemed to improve their performance in some tests (backwards walk and dynamic back extension). These improvements may be due to increased level of PA after recent retirement. This is supported by the Health 2000 Survey (Uutela 2004), the Ikihyvä Päijät-Häme Study (Valve et al. 2003) and by a recent report on the state and development of health-enhancing physical activity in Finland (Fogelholm et al. 2007) reporting that PA is most common in the youngest age groups of those subjects who had reached retirement age.

In the present study the mean performance of the subjects with the best baseline performance (the best third) deteriorated during follow-up on average more than the mean performance of intermediate and poor performers, which is in line with Forrest et al. (2006). Improvements in physical performance occurred mainly among the subjects with the poorest baseline performance. However, regardless of the greater deterioration in the test results the best baseline performers still performed the tests better than the poor performers, which is also in line with Forrest et al. (2006). This may indicate regression towards the mean that is a common phenomenon in longitudinal studies (Era and Rantanen 1997). The better performers have greater reserves to decline than poor performers. In addition, they may have had preclinical disabilities that triggered more precipitous declines in functioning (Onder et al. 2002).

In the present study mean BMI increased in the two youngest age groups (55 to 64-year-olds) and remained unchanged in the older groups. Earlier studies have reported slight changes in body composition with advancing age. In a 12-year follow-up study by Winegard et al. (1996) both height and weight declined significantly in both genders: height losses amounted to 2.5% for males and 3.0% for females, and weight decreased by 5.5% among males and 3.4% among females. A five-year follow-up study by Rantanen et al. (1997) showed on average 1.4% decline in body weight among men and 2.2% decline in women. Suominen (1997) reported statistically significant height decline in both genders during five-year follow-up, but weight decline was apparent only among women and among younger men (75-year-olds). Declining height leads to increased BMI while declining weight leads to decreased BMI. Suominen (1997) reported that decline in body weight among women was not associated with decline in relative proportion of body fat. According to Rikli and Jones (1999b) decline in BMI in older age groups may indicate a loss of muscle mass, bone or organ tissue rather than a loss of body fat. Thus, BMI may not be an adequate indicator of body composition among older adults and decline in BMI may have remarkable consequences for mobility and functional independence.

6.3 Physical activity level and performance in health-related fitness tests

Self-reported methods assessing the level of PA in population studies are inconsistent. Different formulations of the questions and different definitions and categorizations of activities make it difficult to compare results between studies. Rikli and Jones (1999b) reported that 65% of the American study population reported at least moderate level PA. This percentage is close to the proportion of Finnish adults who are reported to be active enough for health benefits (Fogelholm et al. 2007). In the present study a corresponding percentage could not be defined. Vigorous weekly PA was reported by 28% of men and 36% of women at baseline.

In the present study vigorous PA was associated with better HRF test performance, especially among women. Accordingly, a cross-sectional study by van Heuvelen et al. (1994) reported PA-related associations for more fitness indicators among women than men. Rikli and Jones (1999a) also reported clear associations between PA and fitness test performance. Their analysis included both genders, but females were a clear majority. The stronger association between PA and HRF test performance among women may be explained by physiological gender differences. Men have greater muscle mass, strength and power as well as higher aerobic capacity than women. Thus, overall PA, mainly walking in the present study, may not be intense enough to reveal associations with fitness factors among men. A cross-sectional study by Sayers et al. (2005) suggested that men and women may have different strategies to achieve success on different functional tasks. Men appear to rely more on muscle strength in functional tasks that are strength-related. Women on the other hand seem to rely more on contraction velocity. (Sayers et al. 2005.) Thus, the greater muscle strength of men may help them to perform test movements. In the present study the only statistically significant differences between PA groups among men were identified in dynamic back extension and 1-km walk. In the study by van Heuvelen et al. (1994) too, the least active men had poorer walking endurance than the most active men. It sounds logical that vigorous activity, which was mainly walking in the present study, is associated with walking ability. To achieve PA group differences in several test items among men might have needed more specific data on the type, intensity and frequency of PA.

6.4 Health-related fitness tests as predictors of mobility difficulties

Mobility limitations and difficulties are often the first identifiable marks of further deterioration in physical functioning. In population studies this is often indicated by greater occurrence of mobility difficulties than difficulties in everyday activities (ADL). In a four-year follow-up study Guralnik et al. (1995) reported that mobility disability occurred for 19% of the study sample while the occurrence of ADL disability was 10%. A recent follow-up study by Weiss et al. (2007) also indicated a hierarchical pattern in the development of mobility difficulty.

6.4.1 Occurrence of mobility difficulties

Occurrence of WD during the six-year follow-up of the present study was on average 20% and occurrence of SCD was on average 24%. Women were more likely to report both types of mobility difficulties than men. In earlier studies the occurrence of mobility difficulties, limitations and disabilities has varied from study to study depending of the length of follow-up and the definition of the outcome used. During an average 4.9-year follow-up Newman et al. (2006) reported 38% occurrence of mobility limitations and 16% occurrence of mobility disability (severe difficulties or complete inability to perform mobility tasks). In a 2.5-year follow-up study by Visser et al. (2005b) self-reported mobility limitations occurred for 22% of men and 32% of women. During a longer period (4.5 years) the occurrence of new mobility limitations increased to 34% among men and 47% among women (Visser et al. 2005a). According to Rantanen et al. (2001) the occurrence of severe walking disability among older women during three-year follow-up was 23%. Chaves et al. (2000) reported new mobility difficulties for 24% of 70 to 80-year-old women during 1.5-year follow-up. Regardless of the differences in study design and outcome definitions in these studies, women seem to be more prone to mobility problems than men. If the occurrence of mobility difficulties and limitations are interpreted on an annual basis, the occurrence of difficulties in the present study seems to be on a lower level than that in earlier studies. This may be one indication of the high-functioning nature of the present study sample.

In the present study older age groups reported greater occurrence of both WD and SCD than younger groups. Melzer et al. (2004) reported that older age groups seem to be relatively more likely to report mobility disabilities than younger age groups with a corresponding measured performance. The authors suggested that this may be due to differences in living environments or due to attitudes towards reporting (Melzer et al. 2004). Greater occurrence of mobility difficulties among older people may be due to the increased relative exertion of mobility-related tasks. Older people have been reported to have increased muscle co-activation while performing everyday tasks (Hortobagyi et al. 2003) which may be one strategy to compensate age-related decline in several fitness factors. Mobility difficulties reported among older age groups may thus be more due to working at a higher level of effort relative to maximum capability than to the absolute functional demands imposed by the mobility-related task (Hortobagyi et al. 2003).

6.4.2 Tests with the highest predictive value for mobility difficulties

Many studies have analyzed the predictive value of performance-based measurements for mobility-related outcomes as presented in 2.2.5. According to the final logistic regression analyses of the present study poorer performance in 1-km walk and one-leg squat were predictive of both WD and SCD. In addition, poorer performance in dynamic back extension predicted SCD and both inability to perform backwards walk as well as poorer performance in it increased the risk of WD. When the predictive value of HRF tests on WD was assessed in terms of AUC values, 1-km walk, dynamic back extension and backwards walk seemed to be the best predictors. Regarding SCD, highest AUC values indicating the best predictive power were identified for 1-km walk and dynamic back extension. Backwards walk predicted mobility difficulties better than one-leg stand, which may indicate that dynamic balance is more strongly associated with mobility function than static balance. This supports the claim by Duncan et al. (1990) that dynamic balance measures are better than static tasks in assessing functional postural control.

Earlier studies have indicated that balance, muscle strength and walking speed are the most important fitness factors for mobility function among older adults (Guralnik et al. 1994a, Rantanen et al. 2001). Studies have also shown that among high-functioning older adults a combination of test items representing several fitness factors and use of optimally demanding test tasks has greater mobility-related validity than a single, less demanding test item (Lan et al. 2003, Weiss et al. 2007). The tests with the highest mobility-related predictive value identified in the present study also represent the most important fitness factors for mobility. In addition, these tests are safe and feasible with high-functioning older adults (Malmberg et al. 2002b) and they can be performed in field circumstances. In some situations the applicability of the tests may be limited due to the device and time requirements. The dynamic back extension test requires a portable device, the one-leg squat test needs the extra weight loads to be added to the pockets of a weight vest and the 1-km walk requires approximately 10 minutes to perform. However, when compared to laboratory examinations and several other field-based tests with no information about their safety, feasibility and mobility-related validity, these tests provide a practical and validated tool to be used in screening high-functioning older adults.

6.4.3 Role of physical activity in predicting mobility difficulties

The present findings concur with the other longitudinal studies showing that PA is predictive of mobility function (LaCroix et al. 1993, Seeman et al. 1995, Visser et al. 2002, Visser et al. 2005a, Malmberg et al. 2006). In a 2.5-year follow-up study by Seeman et al. (1995) physical exercise predicted better physical performance assessed in terms of a summary score of five performance-based measurements among 70 to 79-year-olds. The authors reported that moderate levels of activity (e.g. leisure walking) conveyed advantages similar to those from strenuous activities (e.g. brisk walking), which supports the latest PA recommendations for older adults (Nelson et al. 2007). A three-year follow-up study among 55 to 85-year-old men and women showed that sports participation, higher level of total PA, walking and household activities were all associated with better maintenance of performance-based mobility function (Visser et al. 2002). In line with that a 4.5-year follow-up study among well-functioning 70 to 79-year-old subjects showed that inactivity was associated with higher risk of self-reported mobility limitations than regular PA. Individuals with an active lifestyle had an intermediate risk. Among the inactive and lifestyle active absence of walking also increased the risk. (Visser et al. 2005a.) These results by Visser et al. (2002, 2005a) support the present findings about the predictive value of PA, mainly walking, on mobility difficulties. Strenuous activities or sports participation seem not to be necessary to maintain good mobility function.

