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A Study with a Comprehensive Geriatric Intervention

JYVÄSKYLÄN YLIOPISTO

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ABSTRACT

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The purpose of the study was to examine the relationship between pain, mobility and postural balance. In addition, the effects of a comprehensive geriatric assessment and individualized intervention on mobility among persons aged 75 years and over were studied. This study forms part of the Geriatric Multidisciplinary Strategy for the Good Care of the Elderly project (n=781), which comprised a baseline assessment succeeded by a two-year geriatric intervention with annual measurements and a one-year postintervention follow-up. Data on musculoskeletal pain and perceived walking difficulties were obtained by questionnaires administered in face-to-face interviews. Mobility assessments comprised maximal walking speed over 10 meters, the Timed Up & Go (TUG) test, Berg Balance scale, and self-reports. Mobility limitation was defined as poor performance or inability to perform the TUG test and perceived difficulties or inability in walking 400 meters. Postural balance was assessed as movement of center of pressure in different standing positions on a force platform.

Persistent musculoskeletal pain was associated with mobility limitation and postural balance impairment independently of several known risk factors. The risk for mobility limitation and balance impairment was highest among persons who had moderate or severe pain (OR 1.84, 95% CI 1.10-3.13; 2.33, 1.44-3.76 respectively) compared to pain-free persons. In addition to the positive effect on walking speed, TUG and Berg Balance test, a comprehensive geriatric intervention reduced the risk for perceived difficulties in walking (OR 0.84, 95% CI 0.75-0.94). The positive effect of the geriatric intervention on mobility was strong particularly among persons with musculoskeletal pain.

The results of the study indicate that musculoskeletal pain is an important determinant of mobility limitation among older people. In addition to walking problems, pain compromises the ability to maintain postural balance. The results suggest that a comprehensive geriatric assessment and individualized intervention may provide an effective means to promote mobility and balance, which is important for maintaining independence in the community. The intervention benefited in particular persons with pain, a group at risk for further mobility decline.

Keywords: aging, pain, mobility limitation, postural balance, comprehensive geriatric assessment, rehabilitation

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Jyväskylä, December 2011

Katri Lihavainen

LIST OF ORIGINAL PUBLICATIONS

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

I Karttunen N*, Lihavainen K*, Sipilä S, Rantanen T, Sulkava R, Hartikainen S. 2011. Musculoskeletal pain and use of analgesics in relation to mobility limitation among community-dwelling persons aged 75 years and older. European Journal of Pain (Jun 28, 2011, Epub ahead of print). *contributed equally

II Lihavainen K, Sipilä S, Rantanen T, Sihvonen S, Sulkava R, Hartikainen S. 2010. Contribution of musculoskeletal pain to postural balance in community-dwelling people aged 75 years and older. Journals of Gerontology Series A: Biological Sciences and Medical Sciences 65, 990-996.

III Lihavainen K, Sipilä S, Rantanen T, Seppänen J, Lavikainen P, Sulkava R, Hartikainen S. Effects of comprehensive geriatric intervention on physical performance among people aged 75 years and over. Aging Clinical and Experimental Research, in press.

IV Lihavainen K, Sipilä S, Rantanen T, Kauppinen M, Sulkava R, Hartikainen S. Effects of comprehensive geriatric assessment and targeted intervention on mobility in persons aged 75 years and over: a randomized controlled study. Clinical Rehabilitation (Oct 17, 2011, Epub ahead of print).

ABBREVIATIONS

ADL	Activities of Daily Living
ANOVA	Analysis of Variance
AP	Antero-posterior
BMI	Body Mass Index
CGA	Comprehensive Geriatric Assessment
CI	Confidence Interval
COP	Center of Pressure
GDS	Geriatric Depression Scale
GEE	Generalized Estimating Equations
GeMS	the Geriatric Multidisciplinary Strategy for the Good Care of the Elderly
IADL	Instrumental Activities of Daily Living
IASP	the International Association for the Study of Pain
ML	Medio-lateral
MMSE	Mini-Mental State Examination
NRS	Numeric Rating Scale
OR	Odds Ratio
RCT	Randomized Controlled Trial
SD	Standard deviation
SE	Standard Error
SF-36	Medical Outcomes Study 36-Item Short-Form General Health Survey
TUG	Timed Up & Go

CONTENTS

1 INTRODUCTION

Health care systems in the Western countries are confronted with ageing populations. By 2040, 27% of people living in Finland will be age 65 or older, and 6% of people will have reached age 85 or older (Statistics Finland 2009). Despite the fact that older people are healthier today than ever before (Heikkinen 2006), with advancing age the prevalence of conditions associated with persistent pain increases. Thus, pain is among the most common reasons for seeing a physician (Jyväsjärvi et al. 1998, Mäntyselkä et al. 2001), and affect an estimated 30-50% of community-dwelling older adults and over 50-80% of long-term care facility residents (Mäntyselkä et al. 2003, Breivik et al. 2006, Soldato et al. 2007, Reid et al. 2011). The high prevalence of pain is particularly noteworthy in light of its interference with daily activities. One of the essential prerequisites for older people's independent functioning in daily life is mobility. In the context of this study mobility refers to the ability to perform tasks such as walking, climbing stairs, and standing from a chair. The ability to maintain an upright posture, known as postural balance, in turn is an important prerequisite for successful performance of these mobility tasks. Therefore, impairments in postural balance may lead to mobility difficulties and increase the risk for falling (Lord et al. 1994, Sihvonen et al. 2004). Difficulties in mobility are often the first noticeable signs of further disability (Fried et al. 2001, Wolinsky et al. 2005, Mänty et al. 2007). Loss of mobility seriously threatens the independence and quality of life of older adults (Ostir et al. 1998, Guralnik et al. 2000). Consequently, prevention or postponement of mobility limitation is a high priority in public health and requires the identification of risk factors such as pain that are amenable to intervention in the older population.

To meet the increasing needs of the older population, innovative approaches to the promotion of the health and mobility of older persons need to be developed. The most common risk factors for mobility decline are widely recognized nowadays. Several well-designed, randomized controlled intervention trials have also shown that there are efficacious and acceptable ways to slow down the progression of mobility limitation; these include progressive resistance strength training (Liu & Latham 2009) and physical activity counseling (Mänty et al. 2009). However, many traditional trials have been structured so as to exclude people who may have difficulties completing the intervention or who may be at high risk of dropping out. In the case of older population, such an approach probably fails to evaluate the effects of an intervention among those who most need treatment and who have the greatest likelihood of benefiting from an individually targeted intervention (Ferrucci et al. 2004). The generalizability of the findings of such studies to typical aged populations is limited. In addition, typically, randomized controlled trials have evaluated the effects of only a single intervention. The range of therapeutic alternatives to promote mobility is wide due to the fact that decline in mobility is aggravated by the complex interaction of several factors, including aging, physical inactivity, diseases and malnutrition. These multiple factors require multifaceted attention and intervention. However, individualized interventions that provide a comprehensive assessment and multifactorial treatments to promote mobility are challenging to study and have received only a little attention. In addition, the traditional health care models have not been able effectively to adapt the research findings; hence there is a need to identify novel approaches through which older people can be helped to maintain their mobility and forestall the onset of disability.

The present study was conducted to obtain insight into musculoskeletal pain as a determinant of mobility limitation and postural balance impairment in older people. In addition, the effects of a real-world project comprising a comprehensive geriatric assessment and individualized intervention on the development of mobility limitation in older persons with and without pain were studied.

2 REVIEW OF THE LITERATURE

2.1 Mobility and postural balance in older people

2.1.1 Determinants of mobility and postural balance

Mobility is often defined as the ability to walk and move either independently or with using an assistive device inside and outside one's home (Shumway-Cook & Woollacott 2001, Webber et al. 2010). In this study, mobility refers to a person's ability to move from one place to another carrying one's own weight, such as in walking or standing from a chair. These mobility functions rely on smooth co-operation between multiple physiological, cognitive and psychological characteristics in relation to the demands of the environment (Dickinson et al. 2000, Shumway-Cook & Woollacott 2001). Several age- and disease-related changes in these prerequisites may lead to mobility limitations, such as difficulties in walking, standing from a chair or climbing stairs, and further development of disability (Guralnik et al. 1995).