Less intensive activities may also be beneficial in delaying mobility decline. (Visser et al. 2002.)

In the present study PA and HRF test performance were independent predictors of WD, but the predictive value of HRF was stronger than that of PA. Other studies have suggested that fitness is a more powerful predictor of mobility difficulties and dependence than PA (Paterson et al. 2004). This suggests that fitness may be more important for mobility function and health than PA. However, according to Blair et al. (2001) exercise dose-response relationships are more important to study than trying to determine whether activity or fitness is more important for health. From the public health perspective, recommendations, interventions and programs should be designed to promote PA rather than fitness, since fitness is developed by activity (Blair et al. 2001).

Consistent with the present findings it has been reported that overweight in terms of high BMI is associated with poorer performance (Apovian et al. 2002) and is predictive of mobility difficulties (LaCroix et al. 1993, Launer et al. 1994, Stenholm et al. 2007). The present study identified further that BMI is predictive of mobility difficulties regardless of PA, and the predictive value of PA on WD was also independent of BMI. A recent study by Lang et al. (2007) likewise reported that PA decreases the risk of mobility difficulties among older people independent of BMI.

To maintain mobility at higher ages, PA that enhances balance, muscle strength and walking ability should be recommended for older adults. Additionally preservation of normal weight should be encouraged. PA is beneficial for mobility function even if begun later in life. Starting activity in old age may restore muscle strength close that of those having a lifelong activity pattern. Berk et al. (2006) reported that initially inactive participants who increased their activity level achieved increments in disability similar to those who had been active throughout their lives.

6.4.4 Optimal cut-off values predicting mobility difficulties

Performance in HRF tests can be evaluated relative to a peer group (norm-referenced standards) or in relation to pre-determined, desired outcomes (criterion-referenced standards). The first performance standards for the proposed HRF tests were determined by age and gender-specific norm-referenced standards (thirds). The values were presented for 55 to 59-year-olds, 60 to 69-year-olds and for 70 to 79-year-olds. Steffen et al. (2002) stated that age-related data should be used with regard to older adults aged over 60 years, and presented age-related mean values and standard deviations for timed up-and-go test, Berg Balance Scale, 6-min walk and for 6-m gait speed separately for men and women in three age groups: 60-69 years, 70-79 years and 80-89 years. Regarding fitness test batteries for older adults, Netz and Argov (1997) presented means and standard deviations for the same age groups with genders combined. Rikli and Jones (1999b, 2001, 2002) presented normative scores for the Senior Fitness Test separately for both genders in five-year intervals: 60-64 years, 65-69 years, 70-74 years, 75-79 years, 80-84 years, 85-89 years and 90-94 years. These norm-referenced values estimate an individual's performance in relation to reference population and performance can be described to be "on average level", "better than average level" or "poorer than average level".

Criterion-referenced standards allow evaluation of an individual's performance in relation to what is needed or recommended in order to achieve a particular level of health or function. They can give an estimation of performance level regardless of other people's scores. When assessing mobility function a fitness criterion might be set according to the performance level that a person needs in order to be able to function independently within the community or to perform some specific activity. (Rikli and Jones 1997.) In the present study self-reported ability to walk 2 km and climb several flights of stairs were used as such activities. Previously the time needed to cross an intersection within the average time allowed by street lights has been determined as a criterion-referenced standard for walking speed (Langlois et al. 1997, Rikli and Jones 1997).

There are no earlier studies identifying mobility-related cut-off values for performance-based tests in prospective study design. Studies reporting mobility-related outcomes are based on cross-sectional designs (Wang et al. 2005, Whitney et al. 2005, Wang et al. 2006). Prospective (Raiche et al. 2000) and retrospective (VanSwearingen et al. 1998) studies in turn have used fall-related outcomes. The present study reported prospective mobility-related cut-off values for several HRF test items targeted at high-functioning older adults. The sensitivity and specificity values of these optimal cut-off values were on the same level as those identified in earlier fall-related studies (Raiche et al. 2000, VanSwearingen et al. 1998). Earlier cross-sectional studies (Wang et al. 2005, Whitney et al. 2005, Wang et al. 2006) showed somewhat higher sensitivity and specificity values than the present study, which may be due to differences in study design and outcome used. Regarding risk of mobility difficulties in the present study, optimal cut-off values for 1-km walk and dynamic back extension showed the highest sensitivity and specificity values.

Optimal cut-off values with reasonable sensitivity and specificity provide practical markers to identify high-functioning older adults who are at increased risk of declining mobility function and occurrence of mobility difficulties. Cut-off values can be utilized in PA counseling to target activity at those components of fitness that are insufficient for good mobility function. When optimal cut-off values identified in the present study were compared to the previously defined norm-referenced values, cutpoints were located either in the poorest fitness third or in the middle third. This may indicate that PA interventions and other preventive actions should be targeted at high-functioning older adults who perform the tests more poorly than the optimal cut-off values, or in the absence of test-specific cut-off values, at those who belong to the poorest fitness third. However, optimal cut-off values may be dependent on the outcome selected, length of follow-up period and functional status of the population. In future studies the optimal cut-off values identified in the present study need to be tested with other population samples of high-functioning older adults.

7. Main findings and conclusions

The purpose of the present study was to evaluate the ability of the proposed HRF tests to detect early difficulties in mobility function. Referring to the specific aims of the study presented in Chapter 3, the main findings can be summarized as follows:

- During the six-year follow-up time the study sample, eligible to be re-tested was selected to younger, healthier and physically more active subjects. The subjects with better baseline test performance were more likely to participate in re-testing than the poor performers.
- Performance in HRF test items deteriorated linearly with age during six-year follow-up. Deterioration was most pronounced in the older age groups and in women.
- Physical activity was associated with performance in several fitness tests among women. Among men vigorously active subjects performed on average better than non-vigorously active subjects only in dynamic back extension and 1-km walk.
- Baseline test performance in HRF tests was strongly predictive of self-reported mobility difficulties. During six-year follow-up poor performance in backwards walk, dynamic back extension, one-leg squat and 1-km walk increased the risk of difficulties.
- Physical activity did not affect the predictive value of HRF test items and BMI on walking difficulties. Activity, fitness and BMI were independent predictors, the least active subjects with the poorest baseline performance or with overweight having the highest risk.
- Optimal cut-off values predicting mobility difficulties were successfully identified for the proposed HRF tests. Regarding walking difficulties the cut-off values with the highest sensitivity and specificity were identified for backwards walk, dynamic back extension and 1-km walk. Regarding stair climbing difficulties the highest sensitivity and specificity were identified for the optimal cut-off values of dynamic back extension and 1-km walk.

The HRF tests analyzed in the present study were developed for use in identifying risks of mobility difficulties among relatively healthy, high-functioning older adults. Additionally, the tests were aimed to be used in physical activity counseling in order to target activity and exercise at those fitness factors that are not adequate for good mobility function.

The validity of the tests for health status and mobility function has been reported and reliability has been analyzed among other study populations. The proposed tests can be safely used among high-functioning older adults. The tests are quick and easy to administer and score and require only minimal equipment. Both normative and criterion-referenced performance standards have been provided, which improve the usefulness and interpretability of the test scores. In order to promote mobility and functional independence among older adults physical activity interventions and other preventive actions should be targeted at those people whose test performance, especially in backwards walk, dynamic back extension, one-leg squat and 1-km walk, remains below the optimal cut-off values.

In future studies a more complete reliability analysis of the most valid test items is warranted. The optimal cut-off values identified in the present study should be tested with other population samples of high-functioning older adults. Furthermore, an exercise intervention trial to analyze the sensitivity of the proposed HRF tests to change over time would be needed.

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Original publications I-IV

Predictive value of health-related fitness tests for self-reported mobility difficulties among high-functioning elderly men and women

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ABSTRACT. ***Background and aims:*** *The functional independence of elderly populations deteriorates with age. Several tests of physical performance have been developed for screening elderly persons who are at risk of losing their functional independence. The purpose of the present study was to investigate whether several components of health-related fitness (HRF) are valid in predicting the occurrence of self-reported mobility difficulties (MD) among high-functioning older adults.* ***Methods:*** *Subjects were community-dwelling men and women, born 1917-1941, who participated in the assessment of HRF [6.1-m (20-ft) walk, one-leg stand, backwards walk, trunk side-bending, dynamic back extension, one-leg squat, 1-km walk] and who were free of MD in 1996 (no difficulties in walking 2-km, n=788; no difficulties in climbing stairs, n=647). Postal questionnaires were used to assess the prevalence of MD in 1996 and the occurrence of new MD in 2002. Logistic regression analysis was used as the statistical method.* ***Results:*** *Both inability to perform the backwards walk and a poorer result in it were associated with risk of walking difficulties in the logistic model, with all the statistically significant single test items included. Results of 1-km walk time and one-leg squat strength test were also associated with risk, although the squat was statistically significant only in two older birth cohorts. Regarding stair-climbing difficulties, poorer results in the 1-km walk, dynamic back extension and one-leg squat tests were associated with increased risk of MD.* ***Conclusions:*** *The backwards walk, one-leg squat, dynamic back extension and 1-km walk tests were the best predictors of MD. These tests are recommended for use in screening high-functioning older people at risk of MD, as well as to target physical activity counseling to those components of HRF that are important for functional independence.*
(Aging Clin Exp Res 2006; 18: 218-226)

INTRODUCTION

The functional independence of elderly populations deteriorates with increasing age (1). Pre-clinical difficulties in mobility (tiredness or modification of task performance) have been shown to precede more serious mobility difficulties (2) and predict both the future use of health and social services (3) and mortality (4). Thus, it is important to detect pre-clinical changes as early as possible, in order to prevent further deterioration of mobility.

Several studies have shown that measurements of physical performance can predict future mobility disability (5-10), and also institutionalization (6, 11) and mortality (6, 12). Both cross-sectional (13-17) and prospective (6-8, 10, 18-21) studies have shown a strong association between measurements of physical performance and self-reported mobility disability.

However, most of these prospective studies used only a few measures of physical performance or were targeted at functionally limited persons, and therefore assessment has only limited value for physical activity counseling.

The purpose of the present study was to investigate the predictive validity of the proposed battery of health-related fitness tests for the elderly (HRFTE) for self-reported mobility difficulties (MD) among high-functioning older subjects who did not report any difficulties in walking 2 km or climbing several flights of stairs at baseline. The predictive validity of many test items in the HRFTE for MD was not

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Key words: Elderly, follow-up study, health-related fitness, mobility.

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previously investigated, and was based on the content-validity of the tests (14). We hypothesized that poor performance on the HRFTE is associated with future occurrence of MD.

METHODS

Study population

This study forms a part of the Kainuu Study on Living Habits and Health (14, 22). A systematic and regionally representative sample of community-based residents between the ages 19 and 63 was drawn from the 1979 census data of a medium-size industrial town and two rural municipalities in north-east Finland (22). The initial sample included 6787 men and women, 5259 (77.5%) of whom answered the baseline questionnaire in 1980. The sample of the present study consisted of all the men and women who were born in 1917-1941 (aged 55 years or over in 1996) and who undertook the HRFTE in 1996 (n=1133, 80.2% of those invited). Only subjects without MD in 1996 were included (subjects without walking difficulties n=788, subjects without stair-climbing difficulties n=647). Postal questionnaires were used to assess subjects' MD in both 1996 and 2002. The selection of subjects and data collection of this study are presented in Figure 1. Of the 788 subjects who had no walking difficulties in 1996, 92 (11.7%) could not be contacted in 2002, had severe health restrictions, or had died. The corresponding number among the 647 subjects without stair-climbing difficulties in 1996 was 76 (11.7%). Lastly, the analyses of the present study included only subjects who had answered the MD questions in the 2002 questionnaire (n=604 for walking difficulties, n=501 for stair-climbing difficulties).

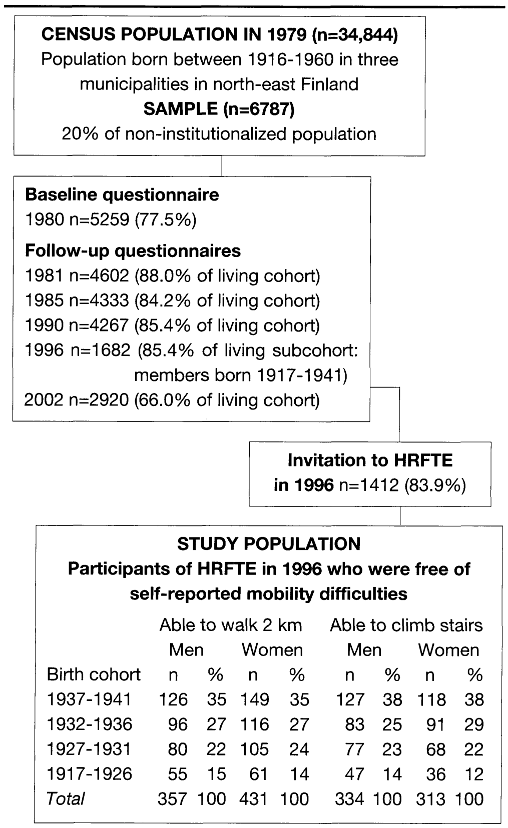

Fig. 1 - *Data collection of Kainuu Study on Living Habits and Health and selection of present study population. HRFTE= Battery of health-related fitness tests for elderly people.*

Procedures

Postal questionnaires, including identical questions on mobility, were sent to the cohort members in 1996 and 2002. Respondents' readiness to participate in the HRFTE in 1996 was pre-screened on the basis of their answers. Exclusion criteria were "living in an institution, or severe difficulties or inability to walk independently outdoors and on stairs". Based on these criteria, 270 (16.1%) respondents were not asked to the testing session in 1996. The invitation to participate in testing contained information about the purpose of the study and the possibility of interrupting the testing session at any time. Each participant signed a statement of informed consent before participation. The study was approved by the ethics committee of the UKK Institute for Health Promotion Research in 1995 and by the Ethical Committee of Pirkanmaa Hospital District in 2002.

A trained team of six health and fitness professionals, all of whom had a degree in sports or health sciences, screened and tested participants individually at a local gymnasium in each of the three target municipalities in 1996. A detailed description of the health screening process has been previously reported (14, 23). Briefly, using selected information from the questionnaires and health screening, the testers applied a systematic safety procedure to exclude non-eligible participants from various tests (14, 23). For example, participants were regarded as non-eligible for several tests if they had any of the following: severe cardiorespiratory or musculoskeletal symptoms or diseases; risk factors for exercise-induced cardiovascular complications, e.g. significant obesity with inactivity; poor visual acuity, hindering safe mobility and testing; poor hearing accuracy, causing difficulties in understanding test instructions.

Assessment of health-related fitness

The UKK Institute for Health Promotion Research has systematically carried out scientific development projects to design practical, reliable and valid tests for the

Table 1 - *Number of HRFTE participants excluded from a specific test, and number of subjects unable to complete tests according to instructions.*

	No walking difficulties in 1996					No stair-climbing difficulties in 1996				
	excluded	**+**	**unable**	**=**	**no result**	**excluded**	**+**	**unable**	**=**	**no result**
6.1-m walk	0		0		0	0		0		0
Backwards walk	5		100		105	3		73		76
One-leg stand	4		1		5	3		1		4
Trunk side-bending	3		0		3	3		0		3
One-leg squat	84		0		84	51		0		51
Dynamic back extension	18		6		24	13		2		15
1-km walk	4		4		8	4		2		6

assessment of health-related fitness (HRF) in middle-aged adults (13, 23-27). The proposed HRFTE is targeted to high-functioning older age groups (55 years and older) and is based on the concept of HRF (28). The HRFTE included seven tests: 6.1-m (20-ft) walk (29), one-leg stand (24), backwards walk (30), trunk side-bending (24), one-leg squat (24), dynamic back extension (31) and 1-km walk (14, 27). A detailed description of the

Table 2 - *Characteristics of study population as percentages among subjects who responded to follow-up questionnaire in 2002 and those who did not.*

	Respondents n=826 %	**Non-respondents n=307 %**
Gender		
men	43	47
women	57	53
Birth cohort		
1937-1941	34	21
1932-1936	26	20
1927-1931	24	24
1917-1926	16	35
Marital status		
single	8	12
married	84	78
widowed	4	6
divorced	4	4
Education		
no professional training or education	30	43
vocational training (preparatory courses)	40	43
secondary education (middle or high school/vocational institute)	24	13
higher education (university/college)	6	1
Physical activity		
vigorous activity at least twice a week	28	16
vigorous activity once a week and some light activity	28	17
light activity weekly	42	65
no regular weekly activity	2	2
Smoking		
never smoker	64	59
current smoker	11	17
past smoker	25	24
Perceived health status		
good	11	5
fairly good	34	29
average	50	55
fairly poor	5	11
poor	0	0

Table 3 - *Total number of subjects who were free of mobility difficulties in 1996, number of subjects who could not be contacted in 2002, number of respondents in 2002, number of subjects without mobility difficulties and number and percentage of subjects reporting mobility difficulties in 2002 according to birth cohort. Missing data section includes subjects who did not answer mobility difficulty questions in 2002 although they responded to the questionnaire in general.*