Two important physiological prerequisites for safe mobility are lower extremity strength (Rantanen et al. 1998a, Rantanen et al. 2001, Lauretani et al. 2003, Sakari et al. 2010), and the ability to generate force at high velocity (Foldvari et al. 2000, Bean et al. 2002, Portegijs et al. 2005). A certain minimum amount of muscle strength and power is needed to generate continuous forward movement, to perform many tasks in daily life (Buchner et al. 1996, Rantanen & Avela 1997, Rantanen et al. 1998a) and to respond to changing environmental and task demands, for example when recovering balance after tripping (Pavol et al. 2002, Pijnappels et al. 2005) or crossing the road at traffic lights (Bean et al. 2003). Several studies have shown that isometric muscle strength and muscle power decline considerably with aging (Rantanen et al. 1998b, Vandervoort 2002, Lauretani et al. 2003, Goodpaster et al. 2006), and that reduced neuromuscular performance plays a major role in the development of mobility limitation (Rantanen et al. 1999, Visser et al. 2002, Marsh et al. 2006b).

In addition to sufficient muscle strength and power, postural balance is needed to maintain an upright posture during tasks requiring stable or dynamic bodily positioning (Rantanen et al. 1999, Tiedemann et al. 2005, Sakari et al. 2010). The maintenance of postural balance is a complex process that is influenced by a wide range of sensorimotor and central processing factors, including lower extremity muscle strength and power, vestibular, proprioceptive and somatosensory functions, visual acuity, and neuropsychological performance. It requires seamless interaction of these characteristics as well as environmental factors (Woollacott & Shumway-Cook 1990, Pollock et al. 2000, Peterka 2002, Horak 2006). With aging, declines occur in the visual (Lord 2006, Kulmala et al. 2009,), somatosensory (Whipple et al. 1993), vestibular (Matheson et al. 1999, Viljanen et al. 2009) and neurophysiologic processing systems (Shumway-Cook & Woollacott 2001, Horak 2006). The changes in these systems reduce the availability of important information from the senses for posture and movement, and may thus cause postural instability along with problems in responding to environmental challenges during mobility the performance of mobility tasks (Era et al. 2006, Lord 2006, Horlings et al. 2008). Mobility tasks, such as walking, are traditionally seen as automatic motor skills, but nowadays attention has also been drawn to their cognitive and affective dimensions (Snijders et al. 2007b). Therefore, impairments in one or more neurophysiologic and cognitive processes may affect the ability to move effectively and safely. These processes, such as perception, attention, orientation, executive functions and memory are important to successful interaction with the environment (Shumway-Cook & Woollacott 2001).

Declines in muscle strength, power and postural balance have been shown to precede mobility difficulties. In addition to neuromuscular performance and balance, decreased aerobic capacity (Fiser et al. 2010), and reduced range of motion in the lower extremity joints restrict mobility (Kerrigan et al. 1998, Sakari et al. 2010). Walking, for example, places demands on multiple organ systems, including the heart, lungs, circulatory, nervous, and musculoskeletal systems. The slowing of walking speed with aging may reflect both age- and pathology-related disturbances in those systems and the high-energy cost of walking (Jones et al. 2009, Studenski et al. 2011). Multiple age-related physiological changes, medical problems and impairments may have a cumulative and even a synergistic impact on mobility (Guralnik et al. 2001). For example, Rantanen et al. (2001) observed that the risk of severe mobility limitation was higher among older women with both strength and postural balance impairment compared with those with only one of those impairments.

In addition to the age-related changes in physiology, the increased prevalence and severity of multiple diseases with aging may cause mobility limitation and mediate the impact of the physiological and psychological determinants of poor mobility (Chaudhry et al. 2010). Mobility limitation has been associated, for example, with arthritis (Ling et al. 2003, Fautrel et al. 2005, Maly 2009), diabetes (Volpato et al. 2005, Sinclair et al. 2008), cardiovascular diseases (Blazer et al. 2006, Brach et al. 2008, McDermott et al. 2009), chronic obstructive pulmonary disease (Roig et al. 2011), neurological disease (Paltamaa et al. 2006, Snijders et al. 2007a), hip fracture (Portegijs et al. 2008), and depressive symptoms (Penninx et al. 1998, Hirvensalo et al. 2007). Furthermore, obesity is related to many of above-mentioned diseases and has also been considered as a major risk factor for mobility limitation in old age (Stenholm et al. 2009). Persistent pain is related to these diseases and chronic conditions and, through them, may influence mobility while also having an independent effect (Leveille et al. 2007).

In addition to these consequences of aging, pathology and impairment on mobility, risk factors related to health behavior, such as physical inactivity, may contribute to the development of mobility limitation (Hirvensalo, Rantanen & Heikkinen 2000). Furthermore, intra-individual factors related to self-efficacy and coping may have effect on mobility. For example, fear of falling (Deshpande et al. 2008, Scheffer et al. 2008, Curcio et al. 2009), fear of moving outdoors (Rantakokko et al. 2009), and fear of pain (Somers et al. 2009) increase the risk for mobility loss due to negative emotion-related avoidance of physical activities.

Mobility limitation is often a dynamic process where an older person can make transitions between different states of limitation (Gill et al. 2006, Gill et al. 2010). Moreover, individual differ in the rate of mobility limitation progression. The onset of mobility limitation can be sudden, for example in the case of a traumatic event, such as a hip fracture or a stroke, or mobility difficulties can progress slowly over many years, usually as a consequence of painful worsening conditions, such as arthritis or diabetes (Guralnik et al. 2001). Individuals who have developed mobility limitation may recover from it, and possibly later on become mobility limited again (Gill et al. 2006, Jagger et al. 2007). Thus, the promotion of mobility requires a focus not only on prevention but also on the maintenance of independent mobility in older persons who are at increased risk for decreasing mobility (Gill et al. 2006).

All in all, maintaining mobility involves multiple physiological and psychological abilities, as well as lifestyle behaviors relative to environmental requirements. Among older people, age- and pathology-related changes in these factors and subsequent loss of ability to ambulate within one's immediate environment may threaten independent living in the community. In addition, decreasing mobility may be a result of a sedentary lifestyle, and also induce a vicious cycle of reduced physical activity and deconditioning that has a direct effect on health in older age (Studenski et al. 2011).

2.1.2 Measurements of mobility and postural balance

Mobility among older persons can be measured either through self-reports or through performance-based tests (Guralnik & Ferrucci 2003). Self-report measures rely on a person's perception of his/her mobility status. In general, persons are asked questions about their ability, difficulties, or need for help in walking a certain distance. The distance typically used in questionnaire is 400 meters (1/4 mile, or 2-3 blocks) (Hoeymans et al. 1996, Sayers et al. 2004). Self-report on perceived degree of difficulty in walking has been found to be a reliable and valid measure of mobility limitation (Fried et al. 2001), and to predict future further disability in older people (Guralnik et al. 1994, Reuben et al. 2004).

In addition to self-reports, mobility can be assessed objectively by physical performance tests. Of the several physical performance measures available, walking speed is widely recognized as a good measure of mobility among older people with wide range of functional capacity, and is also the most often used (Guralnik et al. 2000, Cesari et al. 2005). Measurement of walking speed is a quick, inexpensive and highly reliable method, which is both sensitive to change and easy to use in both clinical and research settings. Several versions of tests measuring walking speed are used, including different distances walked at either maximal or habitual speed. A short, distance-based walking test, such as 10 meters of walking at maximal speed (Aniansson et al. 1980), assess the highest level of neuromuscular capacity of the lower extremities. While maximal walking speed reflects the individual's potential to adapt to varying environmental and task demands, for example when crossing a street at traffic lights, habitual walking speed shows the individual's normal performance level in everyday life. Longer, time-based walking tests, such as the 6-minute walking test, provide more specific information about the aerobic capacity of older persons. Furthermore, walking has been assessed as a part of combined functional task, such as the Timed Up & Go (TUG) test, where the testee is asked to stand up from a chair, walk 3 meters, turn around, walk back, and sit down (Podsiadlo & Richardson 1991). In laboratory settings computerized methods can be used to evaluate various kinematic and kinetic components of the walking cycle; these include step length, step width, and the duration of the stance, swing and double-support phases (Graham et al. 2008).