	Gender	Birth cohort (age in 1996)	Total n in 1996	Died/no contact in 2002	Respondents in 2002	No difficulties in 2002	Difficulties in 2002	Missing data in 2002	% of difficulties in 2002
Difficulties in walking 2 km	Men	1937-1941 (55-59 yrs)	126	6	120	99	12	9	10.8
		1932-1936 (60-64 yrs)	96	12	84	59	15	10	20.3
		1927-1931 (65-69 yrs)	80	16	64	43	13	8	23.2
		1917-1926 (70-79 yrs)	55	16	39	19	9	11	32.1
		Total	357	50	307	220	49	38	18.2
	Women	1937-1941 (55-59 yrs)	149	14	135	106	12	17	10.2
		1932-1936 (60-64 yrs)	116	7	109	87	11	11	11.2
		1927-1931 (65-69 yrs)	105	13	92	50	30	12	37.5
		1917-1926 (70-79 yrs)	61	8	53	16	23	14	59.0
		Total	431	42	389	259	76	54	22.7
Difficulties in stair-climbing	Men	1937-1941 (55-59 yrs)	127	10	117	91	19	7	17.3
		1932-1936 (60-64 yrs)	83	10	73	55	10	8	15.4
		1927-1931 (65-69 yrs)	77	15	62	41	14	7	25.5
		1917-1926 (70-79 yrs)	47	15	32	13	10	9	43.5
		Total	334	50	284	200	53	31	20.9
	Women	1937-1941 (55-59 yrs)	118	8	110	84	13	13	13.4
		1932-1936 (60-64 yrs)	91	7	84	56	17	11	23.3
		1927-1931 (65-69 yrs)	68	7	61	29	26	6	47.3
		1917-1926 (70-79 yrs)	36	4	32	12	11	9	47.8
		Total	313	26	287	181	67	39	27.0

testing methods is presented in the *Appendix*. The tests have shown health-related content validity in terms of mobility status among elderly population (14). A detailed description of the safety and feasibility (14, 23), health- (13, 14) and physical activity- (25) related content validity and reliability (24, 27, 32) of the various tests has been reported elsewhere.

The main purpose of the HRFTE is to identify high-functioning older adults with signs of potential risk of MD. It may also serve as a tool in increasing physical activity, and helps to target exercise to specific factors of HRF that form the risk of functional independence. For example, if subjects perform poorly on the backwards walk test, they can be recommended to perform specific exercises to improve motor performance and especially dynamic balance.

Assessment of self-reported mobility difficulties

Assessment of self-reported MD was based on similar questionnaire information in 1996 and 2002. Subjects reported how well they were able to walk 2 km and climb several flights of stairs without a rest. The response alternatives were: 4="able without difficulty", 3="able with some difficulty", 2="able with severe difficulty" and 1="unable". Only subjects who did not report any difficulties in 1996 (response alternative 4) were included in the study. The response to the 2002 questionnaire was the outcome variable. Subjects reporting difficulties (response alternatives 1-3) were regarded as having MD.

Data analysis

Subjects were divided into four birth cohorts according to their year of birth: 1917-26, 1927-31, 1932-36 and 1937-41. The logistic regression model was used as the statistical method in estimating the odds ratios for difficulties. Analysis included only subjects who answered MD questions in 2002. The results of the HRFTE were used as continuous, predictive variables in analyses. Missing data were handled by the dummy variable adjustment method. Accordingly, a dichotomous indicator variable (0=non-missing, 1=missing) was computed for tests with many missing values due to health-based exclusion or incomplete test performance (one-leg squat and backwards walk). Of the continuous predictive variables, the respective missing values were replaced with the constant value 0. Both continuous variables and dichotomous indicator variables were included as predictors in the logistic regression model. The number of missing values in each test is shown in Table 1. Most of the missing values were due to health-based exclusion, except in the backwards walk test, in which most of the missing values were due to subjects' inability to perform the test according to instructions. The use of dichotomous indicator variables restricted unnecessary drop-out of subjects from analyses and allowed comparison of differences in the occurrence of MD between subjects who were able to complete the test and subjects who were not.

Analyses were performed separately for difficulties in walking and stair-climbing. First the predictive value of each test item was investigated by separate models. Then all the variables having a statistically significant effect on the separate models were included as predictors in one single model. The variables were removed until only the significant predictors ($p<0.05$) were left. Gender, birth cohort, home municipality, marital status, education, body mass index (kg/m^2, BMI), alcohol use, smoking, amount of daily walking, and total level of leisure-time physical activity were included as confounders in all models. Possible interactions between birth cohort, gender and test results were also taken into consideration. Associations between test items were examined by partial correlation coefficients adjusted for birth cohort and gender. All analyses were performed by SPSS software, version 12.0.1 (SPSS Inc, Chicago IL).

RESULTS

Those not responding to the follow-up questionnaire were less likely to be married and had less education than respondents. Non-respondents were on average older than respondents and were more likely to be current smokers. Non-respondents were also physically less active and had poorer perceived health status than respondents (Table 2). The 6.1-m walk, one-leg stand test, trunk side-bending test and 1-km walk were completed by most subjects, whereas the backwards walk and one-leg squat resulted in high numbers of uncompleted tests (Table 1).

The cumulative incidences (%) of MD in 2002 are listed in Table 3. The age-adjusted cumulative incidence for stair-climbing difficulties was higher than that of walking difficulties. In addition, the cumulative incidence of both types of MD was higher among women and older birth cohorts than among men and younger cohorts.

The confounder-adjusted odds ratios for the association between each item of the HRFTE and walking and stair-climbing difficulties are listed in Table 4. The poorer the performance in the 6.1-m walk (s), dynamic back ex-

Table 4 - *Confounder-adjusted* odds ratios (OR) of each health-related fitness test item for occurrence of difficulties in walking 2 km and stair-climbing.*

		p-value	OR	95% CI
Difficulties in walking 2 km				
6.1-m walk	test result (per 1 s)	0.004	1.69	1.18-2.43
Backwards walk	able to complete test (0=yes, 1=no)	<0.001	9.09	3.39-24.34
	test result (per 1 s)	0.001	1.04	1.02-1.07
One-leg stand	test result (per 1 s)	0.012	1.02	1.00-1.03
Trunk side-bending	test result (per 1 cm)	0.034	1.08	1.01-1.15
One-leg squat	able to complete test (0=yes, 1=no)	0.664	0.83	0.35-1.96
	test result (per 1 point†) × birth cohort‡	0.004		
	1937-1941 (55-59 yrs)		1.08	0.97-1.20
	1932-1936 (60-64 yrs)		1.02	0.91-1.14
	1927-1931 (65-69 yrs)		1.28	1.14-1.45
	1917-1926 (70-79 yrs)		1.23	1.06-1.43
Dynamic back extension	test result (per 1 repetition)	<0.001	1.11	1.05-1.17
1-km walk	test result (per 1 min)	<0.001	1.59	1.30-1.95
Difficulties in stair-climbing				
6.1-m walk	test result (per 1 s)	0.006	1.64	1.15-2.34
Backwards walk	able to complete test (0=yes, 1=no)	0.391	1.57	0.56-4.42
	test result (per 1 s)	0.572	0.99	0.97-1.02
One-leg stand	test result (per 1 s)	0.842	1.00	0.99-1.01
Trunk side-bending	test result (per 1 cm) × birth cohort‡	0.037		
	1937-1941 (55-59 yrs)		1.11	0.98-1.27
	1932-1936 (60-64 yrs)		0.93	0.81-1.06
	1927-1931 (65-69 yrs)		1.11	0.98-1.25
	1917-1926 (70-79 yrs)		0.84	0.68-1.03
One-leg squat	able to complete test (0=yes, 1=no)	0.544	0.75	0.30-1.88
	test result (per 1 point†)	<0.001	1.15	1.07-1.24
Dynamic back extension	test result (per 1 repetition)	<0.001	1.13	1.07-1.20
1-km walk	test result (per 1 min)	<0.001	1.61	1.31-1.99

*Adjusted for birth cohort, gender, alcohol use, smoking, marital status, physical activity, daily walking, education, body mass index and home municipality; Logistic regression model. †Sum of points according to ability to squat with progressive amount of extra weight load (carried in pockets of a weight vest) relative to body weight, starting with body weight. ‡interaction of test result and birth cohort. OR= odds ratio; CI= confidence interval.

tension (repetitions) and 1-km walk (min), the higher the risk of both walking and stair-climbing difficulties. Similarly, the poorer the performance in backwards walk (s), trunk side-bending (cm) and one-leg stand (s), the higher the risk of walking difficulties, and the poorer the performance in one-leg squat (points), the higher the risk of stair climbing difficulties. In addition, inability to perform the backwards walk (s) test increased the risk of walking difficulties.

There was an interaction between birth cohort and poor performance in the one-leg squat when considering the occurrence of walking difficulties: poorer test results were associated with an increased risk of difficulties only among the two older birth cohorts [among subjects born in 1927-31 (aged 65-69 yrs in 1996) and 1917-26 (aged 70-79 yrs in 1996)]. Additionally, there was an interaction between birth cohort and test results in the trunk side-bending test: poorer performance was associated with an increased risk of stair-climbing difficulties, in subjects born both in 1937-41 (aged 55-59 yrs in 1996) and 1927-31 (aged 65-69 yrs in 1996). However, neither of the confidence intervals reached the level of statistical significance at $\alpha=0.05$ (95% CI 0.98-1.27 and 0.98-1.25, respectively).

In the final model with all statistically significant single test items as predictors, both inability to perform the backwards walk and poorer performance in that test increased the risk of walking difficulties (Table 5). Poorer time in the 1-km walk also increased the risk. In addition, the interaction between one-leg squat score and birth cohort remained statistically significant, indicating an association between test results and walking difficulties only in the two older birth cohorts [among subjects born in 1927-31 (aged 65-69 yrs in 1996) and 1917-26 (aged 70-79 yrs in 1996)]. Regarding stair-climbing difficulties, poorer performance in the dynamic back extension, one-leg squat and 1-km walk were associated with increased risk.

Some of the test items correlated strongly with each other. In the partial correlation analyses, performance in dynamic back extension, one-leg squat and 1-km walk had the strongest correlations with each other (r=0.24-0.51). In addition, performance in dynamic back extension and 1-km walk correlated with performance in 6.1-m walk (r=0.35 and 0.42) and backwards walk (r=0.30 and 0.26).

DISCUSSION

The main findings of this study showed that, during the 6-year follow-up period, stair-climbing difficulties occurred more often than walking difficulties. Dynamic back extension, one-leg squat and 1-km walk time were the most powerful predictors of stair-climbing difficulties. Regarding walking difficulties, backwards walk and 1-km walk were the most powerful predictors. Additionally, the one-leg squat test predicted difficulties in the two oldest birth cohorts.

The main limitations of this study relate to the representativeness of the study cohort. Those who reported severe difficulty in moving outdoors and on stairs in 1996 (10% of respondents) and those who did not participate in HRFTE, although they were invited to do so (19.8%),

Table 5 - *Confounder-adjusted* odds ratios (OR) of health-related fitness test items for occurrence of difficulties in walking 2 km and stair-climbing when all statistically significant test items in test-specific models were included in one single model. Only statistically significant effects are listed.*

		p-value	OR	95% CI
Difficulties in walking 2 km				
Backwards walk	able to complete test			
	(0=yes, 1=no)	0.003	5.01	1.72-14.62
	test result (per 1 s)	0.026	1.03	1.00-1.06
One-leg squat	able to complete test			
	(0=yes, 1=no)	0.868	0.92	0.37-2.33
	test result (per 1 point†) × birth cohort‡	0.006		
	1937-1941 (55-59 yrs)		1.03	0.92-1.16
	1932-1936 (60-64 yrs)		0.96	0.85-1.09
	1927-1931 (65-69 yrs)		1.23	1.09-1.39
	1917-1926 (70-79 yrs)		1.18	1.01-1.37
1-km walk	test result (per 1 min)	0.001	1.42	1.15-1.76
Difficulties in stair-climbing				
One-leg squat	able to complete test			
	(0=yes, 1=no)	0.676	0.81	0.29-2.22
	test result (per 1 point†)	0.010	1.11	1.03-1.20
Dynamic back extension	test result (per 1 repetition)	0.010	1.08	1.02-1.15
1-km walk	test result (per 1 min)	0.006	1.38	1.10-1.73

*Adjusted for birth cohort, gender, alcohol use, smoking, marital status, physical activity, daily walking, education, body mass index and home municipality; logistic regression model; †Sum of points according to ability to squat with progressive amount of extra weight load (carried in pockets of a weight vest) relative to body weight, starting with body weight; ‡interaction of test result and birth cohort. OR= odds ratio; CI= confidence interval.

were excluded from the study. Additionally, the response rate of the 2002 questionnaire was lower than that of the earlier questionnaire. This was partially due to the application of new ethical rules in Finland: in addition to informed consent, participants were asked to give their written permission to link the new data to former research data. Those who were lost to follow-up were worse at baseline than those who remained in the study. If they had remained in the study, the analysis would probably have had more power to detect MD. However, a corresponding selection bias has also been reported in other studies (13, 33).

Contemporary research findings indicate that lower extremity strength, balance and walking ability are the most essential components of fitness that affect mobility (6-11). In the present study, poorer performance in the one-leg squat (muscular strength) and dynamic back extension (muscular endurance) increased the risk of MD. This is in line with previous studies, which have shown that poor muscle strength predicts poor functional status among the elderly (18, 20, 21) and middle-aged (26) populations. Performance in the one-leg squat test also indicates dynamic balance. In this study, the one-leg squat strength test result predicted walking difficulties only in the two older birth cohorts, which may be an indication of limited lower extremity strength reserves for performing everyday activities at these ages. After comparing the test results between the older and younger birth cohorts of the present study, we found that the strength reserves of the lower extremities needed to be at least 15% of body weight in order to allow subjects to stay free of walking difficulties during follow-up.

Many tests with different levels of challenge for balance performance have been designed for the elderly (6, 9, 14, 16, 34-36). This is necessary due to the heterogeneity of this population. The balance tests of the present study were more challenging than the most commonly used previously validated tests (6-8, 34). Among the high-functioning subjects of the present study, both poor performance (slow walking) and inability to perform the backwards walk test were predictive of walking difficulties. To our knowledge, the predictive validity of this particular balance test has not been previously reported. Regarding the one-leg static balance test, poorer performance increased the risk of walking difficulties when it was analysed separately. This is in line with the previous cross-sectional analysis among the same study population (14). However, in the present study, the predictive power of this test disappeared when it was entered into the final logistic model with the other significant predictors of MD. The predictive power remained non-significant, even when the dynamic balance test was excluded from the model.

Rantanen et al. (9) have reported that poor muscle strength and poor balance are significant independent risk factors of walking disability. They suggested that the co-occurrence of these fitness components increases the risk more than the occurrence of only one, because a deficit in one physiologic system may be compensated for by good capacity in another system. In our study, the results of the one-leg squat and backwards walk correlated with walk time in the 1-km walk, which supports the finding that lower extremity strength, balance and walking are related.

In the present study, walking speed over 6.1-m was predictive of MD only when analysed separately, but was not a statistically significant predictor in the final model. The 6.1-m walk was the same as that used by Bassey et al. (29). However, several modifications of this test are widely used. The 6.1-m walk test was recently used in a large, nationally representative cross-sectional study in Finland (37), which raised the need to report the predictive validity of the test. According to earlier prospective population studies, slow walking speed is the strongest field-based measurement of physical performance predicting functional dependence (8, 10, 19).

Walking performance over a longer distance has previously been identified as a valid indicator of cardiorespiratory fitness (27, 38) and associated with MD in both cross-sectional (14) and prospective (33) studies. In the present study, a poorer 1-km walk time was predictive of both walking and stair-climbing difficulties, which suggests that walking performance over the longer distance (1-km) is a more valid predictor of MD than walking over the shorter distance (6.1-m). Thus, high-functioning older adults, like the subjects of the present study, probably need to be stressed with a longer walk to see a meaningful spread in performance.

Previous studies (13-15) have reported some cross-sectional associations between flexibility and mobility. However, knowledge about the predictive value of flexibility measurements for functional ability is scarce (39). In the present study, trunk side-bending predicted the risk of both types of MD in separate analyses, but the predictive validity of the test disappeared in the final model.

CONCLUSIONS

The proposed HRFTE was designed to be used as a screening method in identifying MD among high-functioning elderly people and as a tool in individual physical activity counseling, to target exercise to the weakest components of fitness. Based on the findings of the present study, the 1-km walk, dynamic back extension, one-leg squat and backwards walk can be recommended for these purposes in several community settings. Of the proposed HRFTE, these four tests had the best predictive validity for MD. They can be recommended in promoting physical activity and functional independence in high-functioning elderly people. However, their applicability may be limited, due to device and time requirements: The dynamic back extension test requires a portable device, the one-leg squat test needs extra weight loads to be added to the pockets of a weight vest, and the 1-km walk requires approximately 10 minutes to perform.

APPENDIX

Description of battery of health-related fitness tests for elderly people and test-specific exclusion criteria.

Test: 6.1-m (20-ft) walk, to assess ability to walk (29).
Method: Subject walks course twice 1) at "usual" pace; 2) as fast as possible, starting from a stationary position.
Outcome: Performance time (s) of second trial (as fast as possible) measured by a stopwatch.
Exclusion criteria: Severe dizziness, severe symptoms of spine, hip and knee which may be aggravated by test.

Test: One-leg standing balance, to assess static postural control when area of support is reduced (24).
Method: Subject stands as still as possible on preferred leg, wearing sports shoes. Opposite foot is placed at knee level along inner side of supporting leg, with thigh and knee rotated outward and arms relaxed.
Outcome: Duration of balance task up to 60 seconds as measured by a stopwatch (s). Subject has two trials to achieve maximum time. If maximum time is achieved on first trial, second trial is not performed.
Exclusion criteria: Severe dizziness, severe symptoms of spine or lower extremities which may be aggravated by test.

Test: Backwards walking, to measure postural control in movement (30).
Method: Subject walks backwards along a marked 6.1-m (20-ft) line with tandem steps (toes touching heel at every step) as quickly as possible. After a 2-meter practice trial, subject performs three trials.
Outcome: Walking times of three trials as measured by a stopwatch (s) from standing position to end of line. Best time is final result.
Exclusion criteria: Severe dizziness, severe symptoms of spine or lower extremities which may be aggravated by test.