An important prerequisite of independent mobility, postural balance, can also be measured quantitatively using technological devices. To maintain balance, the body undergoes continuous movement, known as postural sway. Postural sway can be measured on a force platform which registers and analyzes the vertical forces a person positioned on the platform applies to the base of support. Force platform measurements provide detailed information about body sway velocity and direction in different standing positions or during dynamic movements (Era et al. 1996). It has been assumed that postural balance is best achieved when postural sway is low (McKeon & Hertel 2008). Because of the complex nature of postural balance (Woollacott & Shumway-Cook 1990, Pollock et al. 2000, Peterka 2002, Horak 2006), several other methods in addition to force platform measurements have been devised to evaluate it. For example, various performance-based tests, such as the Berg Balance Scale (Berg et al. 1992), provide information on a person's ability to maintain postural balance during varying tasks in everyday life.

All in all, performance-based (either quantitative technology-based or objective performance-based tests) and self-report measures complement each other by providing useful information about mobility functions in different situations. Thus, self-reports reflect actual activities in ordinary daily life, while performance-based measures assess the upper limit of physical capacity used in performing a given mobility task under controlled conditions (Latham et al. 2008).

2.2 Musculoskeletal pain in older people

2.2.1 Definition and classifications of pain

Pain is defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (IASP 1986). This widely accepted definition implies that a subject can experience pain with or without damage, dysfunction, or disease. It also emphasizes that pain is experienced at both the sensory and emotional levels. However, this definition of pain does not explicitly refer to the complex and dynamic interaction of biological, psychological and social factors that provoke and maintain pain and pain-related problems.

Pain can be categorized according to its underlying causes. However, such a categorization based on the biological mechanism of pain is rarely used in epidemiological studies and is more of a diagnostic aid. The most common type of pain is nociceptive. Nociceptive pain is a normal reaction to tissue damage or disease resulting from a noxious mechanical, thermal, or chemical stimulus. It can be further subdivided into somatic and visceral pain. Somatic pain arises from the tissues, such as joints, bones, and muscles, whereas visceral pain arises from the viscera in the internal organs. Typically, nociceptive pain is acute and disappears when the tissue damage has healed. Neuropathic pain often begins with a tissue injury, but continues to be experienced despite healing of tissue damage (Kalso & Kontinen 2009). In these cases, pain arises as a consequence of a lesion or disease affecting the somatosensory system either in the periphery or centrally (Treede et al. 2008). Due to this pathology, the nerve signals the presence of a noxious stimulus, although no such stimulus any longer exists. A wide spectrum of poorly understood pain conditions, for which no organic cause can be found, has been called idiopathic pain (Kalso & Kontinen 2009).

Musculoskeletal pain is often considered as a symptom of musculoskeletal disorders, that is, conditions that involve muscles, joints, nerves, tendons, ligaments, bursae and bones. The prevalence of certain musculoskeletal pain-related disorders, such as osteoarthritis and other degenerative conditions, increases with age (Johnell & Kanis 2006, Grotle et al. 2008, Hicks et al. 2009). However, pain is not necessarily a secondary symptom; in many cases pain is the disorder itself (Siddall & Cousins 2004). This is especially true of most persistent pain stemming from the musculoskeletal system, where no pathophysiologic cause of the pain can be found (Turk & Okifuji 2002, Creamer 2004). Thus, musculoskeletal pain can be categorized as specific or non-specific. Specific pain has a distinct and detectable cause, such as an inflammation, a fracture, a tumor, or a muscle spasm. For non-specific pain, a sufficient underlying pathology is absent. Although persons with non-specific pain can undergo anatomical changes, such as degenerative processes in the discs, bones or cartilages, such anatomical deviations are not necessarily symptomatic and are therefore not regarded as a sufficient explanation for pain experienced by the subject (Jayson 1997, Carragee et al. 2005).

In the initial stages of experiencing pain, the pain is described as acute (i.e. of less than 3 months' duration). This pain is assumed to be transitory, lasting only until the noxious stimulus is removed or the underlying damage or pathology has healed. Pain that extends beyond the expected period of healing is called chronic or persistent. Nowadays it is widely believed that the term "persistent" is a more accurate description as it includes information on the way in which the pain may interrupt functioning, well-being and quality of life. In addition, the term "chronic" expresses a more negative view of the prognosis. The two common time markers used to define persistent pain are durations of over three (Elliott et al. 1999) or six months (Von Korff & Saunders 1996, Turk & Okifuji 2002) from the onset of pain. In the worst case, persistent pain that is not accurately treated can induce changes to the nervous system, which transmits and interprets messages, such as the sensation of pain. This in turn may contribute to prolonging and intensifying the pain (Apkarian et al. 2009).

2.2.2 Measurements of pain

Pain is essentially a subjective experience. Thus, it cannot be measured objectively (Katz & Melzack 1999), although hints as to its severity may be received from the person's behavior, such as avoiding movement of or touching the painful body part. It should be noted that advanced biological information about pain can be obtained from brain imaging. While brain imaging is a valuable source of information about physiological pain processes (Apkarian et al. 2011), it is costly, time-consuming and does not measure the subjective experience of pain. Thus, clinical practice and epidemiological studies rely mainly on self-reports of pain. Assessment of pain, based on self-reports, is possible for various parameters, such as duration, frequency, location, severity, and the degree of disability caused by it. These may be measured by separate questions or with specially designed pain indices and pain-rating scales such as the McGill Pain Questionnaire (Melzack 1975), Brief Pain Inventory (Cleeland & Ryan 1994), the Visual Analogue Scale (VAS) (Huskisson 1974), the Numeric Rating Scale (NRS), the Faces Pain Scale, and the verbal rating scales (VRS) (Katz & Melzack 1999). In addition, pain is one dimension in several generic health–related quality of life (HRQoL) measuring instruments, such as the Medical Outcomes Study 36-Item Short-Form General Health Survey (SF-36) (Ware & Sherbourne 1992).

In clinical examination, assessment of pain aims at clarifying underlying the cause and determining whether the pain is nociceptive, neuropathic, or idiopathic. In case of neuropathic pain, pain questionnaires and scales are suitable for assessing the intensity and interference of pain; however, accurate sensory examination with quantitative sensory testing is also needed (Haanpää et al. 2011). In addition to the pain questionnaires and scales mentioned above, specific neuropathic assessment instruments have been designed to evaluate the various symptoms of neuropathic pain (Galer & Jensen 1997). The Assessment

Committee of the Neuropathic Pain Special Interest Group (NeuPSIG) of the International Association for the Study of Pain (IASP) has recently produced comprehensive recommendations on the assessment of neuropathic pain (Haanpää et al. 2011).

2.2.3 Mechanism of pain in older people

Knowledge of the physiology of pain has progressed as a result of the innovations in electrophysiologic and imaging techniques during the past few decades. The mechanism of pain is now seen as involving multiple pathways, with complex cellular and molecular processes at multiple levels of the nervous system (Renn & Dorsey 2005). This thesis is not intended to include a comprehensive review of pain physiology. However, some basic mechanisms are presented so that pain can be understood as a process with objective, physiologic sensory aspects as well as subjective emotional and psychological dimensions.

The pathway from tissue damage to the sensation of pain can be divided into four steps: transduction, transmission, modulation, and perception. Transduction refers to the action potential of nociceptors, which is caused by tissue damage. Typically, nociceptors are free nerve endings that sense chemical, mechanical, and thermal tissue damage in different parts of the body. Pain signals stemming from tissue damage are transmitted from peripheral nociceptors to the brain through spinal neurones. Modulation refers to all cellular and molecular processes that are either inhibitory or excitatory on the signal transporting pathway from the peripheral to central nervous systems. Perception is the end of this chain of events, the sensation of pain (Kalso & Kontinen 2009).

The nervous system responsible for the sensation and perception of pain is divided into afferent pathways, the central nervous system, and efferent pathways. There are four main types of sensory afferent fibres (Aα, Aβ, Aδ and c) that transmit pain impulses from the periphery through the dorsal root ganglion to the dorsal horn of the spinal cord, where they synapse with projection neurons and interneurons. The function of interneurons in the efferent pathways of the spinal cord may be either excitatory or inhibitory, and are thus responsible for the modulation of pain. Pain impulses enter different parts of the brain through a process where the ascending retricular formation prepares the higher regions of the brain to receive the pain message, while the thalamus organizes the sensory input and directs this to the cortex (Kalso & Kontinen 2009). The perception of pain is a cortical process, in which various cortical regions, such as the primary and secondary somatosensory cortex, insular anterior cingulated cortex and prefrontal cortex, are involved. The cortical processing of pain has sensory components that relate to the site, duration and strength of a stimulus as well as emotional, memory, and affective elements of pain. Although the mechanism of pain from nociception to perception is commonly determined according to physiological processes, it is important to keep in mind that pain can also occur without nociception. There is no consistent relationship between the pain-causing stimulus and the pain that is finally perceived (Dickenson, Bee & Suzuki 2005). An individual's memories, expectations, and emotions modify the experience of pain (Estlander 1989).

With advancing age, pain perception (Gibson & Farrell 2004), central pain processing (Gibson & Helme 2001), and the plasticity of pain responses (Farrell & Gibson 2007) are altered, which may be related in part to structural and functional changes in the brain. These normal and pathological aging-associated brain changes contribute to pain homeostenosis which means the diminished ability of an organism to effectively respond to the stress of persistent pain. Several factors may be related to this diminished ability in older people, including cognitive impairments, altered pharmacokinetics and pharmacodynamics, polypharmacy, high comorbidity, social losses, loneliness, depressive symptoms, anxiety, and impairments in physical capacity (Karp et al. 2008). The normal aging- and pathology-related changes in the brain may cause impaired descending inhibition and other dysfunction in pain physiological mechanisms (Apkarian et al. 2004, Farrell & Gibson 2007, Karp et al. 2008, Buckalew et al. 2010, Cole et al. 2010).

There are also several other changes that may impact on pain processing in old age. The density and number of peripheral fibers decrease, and their conduction velocity may slow somewhat (Gibson 2003). Degenerative changes within bones, joints and other tissues in the body can lead to pain (Benoist 2003). In addition, changes in physiological processes, including motility, secretions, blood flow, and absorptive surfaces in the gastrointestinal structures, affect response to pain treatment and sensitivity to adverse effects of medications. The effects of age on pain perception are contradictory. It has been reported that somatosensory thresholds for heat pain stimuli increase with age, whereas pressure pain thresholds have been shown to decrease with aging (Gibson & Farrell 2004).

In sum, aging affects individuals differently, including their experience of pain. A key distinction between old and young individuals with persistent pain is that, among former, the normal and disease-related dysfunctional changes that accompany aging cause impaired pain inhibition and thus alter the experience of pain and contribute to the development of disability. Therefore, particular attention to individualized management of pain is required in older people.

2.2.4 Association of musculoskeletal pain with mobility and postural balance

The prevalence of persistent pain is known to increase with aging, and ranges from 30% to 60% among community-dwelling older people (Landi et al. 2001, Pitkälä et al. 2002, Hartikainen et al. 2005, Soldato et al. 2007), and from 45% to 85% among residents of nursing homes and long-term care facilities (Leong & Nuo 2007, Boerlage et al. 2008, Zanocchi et al. 2008). Older adults are prone to chronic painful conditions, especially arthritis, degenerative spine disease, peripheral neuropathies, cancer, postherpetic neuralgia, and bone and joint disorders (AGS Panel on Persistent Pain in Older Persons 2002). Recent studies have suggested a link between persistent pain, particularly back pain, and vitamin D-deficiency (Al Faraj & Al Mutairi 2003, Plotnikoff & Quigley 2003, Hicks et al.

2008) which is common among older people due to limited sunlight exposure and nutritional deficiencies (Maggio ym. 2005). Because of the high prevalence of diabetes in the developed countries, the incidence of painful diabetic neuropathy is also increasing (Vinik et al. 2008). On the other hand, the prevalence of some regional pain, such as headache, declines at older age (Thomas et al. 2005).

Persistent pain has multiple consequences on the societal level, but especially for the individual with pain. Human suffering, a lower quality of life, restrictions on physical activity, daily activities and hobbies, mobility limitations, sleep problems and increased health care costs are typical consequences at the individual level (Mäntyselkä et al. 2001, Aaron et al. 2002, Mäntyselkä et al. 2002, Marty et al. 2008). It seems that interference of pain with daily activities increases with age (Thomas et al. 2004a, Thomas et al. 2007). This is probably due to the fact that musculoskeletal pain, especially in the lower extremities and back, influences balance and mobility through multiple pathways. Severe pain often leads to the restriction of painful movements, and abnormal changes in movement patterns. These changes and adaptations may induce more pain, resulting in further activity restriction (Keefe et al. 1991, Hurwitz et al. 1997). In addition, fear of pain may cause avoidance of movement which in turn maintains both fear and pain. It is also possible that pain places additional demands on the attention (Vancleef & Peters 2006), and thus distracts from maintaining the balance needed for intact mobility. These factors may lead to a vicious circle where older people affected by pain reduce their physical activity, thereby accelerating the development of further mobility limitation (Guralnik et al. 2001, Visser et al. 2005).

Thus far, an increasing number of studies have demonstrated that older persons with pain comprise a special group of people at risk for mobility limitation (e.g. Messier et al. 2002, Weiner et al. 2003, Buchman et al. 2007, Leveille et al. 2007, Eggermont et al. 2009, Shah et al. 2011). However, studies on the relationship between pain and mobility limitation have shown varying results due to the differences in the dimensions of pain and mobility outcomes studied. The majority of the previous studies have reported a relationship between musculoskeletal pain and self-reported difficulties in walking (Leveille et al. 2001, Mottram et al. 2008, Covinsky et al. 2009). Only a few population-based studies have examined the association between pain and mobility measured by physical performance testing. Perceived difficulties in mobility usually overlap with pain experience, and the use of objective measures of mobility may better reflect the direct effects of pain on mobility limitation.

Most of the previous studies indicate that older persons with pain in a selected site (e.g., in the foot, knee, or low back) show a variety of mobility-related impairments and limitations. For example, structural deformities and painful conditions in foot, such as hallux valgus and peripheral neuropathy (Leveille et al. 1998a, Menz & Lord 2001, Chaiwanichsiri et al. 2009), and osteoarthritis in the ankle (McDaniel et al. 2011) increase the risk for decreased walking speed, impaired balance, and falls. Osteoarthritis is the most common cause of knee pain in older people (Mäntyselkä et al. 2001, Thomas et al. 2004b). However, even in the absence of radiographic changes due to arthritis, musculoskeletal pain in knee is associated with mobility limitation (Hochberg et al. 1989, Creamer et al. 2000). Persons with severe knee pain (Lamb et al. 2000, Eggermont et al. 2009), and painful osteoarthritis (Nebel et al. 2009, McDaniel et al. 2011) typically have reduced walking speed. In general, factors such as obesity (Creamer et al. 2000, Lamb et al. 2000, Sutbeyaz et al. 2007), psychosocial impairments (e.g. depression, anxiety, poor self-efficacy)(Lamb et al. 2000, Maly et al. 2005), and poor muscle strength (Jadelis et al. 2001, Messier et al. 2002, Ling et al. 2003) intensify the effects of knee pain on walking and balance ability. In addition, previous studies have shown a strong relationship between low back pain and self-reported mobility limitations (Leveille et al. 1999, Weiner et al. 2003).