Test: Trunk side-bending to right and left, to measure average range of motion in lateral flexion of thoracic and lumbar spine and pelvis (24).
Method: Subject stands on marked lines (15 cm apart) with back against wall and arms and fingers straight at the sides of the body (baseline). Subject slides middle finger along lateral thigh to right and then left as far as possible, keeping shoulders and buttocks in contact with wall and heels in contact with floor. Tester measures distance between baseline and maximum slide of middle finger tip.
Outcome: Average distance (cm) between maximal right and left side-bending range of motion, measured by a tape measure.
Exclusion criteria: Severe dizziness, severe spinal symptoms which may be aggravated by test movement.

Test: Dynamic back extension, to assess trunk extensor muscle endurance (31).
Method: Subject lies in a semi-inclined body position (50 degrees) in a portable standing hyper-extensor (Standing Hyper Extensor, HUR Ltd., Kokkola, Finland) with hips and lower legs supported, fingers crossed behind neck and upper body lying on table. Subject raises upper body off table to a straight back level (45 degrees from table level) and returns to starting position as quickly as possible.
Outcome: Maximum number of repetitions in 30 seconds.
Exclusion criteria: Moderate to severe diseases or symptoms of cardiovascular system, severe spinal, hip and knee symptoms which may be aggravated by test movement.

Test: One-leg squat with increasing weight, to assess functional strength restrictions of leg extensors (24).
Method: Subject takes a short step forward, first with right leg, squats down until knee of tracking leg lightly touches mat, then rises immediately, and steps back to starting position. Squat is repeated with left leg.
Outcome: Load limit for a successful squat task measured as maximum weight relative to subject's body weight, up to 125% (1-13 points). Test starts with body weight (i.e., no added weight) and 5% increments of body weight are added at 4 successive steps of 10%, 15%, 20% and 25%, using a weight vest.
Exclusion criteria: Dizziness, severe diseases or symptoms of cardiovascular system, moderate or severe symptoms of spine, hip and knee which may be aggravated by test movement.

Test: 1-km walk, to assess sub-maximal aerobic capacity (27).
Method: Subject walks as fast as possible on a flat surface using normal walking style.
Outcome: Walking time (min) measured by a stopwatch.
Exclusion criteria: Severe diseases or symptoms of cardiovascular system, severe dizziness, severe symptoms of spine, hip and knee which may be aggravated by test.

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Health-related fitness tests as predictors of difficulties in long-distance walking among high-functioning older adults

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ABSTRACT. ***Background and aims:*** *Health-related fitness (HRF) tests are valid predictors of self-reported mobility difficulties among high-functioning older adults. The aim of the present study was to identify optimal cut-off values for HRF tests predicting self-reported difficulties in walking 2 km (WD).* ***Methods:*** *Subjects were 55- to 69-year-old men and women who were free of WD at baseline. The HRF assessment in 1996 included seven test items, and postal questionnaires were used to assess occurrence of new WD in 2002. Analysis of covariance and receiver-operating characteristic analysis were used as statistical methods.* ***Results:*** *In a 1-km walk, the sensitivity and specificity at the optimal cut-off 10:15 (min:s) for men were 63% and 75%, and at the cut-off 10:47 for women 70% and 71%. In dynamic back extension, the sensitivity and specificity at the optimal cut-off 16.5 (repetitions) were 67% and 65% in men and 82% and 59% at cut-off 13.5 in women. Correspondingly, in backward walking, the sensitivity and specificity at the optimal cut-off 27.7 (seconds) were 65% and 69% in men and 74% and 61% at cut-off 35.0 in women.* ***Conclusions:*** *The 1-km walk, dynamic back extension and backward walking tests had the best predictive value for WD. These tests, with identified cut-off values, can be used to screen individuals who are at increased risk of WD. Tests can also be used in physical activity counseling to target activity to those components of HRF that indicate poor fitness and are important for good walking ability.*
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INTRODUCTION

According to the disablement process model presented by Verbrugge and Jette (1), decline in various components of fitness (impairment) precede functional limitations and disability. Pre-clinical difficulties in mobility, such as self-reported tiredness or modification of task performance, have been shown to precede more serious mobility difficulties (2), and predict future use of health and social services (3) and mortality (4). In order to be able to retard the disablement process, it is important to detect negative changes in mobility as early as possible.

Both self-reports and performance-based measures have been used to assess mobility status of older adults (5-9). Self-reported information and results of performance-based measurements have been reported to complement each other (5, 10-12). However, in the early stages of mobility decline, self-reports alone seem to be less sensitive to changes than performance-based measurements (5) and they may lack the ability to detect deterioration in mobility.

Earlier prospective studies (9, 13-16) have shown that measurements of physical performance are valid predictors for mobility difficulties among elderly people. There is no gold standard to identify mobility-related limitations by means of one objective test, and thus tests associated with mobility difficulty have been used to monitor the underlying characteristics of mobility-related limitations (6). Our previous prospective study (17) investigated whether several components of health-related fitness (HRF) are valid in predicting the occurrence of self-reported mobility difficulties (difficulties in walking 2 km and climbing several flights of stairs). The present study forms a continuation to the previous report, and the purpose was to identify optimal cut-off values for tests predicting self-reported walking difficulties (WD) among high-functioning older adults during a six-year follow-up period. Optimal cut-off values can be used to identify older persons who are at risk of deterioration of walking ability. WD

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Key words: Follow-up study, health-related fitness, mobility, older adults.

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was chosen as the outcome, because walking is a basic mobility function (6) and is also a relatively environment- and culture-free marker of the development of more severe mobility difficulties and disabilities (18).

METHODS

Subjects

The study forms a part of the Kainuu Study on Living Habits and Health. A systematic and regionally representative sample of community-based residents between the ages of 19 and 63 years was drawn from the 1979 census data of a medium-sized industrial town and two rural municipalities in north-east Finland (19). The initial sample included 6787 men and women, 5259 (77.5%) of whom answered the baseline questionnaire in 1980. The cohort was followed-up by postal questionnaires in 1981, 1985, 1990, 1996 and 2002. In 1996 and 2002, respondents aged 55 years and older were invited to assessment of HRF in their home municipalities. The sample of the present study consisted of all the men and women who were born between 1927 and 1941 (subjects aged 55 to 69 years in 1996), who did not report WD, and who participated in the HRF assessment in 1996 (n=672). Over a period of six years, 135 persons (20% of the sample) were lost to follow-up, because they could not be contacted (n=62), refused to respond to the follow-up questionnaire (n=67), or had severe health restrictions (n=6). Thus, the analysis identifying optimal cut-off values included 537 persons who responded to the questionnaire in 2002.

Procedures

Postal questionnaires were sent to the cohort members in both 1996 and 2002, and respondents' readiness to participate in HRF assessment in 1996 was pre-screened on the basis of their answers. Exclusion criteria were "living in an institution" or "having severe difficulties or inability to walk independently outdoors and up and down stairs". Each participant signed a statement of informed consent before participation. The study was approved by the ethics committee of the UKK Institute for Health Promotion Research in 1995 and by the Ethical Committee of Pirkanmaa Hospital District in 2002.

Assessment of health-related fitness. Assessment of HRF was conducted by the proposed battery of HRF tests targeted at high-functioning older adults (17, 20, 21). The battery includes measurements of all main components of HRF, which provides applicability in physical activity counseling. The individual test results can be used in targeting physical exercise at those components of HRF that need to be improved for good mobility and functional independence.

The present study included seven HRF tests targeted at high-functioning older adults: 6.1-m (20-ft) walk (22, 23), backward walk (24), one-leg stand (25), trunk side-bending (25) one-leg squat (20, 25), dynamic back extension (26) and 1-km walk (20, 27). The tests were selected from a former battery of HRF tests for middle-aged adults (25, 28). In a cross-sectional study (20), the tests were modified to be feasible for older adults, and showed health-related content validity among the present study population.

A team of six trained health and fitness professionals, all of whom had a degree in sport or health sciences, screened and tested the participants individually at a local gymnasium in each of the three target municipalities in 1996. Using the selected information from the questionnaires and health screening, the testers applied a systematic safety procedure, to exclude non-eligible participants from selected tests (20, 28). The time needed for one person to complete the whole test battery, including pre-testing health screening, was about 60 minutes. The descriptions of HRF tests and test-specific exclusion criteria are listed in the *Appendix*.

Assessment of self-reported walking difficulties. Assessment of WD was based on similar questionnaire information in 1996 and 2002. Subjects reported how well they were able to walk 2 km without a rest. The response alternatives were 4= "able without difficulty", 3= "able with some difficulty", 2= "able with severe difficulty" and 1= "not able". Only subjects who did not report any difficulties in 1996 (response alternative 4) were included in the study. The response to the 2002 questionnaire was the outcome variable. Subjects reporting difficulties (response alternative 1-3) were regarded as having WD.

Statistical analysis

Analysis of covariance was used to analyse baseline differences in HRF test performance between subjects who reported WD at follow-up and subjects who did not.