In addition to specific pain sites, a few studies have investigated the overall number of pain locations and pain severity ratings in relation to mobility in older people. In general, these studies have showed a dose-response relationship between pain and mobility limitation. Older people who experience pain in multiple sites have more mobility problems than persons with single-site pain or without pain (Keenan et al. 2006, Leveille et al. 2007, Mottram et al. 2008, Eggermont et al. 2009). Accordingly, widespread pain has frequently been reported to present the strongest risk for difficulties in mobility tasks (Leveille et al. 2001, Leveille et al. 2007, Eggermont et al. 2009, Eggermont et al. 2010). Widespread pain refers to axial, left- and right-sided, and upper and lower segment pain (Wolfe et al. 1990). However, also multisite pain that does not meet the criteria for widespread pain is an independent predictor of mobility limitation (Peat et al. 2006, Eggermont et al. 2009, Shah et al. 2011). It has also been concluded that more severe pain is associated with multisite pain (Croft et al. 2005).

Studies have shown that greater dissemination of pain is associated with self-reported difficulties in mobility tasks, but not with inability to perform those tasks (Leveille et al. 1999, Leveille et al. 2001). In addition, pain is more often related to self-reported mobility problems than objectively measured performance in mobility tests. For example, in the study by Eggermont et al. (2010) persons with widespread or multisite pain reported difficulty walking a quarter of a mile or climbing 10 steps, but did not demonstrate poorer performance in the physical performance test (Short Physical Performance Battery, SPPB) or in walking speed. Similar findings have been reported at least among persons with low back pain (Weiner et al. 2003), and among women with disabilities (Leveille et al. 2001, Leveille et al. 2007).

In addition, pain has been identified as a risk factor for falls. For example, Leveille and colleagues (2009) found in their study of community-dwelling Americans over age 70 years that chronic pain was associated with increased risk of falls over a one-and-half-year period. The greatest risk for falls was observed in persons who had multisite pain, severe pain or who reported high interference of pain compared with their peers with no pain or with milder pain. A similar relationship between pain and risk for falling has also been documented in a cross-sectional study with a population-based sample of persons with mean age of 65 years (Blyth et al. 2007). A number of studies have identified several risk factors for falling, one of the most important of which is impaired balance (Rubenstein & Josephson 2002, Tinetti & Kumar 2010). So far, however, the relationship between musculoskeletal pain and postural balance has not been evaluated in older people.

The role of analgesics, often inadequately used in pain management among older people (Pahor et al. 1999, Pokela et al. 2010), has rarely been addressed in the studies on pain and mobility but may contribute to the relationship between them. For instance, little is known about whether the association between pain and mobility varies according to the use of analgesics.

2.3 Comprehensive geriatric assessment and individualized intervention in the promotion of mobility

2.3.1 Content of comprehensive geriatric assessment

Comprehensive Geriatric Assessment (CGA) has been used for many years to evaluate the complex needs of frail hospitalized older persons. CGA is a multidimensional and interdisciplinary diagnostic process intended to determine an older person's medical, psychosocial, and functional capacity and problems with the objective of developing an overall plan for treatment and long-term follow-up (Rubenstein 1984). CGA implies the delivery of treatment to meet the individual needs of the older person and as such moves from the diagnostic approach to concrete interventions. Thus, it is aimed at promoting health and independence by developing a coordinated and integrated plan for treatment and rehabilitation which are followed up in the long term. In general, rehabilitation is defined as a process of restoration of a functional capacity to the previous or to the highest possible level after the occurrence of a disabling event. The primary goal of geriatric rehabilitation is often to improve or maintain the current level of functional capacity and to prevent further disability (Tallis 1992).

With the continuing growth in the proportion of the aged population, there is an increasing need for CGA and individually tailored geriatric interventions to reduce and postpone disability both among inpatients and community-dwelling people. However, few strategies to tackle this current challenge have been introduced in primary care. Recently, policy statements and consensus reports, such as "Silver paper: the future of health promotion and preventive actions, basic research, and clinical aspects of age-related disease - a report of the European Summit on age-related disease" have highlighted the importance of CGA as a central part of the geriatric medicine (Cruz-Jentoft et al. 2009).

Several different models for CGA, such as a consultation team service, and a geriatric evaluation and assessment unit (Ellis et al. 2011) have been described in the research literature. Most of these have been carried out in hospital settings among frail older patients (Reuben et al. 1995, Stenvall et al. 2007, Pilotto et al. 2009). The effectiveness of these models has varied: some trials have shown a positive effect on a length of stay in hospital, institutionalization, functional capacity, and survival (Rubenstein et al. 1984, Applegate et al. 1990, Asplund et al. 2000, Saltvedt et al. 2002), and others have had no significant effect on outcomes such as institutionalization (Kircher et al. 2007), functional decline (Winograd et al. 1993, Reuben et al. 1995), and mortality (Cohen et al. 2002). A recent meta-analysis of 13 intervention studies (Van Craen et al. 2010) showed a significant effect in favor of CGA on functional decline at discharge from hospital and on institutionalization after one year. No significant effects of CGA on mortality, hospital readmission, and length of stay in hospital were found (Van Craen et al. 2010). On the other hand, a review by (Ellis et al. 2011), which evaluated the effectiveness of CGA in hospital for older adults admitted as an emergency, found that more older patients are likely to survive and return home if they receive CGA whilst an inpatient compared to usual care. Thus, CGA and intensive follow-up seems to have an important value in detecting and meeting the specific needs of frail older persons who have been admitted to hospital or who have been considered for long-term care.

In addition, CGA can be performed by community health professionals and primary care providers, who refer patients to a geriatrician or other specialists for more comprehensive evaluation and management when necessary. In primary care, CGA is used to address the major problems commonly encountered in old age, such as impairments in cognitive and physical capacity, falls, frailty, polypharmacy, malnutrition, and poor hearing and vision with the aim of providing medical, psychosocial and rehabilitative care, and arranging longer-term follow-up. CGA has multiple measurable dimensions, usually grouped into the four domains: 1) medical (including anamnesis, clinical examination, laboratory data and problem list, disease-specific severity indicators, and preventive health practices), 2) functional capacity (including basic activities of daily living, instrumental activities of daily living, physical performance, and mobility), 3) psychological health (including mainly cognitive and affective status, quality of life), and 4) socio-environmental parameters (such as social networks and support, environmental safety, needs and adequacy of services) (Rubenstein 2004).

The program types and levels of intensity of outpatient CGA have varied from a brief screening assessment and hospital consultation to intensive in-home assessment with individualized intervention programs in community settings (Cohen et al. 2002, Stuck et al. 2002, Monteserin et al. 2010). For instance, preventive home visit programs have received much attention in the past two decades. They are one mode of CGA and include multidimensional assessment of risk factors for disability and interventions with follow-up through home visits or telephone contacts offered to community-dwelling older adults rather than selected groups of older people, such as to those recently discharged from hospital (Huss et al. 2008). The evidence on the positive effects of CGA in community-dwelling older adults is generally weaker than in the inpatient models. In addition, critical appraisal of the available evidence is difficult, because the programs show much heterogeneity as well as considerable overlap (Parker et al. 2000, Huss et al. 2008).

A meta-analysis showed that non-institutional programs such as in-home CGA for community-dwelling persons, in-home CGA for persons recently discharged from hospital, and CGA provided in an outpatient setting had no effect on physical or cognitive function (Stuck et al. 1993). On the other hand, health care systems have developed and several new studies have been published since the meta-analysis by Stuck et al. (1993), and these have shown that CGA confers health benefits also in outpatient settings (Cohen et al. 2002, Huss et al. 2008, Monteserin et al. 2010). For example, a controlled trial of CGA and health management after discharge from hospital found significant improvements in mental health, but not in functional capacity, in frail older persons (Cohen et al. 2002). In addition, a geriatric intervention after CGA by primary care reduced morbidity and mortality in persons over age 74 years at risk for frailty (Monteserin et al. 2010). This is in line with the findings of studies that have shown beneficial effects of community-based CGA with multidisciplinary program on functional capacity and mental well-being among vulnerable frail people (Reuben et al. 1999, Boult et al. 2001, Melis et al. 2008). For example, a fairly simple home intervention with problem-based selection procedure by a primary care physician prevented deterioration of functional skills for about 3 months and improved well-being for at least half a year (Melis et al. 2008). Previous research has also documented that a multidimensional preventive home visit program can work for older persons with relatively good health at baseline if this is accompanied by a high-intensity follow-up with a comprehensive clinical examination (Elkan et al. 2001, Stuck et al. 2002, Huss et al. 2008).

In conclusion, all of the CGA-based programs have not been effective, mainly owing to poor intensity and targeting and inadequate follow-up. It seems to be important that the right level of intervention is tailored to the right subgroup of older people. In general, for frail and acutely ill high-risk persons being considered for long-term care, a systematic CGA and individualized management strategy with intensive follow-up is extremely important to ensure their needs are assessed and met (Caplan et al. 2004, Van Craen et al. 2010). As Table 1 shows, CGA and targeted intervention programs slow functional decline among older people at increased risk for disability, such as persons with depressive symptoms and functional impairments (Leveille et al. 1998b, Reuben et al. 1999, Burns et al. 2000, Stuck et al. 2000, Boult et al. 2001, Cohen et al. 2002, Gill et al. 2002, Caplan et al. 2004, Melis et al. 2008). On the other hand, some CGA programs have not been effective in preventing functional decline in ability to perform activities of daily life (van Haastregt et al. 2000, Hebert et al. 2001, Bouman et al. 2008). However, preventive home visits with attention to preventive interventions such as exercise, nutrition, and health risk appraisal are recommended for older persons at lower risk for functional decline (Stuck et al. 2002, Huss et al. 2008).

2.3.2 Effectiveness of comprehensive geriatric assessment and individualized intervention in preventing mobility decline

During the past two decades, several experimental studies have reported on the effects of CGA and various intervention programs on mortality, functional capacity in basic (ADL) and instrumental (IADL) activities of daily living, and hospital and nursing home admissions among frail, hospitalized older people as well as in outpatient settings. However, only a few of these studies have included mobility outcomes, such as perceived walking limitations or objectively measured physical performance tests. Table 1 summarizes the results of randomized controlled trials (RCT) including geriatric assessment, intervention and mobility outcomes. CGA programs have varied in their structural components such as assessment instruments of functional capacity. Most of the studies have included various self-report indices which evaluate the ability to perform activities of daily living, such as the Barthel index (Mahoney & Barthel 1965), the Lawton index (Lawton & Brody 1969), the Katz activities of daily living scale (Katz 1983), the Physical Functioning Dimension of the Sickness Impact Profile (Gilson et al. 1975), and the Functional status questionnaire (Jette et al. 1986). Mobility is one of the most essential determinants of independent functioning in daily life. Despite the fact that the indices of functional capacity include domains of mobility such as the ability to walk a short distance and stand up from a chair, these measures may not be sensitive enough to recognize and differentiate problems and changes in mobility (Fried et al. 1996). Thus, there is need for studies in which the effects of CGA and management strategies on mobility are investigated by applying specific tools such as physical performance tests.

So far, the controlled trials by Reuben at al. (1999), Cohen et al. (2002) and Melis et al. (2008) have studied the effects of a geriatric assessment and health management on objectively measured physical performance among older people. These studies have been conducted either in acutely hospitalized persons or in community-dwelling people. The study by Cohen et al. (2002) found that inpatient CGA and multidisciplinary management services had a positive effect on physical performance at the time of discharge from hospital. Statistically significant effects were not found in the outpatient CGA model and management program. The researchers used the Physical Performance test (Reuben & Siu 1990), which includes writing a sentence, simulated eating, turning 360 degrees, putting on and removing a jacket, lifting a book and putting it on a shelf, picking up a penny from the floor, and walking 50 feet (15.24 m). On the other hand, a single outpatient comprehensive geriatric assessment coupled with an adherence intervention demonstrated a significant improvement in the same test among community-dwelling older persons who had specific geriatric conditions (Reuben et al. 1999).

Although a randomized controlled trial by Melis et al. (2008) found that CGA with problem-based management improved functional performance in basic and instrumental activities of daily living, only a trend toward positive intervention effects was observed in physical performance measured by the

Timed Up & Go among frail community-dwelling people. On the other hand, the duration of the home-based individualized intervention was only three months, and it did not involve any supervised exercise strategy. Accordingly, it may not be possible in such a short study period to observe significant changes in physical performance without a regular and intensive training program. A study by Leveille et al. (1998b) did not include comprehensive geriatric assessment but addressed known risk factors for disability and targeted a plan for physical activity and self-management of chronic illness with follow-up. The results of the study were in line with those of Melis et al. (2008), showing that the intervention group had fewer disability days and better functioning in activities of daily living compared to the control group. However, physical performance was not altered by the intervention; only the Timed Up & Go test showed modest but not statistically significant improvements in the intervention group compared with controls (Leveille et al. 1998b).

In addition to specific CGA programs, multifactorial intervention strategies have been used in studies aimed at preventing falls among older people Typically, the interventions in question have often been based on structural assessment of several dimensions of health and functional capacity (van Haastregt et al. 2000, Shumway-Cook et al. 2007), and may thus be compared to the CGA programs. For example, a study by Shumway-Cook et al. (2007) measured physical performance as a secondary outcome in addition to the incidence rate of falls. One RCT investigated the effects of a 12-month community-based multifactorial intervention on falls and risk factors such as mobility problems. In contrast to the traditional CGA programs, the participants in the intervention group were given the opportunity to participate in regular group exercise classes for up to 12 months. The intervention produced small but significant improvements in physical performance measures such as the Berg Balance Scale, chair stands and Timed Up & Go test. This is in line with the other studies on fall prevention which have shown a positive effect on physical performance (Lord et al. 2005, Hill et al. 2008).

TABLE 1 Randomized controlled trials including comprehensive geriatric assessment or similar, individualized intervention, mobility and functional status outcomes among community-dwelling people.

Study	Participants, mean age (SD)	Duration and intervention	Effect	Outcome measures
Leveille et al.1998b	Chronically ill men and women (56%) 77.1 (5.2) years n=201	12 months Physical activity and disease self-management program, telephone contacts	+ 0	Bed disability days 6-minute walking, usual gait speed, chair stand, TUG, the physical performance and mobility exam, MOS-SF-36
Reuben et al. 1999	Men and women (82%) with at least one of four geriatric conditions 75.9 (5.9) years n=363	15 months Single CGA consultation, recommendations, telephone contacts	+ + 0	MOS SF-36 Restricted activity days The Physical Performance test
Burns et al. 2000	Men (97%) and women admitted to the health services 71.3 (5.0) years n=98	24 months Long-term management program	+ 0	Lawton & Brody (IADL) Katz (ADL)
Stuck et al. 2000	Men and women (73%) without severe impairments 81.6 (4.6) years n=791	36 months Referral and recommendations, health counseling	+	Lawton & Brody (IADL)
Van Haastregt et al. 2000	Men and women (66%) at risk for falls 77.2 (5.1) years n=316	18 months Home visits, environment or assistive devices, counseling, referrals	0	Self-reported walking ability
Boult et al. 2001	Men (56%) and women at risk for hospital admission 78.8 (5.6) years n=568	18 months Multidisciplinary management, telephone contacts	+	Sickness Impact Profile : Dimension of physical functioning
Hébert et al. 2001	Men and women (64%) at risk for functional decline 80.3 (4.4) years n=503	12 months Referral, recommendations, telephone contacts	0	Functional autonomy measurement system

continues

TABLE 1 continues

Study	Participants, mean age (SD)	Duration and intervention	Effect	Outcome measures
Gill et al. 2002	Physically frail men and women (80%) 83.2 (5.1) years n=188	12 months Home-based physiotherapy program, environment or assistive devices, education	+	Self-reported disability score
Cohen et al. 2002	Men (98%) and women discharged after acute hospitalization 74.2 years n=1338	12 months		
		Care at inpatient clinic	+	MOS-SF-36, Katz (ADL)
			+	The Physical Performance test
		Care at outpatient clinic	0	
Caplan et al. 2004	Men and women (60%) discharged home from emergency department 82.2 (5.9) years n=739	18 months Recommendations, referrals, appropriate services	+	Barthel (ADL)
Shumway-Cook et al. 2007	Sedentary men and women (77%) 75.6 (5.9) years n=453	12 months Group exercise 3 times/week, fall prevention education	+	Berg Balance Scale, Chair stand, TUG
Rubenstein et al. 2007	Men (97%) and women at risk for disability 74.4 (6.0) years n=792	18 months Referrals, telephone contacts	0	Functional Status Questionnaire
			+	Subgroup of persons with poor functioning in IADL at baseline
Bouman et al. 2008	Men and women (60%) with poor health 75.7 (3.8) years n=330	24 months Home visits, advice, referrals, telephone contacts	0	Groningen Activity Restriction Scale
Melis et al. 2008	Men and women (75%) with one or more limitations in cognition, functioning, or mental well-being 82.3 (6.3) years n=151	6 months Individualized management program	+	Groningen Activity Restriction Scale
			0	TUG