The receiver-operating characteristic (ROC) curve was used as a statistical method in finding the predictive value of HRF tests. ROC analysis evaluates the accuracy of tests by summarizing their potential to discriminate subjects into those who developed WD and those who did not. The area under the curve (AUC) was used as a measure of the overall performance of the ROC curve, since it is equal to the probability that a random person with WD will have a poorer test result than a random person without WD. The AUC assumes values between 0 and 1, where an AUC of 1 is perfect discrimination and 0.5 represents a test equal to chance. The analyses were first performed in four age groups but, since there were no consistent age-related trends in the results and the number of WD cases in each group was relatively small, the age groups were combined for final analyses. On the basis of the ROC analyses, gender-specific cut-off values were calculated for all tests with their respective sensitivity and specificity. The true positive rate (sensitivity) was plotted against the false positive rate (1-specificity). The perfect cut-off point is shown in the upper left corner of the ROC diagram, and the point closest to this was considered to be the optimal cut-off value, to minimize misclassifications (29, 30). In addition, agreement between dichotomized (above or below cut-off) test performance variables was assessed by kappa-coefficients.

To avoid excess decrease in the sample size, we assumed that subjects who were eligible to participate in the HRF assessment, but who had interruptions in specific tests, were regarded as poor performers and were given a test value indicating poor performance (equal to the poorest measured test value). Seventy-three subjects were unable to complete the backward walk according to test instructions, 64 subjects did not have a result in the one-leg squat, 4 subjects interrupted the dynamic back extension and 3 subjects interrupted the 1-km walk. All analyses were conducted separately for men and women with SPSS software, version 12.0.1 (SPSS Inc, Chicago, IL).

RESULTS

Subjects who were lost to follow-up (n=135) were older, physically less active, and had poorer perceived health status than subjects who answered the follow-up questionnaire in 2002 (n=537). Correspondingly, among respondents, subjects who developed WD (n=93) during follow-up were older, physically less active, and had poorer health status than subjects who did not report WD (n=444). The general characteristics of the study sample are listed in Table 1.

The occurrence of new WD cases by the year 2002 was 17% among men and 18% among women. Subjects who reported WD at follow-up performed on average more poorly at baseline HRF assessment than those who maintained their self-reported walking ability. The difference between the groups was statistically significant in the 6.1-m walk, one-leg squat, dynamic back extension and 1-km walk in both genders. In addition, men who reported WD at follow-up performed more poorly in the one-leg stand than men without WD, and women with WD performed on average more poorly in the backward walk and trunk side-bending than women without WD (Table 2).

The results of ROC analysis are listed in Table 3. The AUC values varied between 0.59 and 0.75 in men, and between 0.65 and 0.77 in women. In both genders, the 1-km walk, dynamic back extension and backward walk tests showed the highest AUC values, indicating that they had the highest predictive value for WD.

The optimal cut-off value for the 1-km walk time was 10:15 (min:s) in men and 10:47 in women. The sensitivity values showed that 63% of men and 70% of women who

Table 1 - *General characteristics of study sample in 1996, according to whether subjects reported self-reported walking difficulties in 2002 or not.*

		No WD* n=444	WD* n=93	
		%	%	*p*-value
Gender	women	55	57	
	men	45	43	0.690
Age group	55-59	46	26	
	60-64	33	28	
	65-69	21	46	<0.001
Marital status	single	7	9	
	married	87	78	
	widowed	2	5	
	divorced	4	8	0.058
Education	no vocational training or education	23	31	
	vocational training (preparatory courses)	37	43	
	secondary education (middle or high school/vocational institute)	31	21	
	higher education (college/ university)	8	5	0.179
Physical activity	vigorous activity at least twice a week	38	27	
	vigorous activity once a week and some light activity	33	31	
	no vigorous activity	29	42	0.002
Smoking	never smoker	65	65	
	current smoker	8	15	
	past smoker	27	20	0.091
Perceived health status	good	16	10	
	fairly good	43	27	
	average	39	56	
	fairly poor	2	7	<0.001

*WD= self-reported difficulty in walking 2 km without resting.

reported WD at follow-up walked the 1-km distance more slowly than the cut-off values.

The optimal cut-off value for dynamic back extension was 16.5 (repetitions per 30 s) in men and 13.5 in women. According to the sensitivity values, 67% of men and 82% of women who had WD in 2002 performed the test worse than the cut-off values. Regarding specificity, only 59% of the women without WD performed better than this cut-off.

The optimal cut-off for the backward walk was 27.7 (s) in men and 35.0 in women. Sensitivity values indicated that 65% of men and 74% of women with WD performed the test more slowly than the cut-off values.

The greatest agreement between the dichotomized test performances was identified for the 1-km walk and dynamic back extension in both genders. The proportion of agreement was 70% among men (kappa-coefficient 0.34) and 74% among women (kappa-coefficient 0.47).

DISCUSSION

The purpose of the present study was to provide practical assessment tools to identify persons at risk of WD among high-functioning older adults. The study was based on our previous report (17), which found that all of the tests analysed were predictive for WD when analysed independently: the risk of incident WD (OR) increased from 1.02 (one-leg stand) to 1.69 (6.1-m walk) according to one unit of negative change in test performance. According to multivariate analysis, the backward walk and 1-km walk were the most powerful predictors of WD. In ad-

Table 2 - *Unadjusted comparison of mean baseline health-related fitness test results between subjects who developed self-reported walking difficulty during follow-up and subjects who maintained their walking ability.*

		WD at follow-up		No WD at follow-up		
		Mean (SE*)	**n**	**Mean (SE*)**	**n**	***p*-value**
One-leg stand (s)	Men	33.8 (1.4)	38	44.1 (0.4)	201	0.003
	Women	28.7 (2.8)	51	34.7 (1.3)	243	0.057
Backward walk (s)	Men	27.3 (1.6)	28	24.3 (0.6)	188	0.087
	Women	38.8 (1.9)	37	31.6 (0.8)	211	0.001
6.1-m walk (s)	Men	3.54 (0.10)	40	3.20 (0.04)	201	0.002
	Women	3.82 (0.08)	53	3.55 (0.04)	243	0.003
Trunk side-bending (cm)	Men	14.8 (0.6)	39	15.6 (0.3)	200	0.132
	Women	13.8 (0.5)	53	15.3 (0.2)	242	0.003
One-leg squat (points)	Men	8.7 (0.6)	38	11.2 (0.3)	201	<0.001
	Women	5.8 (0.6)	50	7.7 (0.3)	242	0.003
Dynamic back extension (repetitions per 30s)	Men	14.4 (0.9)	39	18.9 (0.4)	198	<0.001
	Women	12.2 (0.7)	49	14.8 (0.3)	236	0.001
1-km walk (min:s)	Men	10:41 (0:13)	36	9:30 (0:05)	199	<0.001
	Women	11:10 (0:10)	53	10:16 (0:05)	243	<0.001

WD= self-reported walking difficulty; SE=standard error.

Table 3 - *Area under curve (AUC) values and optimal cut-off values predicting self-reported walking difficulty during six-year follow-up, with corresponding sensitivity and specificity for health-related fitness tests.*

		n	AUC	95% CI	*p*	cut-off	SE* %	SP† %
Men	One-leg stand (s)	239	0.67	0.57-0.76	0.001	32.3	58	71
	Backward walk (s)	241	0.72	0.63-0.80	<0.001	27.7	65	69
	6.1-m walk (s)	241	0.68	0.60-0.77	<0.001	3.3	70	61
	Trunk side-bending (cm)	239	0.59	0.49-0.70	0.065	15.4	59	56
	One-leg squat (points†)	239	0.66	0.56-0.76	0.001	12	55	77
	Dynamic back extension (repetitions /30 s)	237	0.72	0.64-0.81	<0.001	16.5	67	65
	1-km walk (min:s)	238	0.75	0.66-0.84	<0.001	10:15	63	75
Women	One-leg stand (s)	295	0.65	0.57-0.73	0.001	24.4	62	60
	Backward walk (s)	296	0.70	0.63-0.78	<0.001	35.0	74	61
	6.1-m walk (s)	296	0.67	0.58-0.76	<0.001	3.8	64	73
	Trunk side-bending (cm)	295	0.67	0.59-0.75	<0.001	13.4	57	76
	One-leg squat (points†)	292	0.67	0.58-0.75	<0.001	7	64	64
	Dynamic back extension (repetitions /30 s)	289	0.69	0.62-0.76	<0.001	13.5	82	59
	1-km walk (min:s)	296	0.77	0.70-0.83	<0.001	10:47	70	71

*SE= sensitivity; †SP= specificity.

dition, the one-leg squat predicted difficulties among the oldest subjects. Based on these results the present study aimed at identifying optimal cut-off values for the proposed HRF tests, in order to provide practical tools for screening purposes and physical activity counseling targeted at high-functioning older adults.

The findings of the present study show that all the tests included in the proposed test battery, except for trunk side-bending among men, predicted WD. The highest AUC values were found for the 1-km walk (0.75 in men, 0.77 in women), dynamic back extension (0.72 in men, 0.69 in women) and backward walk (0.72 in men, 0.70 in women). This indicates that these three tests have the highest ability to identify individuals who are at risk of WD. Stel et al. (31) reported AUC of 0.67 for mediolateral sway, 0.61 for tandem stand, 0.58 for leg extension strength, and 0.57 for hand grip strength in predicting recurrent falls among 69- to 92-year-old subjects in 1-year follow-up. Compared with these results, our AUC values were higher with a longer follow-up period. Chaves et al. (32) studied the predictive value of combinations of mobility measures (self-reported modification in mobility tasks, one-leg standing balance, tandem stand, chair stand, hip extensor strength, grip strength, and time to walk 1 m) for self-reported mobility difficulty in 18-month follow-up among high-functioning women aged 70-80. They reported AUC of 0.73 for the best predictive model (self-reported modification in mobility tasks, one-leg standing balance, and 1-m walk), which is close to the highest AUC values of the present study.

In the cross-sectional study of Bischoff et al. (33), ROC analysis revealed high diagnostic validity for discriminating community-dwelling and institutionalized elderly women by the timed "up and go" test (AUC 0.97). The higher AUC found by Bischoff et al. (33), compared with ours, may partly be due to their cross-sectional study design and the nature of the outcome variable used: categorization of subjects into community-dwelling and institutionalized is clearer than that of high-functioning subjects according to their self-reported walking ability.

Most previously validated tests or test batteries have established population-based norm-referenced values for test performances (7, 10, 14, 15, 34). An earlier longitudinal study (35) and a retrospective study (36) identified criterion-referenced cut-off values with established sensitivity and specificity for measurements of physical performance among older adults. Raiche et al. (35) identified the optimal cut-off value for the Tinetti balance scale in order to predict fall risk, with sensitivity of 70% and specificity of 52%. VanSwearingen et al. (36) reported 79% sensitivity and 71% specificity for the Physical Performance Test and 62% sensitivity and 87% specificity for the Modified Gait Abnormality Rating Scale, in order to identify older veterans with a history of recurrent falls. In the present study, optimal cut-off values with the highest sensitivity and specificity (%) predicting WD were identified for 1-km walk, dynamic back extension, and backward walk. These percentages are close to those reported in earlier studies.

A few cross-sectional studies have also reported criterion-referenced cut-off values for physical performance measurements (12, 37). Wang et al. (12) studied cut-offs for five performance tests (functional reach, 5-minute walk, 50-ft (15.2-m) walk, 5-step test, and timed floor transfer) in order to distinguish subjects with mobility disabilities, with decreased mobility, and with no mobility difficulties among 60-91-year-old men and women. In the present study, we categorized subjects into only two categories: subjects without WD and subjects with new WD. The optimal cut-off for the 50-ft walk test as reported by Wang et al. (12) had 74% sensitivity and 67% specificity in distinguishing impaired mobility from intact mobility. The corresponding percentages were 71 and 79 for the optimal cut-off for the 5-minute walk test. In the present study, the optimal cut-offs for the walk tests showed somewhat lower sensitivities (6.1-m: 70% in men, 64% in women, 1-km: 63% in men, 70% in women) and specificities (6.1-m: 61% in men, 73% in women, 1-km: 75% in men, 71% in women) than those presented by Wang et al. (12).

When walk test results are expressed as walking speed (m/s), it may be seen that the speeds of the present study (6.1-m walk: 1.85 m/s for men, 1.61 m/s for women, 1-km walk: 1.63 m/s for men, 1.55 m/s for women) are much faster than those of Wang et al. (12) (50-ft walk: 0.71 m/s, to distinguish decreased and disabled persons, 0.96 m/s, to distinguish able and decreased persons). This may be due to differences in study design (prospective *vs* cross-sectional) and subject characteristics between the two studies. The present study was targeted at high-functioning older adults who did not report severe health restrictions at baseline (see *Appendix*). Walking two distances (6.1-m and 1-km) showed relatively equal speeds, which indicates that the subjects of the present study were well able to maintain their high walking speed over relatively long distances.

Whitney et al. (37) studied cut-off points for the five-times-sit-to-stand test and dynamic gait index, in order to identify subjects with and without balance disorders among 14-90-year-old men and women. They reported 66% sensitivity and 67% specificity for the five-times-sit-to-stand test and 82% sensitivity and 88% specificity for the dynamic gait index. In the present study, the sensitivity (55% in men, 64% in women) and specificity (77% in men, 64% in women) for the one-leg squat were on a corresponding level to the sensitivity and specificity values for the five-times-sit-to-stand test of Whitney et al. (37), but the sensitivity and specificity values for the optimal cut-offs for our walk tests were lower than those presented for the dynamic gait index by the above authors.

In summary, the sensitivities and specificities of the optimal cut-off values identified for the tests with highest predictive value for WD are at the same level in the present study as those identified by Raiche et al. (35) and VanSwearingen et al. (36). The earlier cross-sectional studies (12, 37) showed somewhat higher sensitivities and specificities than the present study.

Previous studies have suggested that subjects' age may affect sensitivity and specificity values. Whitney et al. (37) reported that the five-times-sit-to-stand test and dynamic gait index showed higher sensitivity and specificity for optimal cut-off values among subjects aged under 60 years of age when compared with those aged 60 and older. In the present study, all subjects were older than 60 at follow-up, and there were no consistent age-related trends in the optimal cut-off values with corresponding sensitivities and specificities. Melzer et al. (8) reported that there are also differences across age groups in reporting mobility disability: younger age groups are relatively less likely to report mobility disabilities than older age groups with corresponding measured performances. They suggested that this was due to differences in living environments or attitudes toward reporting.

To conclude, the 1-km walk, dynamic back extension and backward walk tests had the best predictive value for WD among high-functioning older adults. The greatest agreement between test performances in predicting WD was identified between the 1-km and dynamic back extension tests in both genders. These results complement our previous findings about the predictive value of HRF tests for mobility difficulties among older adults (17). These tests, with their identified cut-off values, can be used to screen individuals who are at increased risk of WD, and also used in physical activity counseling, to target activity to those components of fitness that are not adequate for good walking ability. In the future, it would be important to validate the cut-offs identified in the present study in other study samples.

APPENDIX

Description of battery of health-related fitness tests for older adults and test-specific exclusion criteria.

Test: One-leg standing balance, to assess static postural control when area of support is reduced (25).
Method: Subject stands as still as possible on preferred leg, wearing sports shoes. Opposite foot is placed at knee level along inner side of supporting leg, with thigh and knee rotated outward and arms relaxed.
Outcome: Duration of balance task up to 60 seconds as measured by a stopwatch (s). Subject has two trials to achieve maximum time. If maximum time is achieved on first trial, second trial is not performed.
Exclusion criteria: Severe dizziness, severe symptoms of spine or lower extremities which may be aggravated by test.

Test: Backward walking, to measure postural control in movement (24).
Method: Subject walks backward along a marked 6.1-m (20-ft) line with tandem steps (toes touching heel at every step) as quickly as possible. After a 2-meter practice trial, subject performs three trials.
Outcome: Walking times of three trials as measured by a stopwatch (s), from standing position to end of line. Best time is final result.
Exclusion criteria: Severe dizziness, severe symptoms of spine or lower extremities which may be aggravated by test.

Test: 6.1-m (20-ft) walk, to assess ability to walk (22, 23).
Method: Subject walks course twice: 1) at "usual" pace; 2) as fast as possible, starting from a stationary position.
Outcome: Performance time (s) of second trial (as fast as possible), measured by a stopwatch.
Exclusion criteria: Severe dizziness, severe symptoms of spine, hip or knee which may be aggravated by test.

Test: Trunk side-bending to right and left, to measure average range of motion in lateral flexion of thoracic and lumbar spine and pelvis (25).
Method: Subject stands on marked lines (15 cm apart), with back against wall and arms and fingers straight at the sides of the body (baseline). Subject slides middle finger along lateral thigh to right and then left as far as possible, keeping shoulders and buttocks in contact with wall and heels in contact with floor. Tester measures distance between baseline and maximum slide of middle finger tip.
Outcome: Average distance (cm) between maximal right and left side-bending range of motion, measured by a tape measure.
Exclusion criteria: Severe dizziness, severe spinal symptoms which may be aggravated by test movement.

Test: One-leg squat with increasing weight, to assess functional strength restrictions of leg extensors (25).
Method: Subject takes a short step forward, first with right leg, squats down until knee of tracking leg lightly touches mat, then rises immediately, and steps back to starting position. Squat is repeated with left leg.
Outcome: Load limit for a successful squat, measured as maximum weight relative to subject's body weight, up to 125% (1-13 points). Test starts with body weight (i.e., no added weight) and 5% increments of body weight are added at 4 successive steps of 10%, 15%, 20% and 25%, using a weight vest.
Exclusion criteria: Dizziness, severe diseases or symptoms of cardiovascular system, moderate or severe symptoms of spine, hip or knee which may be aggravated by test.

Test: Dynamic back extension, to assess trunk extensor muscle endurance (26).
Method: Subject lies in a semi-inclined body position in a portable standing hyper-extensor*, with hips and lower legs supported, fingers crossed behind neck, and upper body lying on table. Subject raises upper body off table to a straight back level (45 degrees from table level) and returns to starting position as quickly as possible.
Outcome: Maximum number of repetitions in 30 seconds.
Exclusion criteria: Moderate to severe diseases or symptoms of cardiovascular system, severe spinal, hip or knee symptoms which may be aggravated by test.

Test: 1-km walk, to assess sub-maximal aerobic capacity (27).
Method: Subject walks as fast as possible on a flat surface using normal walking style.
Outcome: Walking time (min), measured by a stopwatch.
Exclusion criteria: Severe diseases or symptoms of cardiovascular system, severe dizziness, severe symptoms of spine, hip or knee which may be aggravated by test.
*Standing Hyper Extensor, HUR Ltd., Kokkola, Finland

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