+ Positive intervention effect (statistically significant, $p<0.05$) 0 No intervention effect
ADL= Activities of daily living
IADL=Instrumental activities of daily living
MOS SF-36=Medical Outcome Survey Short Form Health Survey
TUG= Timed Up & Go test

2.3.3 Comprehensive geriatric assessment and individualized intervention in relation to pain

Most health conditions associated with aging carry a substantial burden of pain. Aging affects individuals differently, and increases the variance in physiology and metabolism related to pain (Fine 2009). Thus, particular attention to individualized assessment and treatment of pain is needed, and the pain management approach should reflect an individual's unique requirements and limitations. Assessment of pain is an important part of CGA and a consensus exists on recommendations for comprehensive assessment of pain in older adults (Hadjistavropoulos et al. 2007). In previous CGA studies, pain has usually been evaluated as part of a health-related quality of life measure, such as the SF-36 (Ware & Sherbourne 1992).

The management of pain should be one of the primary targets of an intervention among persons with pain. The current evidence for the primary care management of pain in older persons supports the use of both pharmacological and non-pharmacological strategies (AGS Panel on Persistent Pain in Older Persons 2002, AGS Panel on Pharmacological Management of Persistent Pain in Older Persons 2009). Traditionally, the management of pain has been led by physicians, and interdisciplinarity has not been utilized as a way effectively to address the multidimensional aspects of pain in older people. This seems to be increasingly unsustainable, and alternative models of care are needed. Multidisciplinary team of CGA and individualized interventions may provide an effective shift in care away from the traditionally used constricted model. Nevertheless, relatively few studies on CGA have documented the effects of interventions on pain or have focused specifically on persons with pain. For example, Cohen et al. (2002) showed that inpatient CGA and management had positive effect on bodily pain at discharge from geriatric unit and one year after it. On the other hand, no effects on pain were found among persons who received CGA in the outpatient unit (Cohen et al. 2002).

3 AIMS OF THE STUDY

The purpose of this study was to investigate the association between musculoskeletal pain, postural balance and mobility in older people. In addition, this study examined the effects of a comprehensive geriatric assessment and multifactorial intervention on physical performance and the development of mobility limitation in older people aged 75 years and over. The specific aims of the present investigations were to determine:

1. Whether musculoskeletal pain is associated with mobility, and whether the association varies according to the use of analgesics (I).
2. Whether musculoskeletal pain is associated with postural balance (II).
3. The effects of a comprehensive geriatric assessment and individualized intervention on physical performance (III) and perceived mobility limitation (IV).
4. The effects of a comprehensive geriatric assessment and individualized intervention on mobility among persons with musculoskeletal pain (IV).

4 METHODS

4.1 Study design and participants

This experimental study is part of a broader population-based study, the Geriatric Multidisciplinary Strategy for the Good Care of the Elderly (GeMS), which was designed to develop a model of geriatric assessment, care and rehabilitation suited to the needs of primary health care. It comprised a baseline assessment, a two-year intervention with annual measurements and a one-year follow-up. The study was conducted in the city of Kuopio, Eastern Finland between November 2003 and December 2007. The design and the data used in the original publications are summarized in Table 2.

The target population consisted of all the 75-year-old and older residents of Kuopio. In November 2003, when the study was launched, Kuopio had 88 253 inhabitants, of whom 6% (5615 persons) were aged 75 years or older. Contact information on the population was gathered from the Finnish population register. A random sample of 1 000 persons was randomly divided into two same-sized groups, an intervention and a control group. After excluding subjects who had died, refused to participate or had moved out of the area, a total of 781 subjects participated in the study (404 in the intervention group and 377 in the control group). The study protocol included an annual examination over a three-year period from 2004 to 2007 for both the intervention and control groups. Attrition during the follow-up was mainly due to deaths, but also to refusals that occurred to some extent in both groups. For the purposes of the present study, the data used were obtained from the structured interviews carried out annually by a physician and trained nurse, and the physical performance and postural balance tests carried out by a trained physiotherapist. A flow chart of the GeMS is presented in Figure 1.

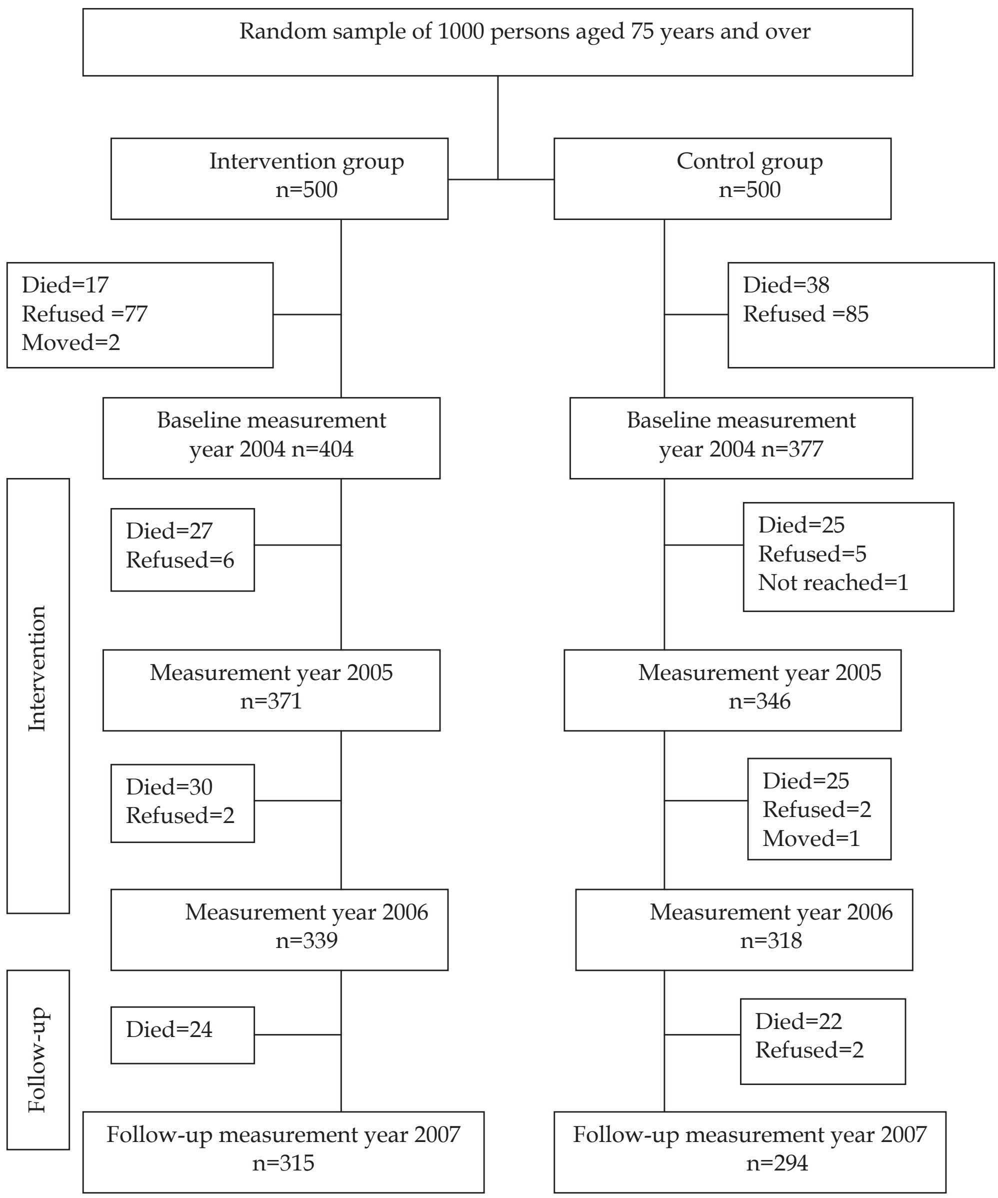

FIGURE 1 Flow chart of the GeMS project.

TABLE 2 Study designs, populations and outcomes.

Study	Design	Participants	Age (mean ± SD)	Primary outcome
I	Observational Cross-sectional	436 women 186 men	75-98 (80.4 ± 4.5)	Mobility limitation
II	Observational Cross-sectional	428 women 177 men	75-98 (80.4 ± 4.4)	Impaired postural balance
III	Experimental Controlled trial 2-year intervention with 1-year follow-up Subgroup analyses for those who were able to participate in the physical performance tests	668 women and men Intervention group n=348 Control group n=320	75-98 (80.6 ± 4.7)	Physical performance: Walking speed Timed Up & Go-test Berg Balance Scale
IV	Experimental Controlled trial 2-year intervention with 1-year follow-up Subgroup analyses for those with pain and without pain	781 women and men Intervention =404 Control n=377 Intervention n=137 Control n=128 Intervention n=177 Control n=165	75-98 (81.1 ± 5.0)	Mobility limitation

4.2 Ethics

The GeMS study was approved by the Research Ethics Committee of the Hospital District of Northern Savo. All the participants were informed about the study and they or their family members gave a written informed consent. Studies were carried out according to the guidelines for good scientific practice laid down in the Declaration of Helsinki.

4.3 Measurements

4.3.1 Mobility

Mobility was measured using the Timed Up & Go test (TUG) (I, III), 10-meter walk test (III), and self-reports (IV). The TUG measures a combination of many factors needed in mobility such as muscle strength and power, postural balance and walking ability (Podsiadlo & Richardson 1991). In the TUG, participants were asked to rise from a standard chair with armrests, using their arms for support if needed, walk three meters as fast as possible, turn and return to a fully seated position in the same chair. The time taken to complete the test was measured by a stopwatch. In the TUG and walk test, participants wore their regular footwear and were allowed to use their usual ambulatory aid if necessary. Previous studies have shown excellent intra- and interrater reliability in the range 0.92 to 0.99 (Steffen et al. 2002, Lin et al. 2004). Participants were considered to have mobility limitation if the time exceeded 13.5 seconds or if they were unable to perform the TUG test (I). The cut-off point of 13.5 seconds was based on a previous study, in which it was associated with an increased risk of falling among people aged 65-95 years (Shumway-Cook, Brauer & Woollacott 2000).

Maximal walking speed was assessed over a 10-meter distance timed with a stopwatch. Participants were allowed three meters for acceleration before the start line and they were encouraged to walk as fast as possible without risking their health. Maximal walking speed (m/s) was calculated by dividing the 10-m distance by the time taken to walk it. The test-retest precision has been documented previously to be 5% (Sipilä et al. 1996, Steffen et al. 2002). The recommended criterion for clinically meaningful change in maximal walking speed is 0.05 m/s (Perera et al. 2006).

Self-reported mobility limitation was evaluated using a structured question on perceived ability to walk 400 meters. Four alternative response options were given: (1) unable to manage, (2) able to manage only with help of another person, (3) able to manage independently but with difficulty, (4) able to manage without difficulty. Participants reporting inability and need for the help of another person were categorized as having mobility limitation.

4.3.2 Postural balance

Balance was measured by a trained physiotherapist using a force platform system (Good Balance; Metitur Ltd, Jyväskylä, Finland) and Berg Balance Scale (Berg et al. 1992). The force platform device is designed to register vertical forces, and to calculate anteroposterior (AP) and mediolateral (ML) sway velocity (mm/s), and velocity moment (mm^2/s) from the movement of the centre of pressure (COP). Velocity moment refers to the first moment of velocity calculated as the mean area covered by the movement of COP during each second of the test. The amplified analogue signals were recorded at a rate of 50 Hz and transmitted to the computer through a serial port. All filtering and data processing was conducted in digital form by the software. Four different test conditions, during which COP movement was recorded for 20 or 30 seconds depending on the test, were used. In tests where the participant had been instructed to stand barefoot as still as possible, higher sway values indicated greater postural instability. The test conditions were: 1) normal standing for 30 s, feet comfortably apart, with eyes open, 2) normal standing for 30 s, feet comfortably apart, with eyes closed, 3) standing feet together side by side for 30 s, with eyes open, 3) semitandem standing for 20 s, the heel of one foot positioned alongside the big toe of the other foot, with eyes open. The semitandem test was done twice, first with one foot and then with the other foot in front. The result of the better trial was taken for the analyses. To minimize the effect of body height on COP movement, the values of the original ML and AP speed variables were adjusted using the formula [(balance variable/participant's height (cm)) x 180]. For velocity moment the effect of body height was compensated for according to the formula [(balance variable/participant's height in cm^2) x 180^2] (Era et al. 1996).

Impaired balance was defined on the one hand according to the participant's ability to perform the semitandem test and on the other hand according to the quality of balance performance as sway measurements. Participants were categorized into tertiles according to the distribution of the mean velocity moment in semitandem standing. The first and second tertiles (lowest sway velocity moment), representing the best performance in the semitandem test were combined (n=278). Those unable to perform the semitandem test (n=185) were combined with the persons in the third tertile (n=142), whose balance performance was the poorest. Thus, impaired postural balance (n=327) was defined as being unable to perform the semitandem test or having the highest sway velocity moment in it.

The Berg Balance Scale was used to evaluate an individual's ability to perform different tasks related to the skills of sitting down, standing up, reaching, turning around oneself, looking over one's shoulders and standing on one foot. The ability to perform each of the 14 tasks is rated from 0 (incapable) to 4 (safe and independent). The total score ranges between 0 and 56, with higher scores indicating better functional balance in mobility tasks. The psychometric properties of reliability and validity have been well demonstrated for the Berg Balance Scale. Studies on older people have shown high intra- and interrater reliability (ICC 0.98, ratio of variability to total 0.96–1.0, r_s.88) (Berg et al. 1992, Steffen et al. 2002).

4.3.3 Musculoskeletal pain

A specially trained nurse examiner interviewed the participants on musculoskeletal pain at the research clinic or in their home. The assessment included questions about the presence, frequency and severity of pain. Pain was defined as pain experienced in the shoulders, neck, back, hips, knees, or other sites in the upper or lower body for at least seven days during the month immediately preceding the assessment. To measure the severity of pain, a 10-point Numeric Rating Scale (NRS), which has the numbers 1-10 written successively from left to right and where the person circles the number that corresponds best to his/her pain, was used. Pain was categorized into two groups according to severity: mild (2–4), and moderate to severe pain (5-10). Participants reporting mild or moderate to severe pain were compared with those who reported no pain.

4.3.4 Descriptive, mediating and confounding factors

Background information

The participants' weight and height were measured, and body mass index (BMI) was calculated by dividing body weight (kg) by body height squared in meters. Residential status was determined on the basis of living conditions at the time of examination. Home living status was coded for subjects living in their own home or in sheltered accommodation. Institutional care included nursing homes, residential care homes and long-term hospital care. Cognitive function was assessed using the Mini Mental State Examination (MMSE) (Folstein, et al. 1975). Self-rated health was measured by the question: "How would you rate your health at the moment?" Participants selected one of the five response categories ranging from very good to very poor health. In the analysis, categories 1-3 (good self-rated health) and 4-5 (poor self-rated health) were combined. Length of education was asked in the questionnaire and classified into two categories: (a) 6 years or less and (b) more than 6 years.

Physical activity

Information on level of physical activity was collected using a modified version of the scale of Grimby (1986). The participants were categorized on the basis of their self-reported physical activity into a sedentary group (no exercise, or at most light walking 1-2 times a week) and a more active group (walking or other light exercise several times a week, or moderate exercise 1-2 times a week, or moderate to vigorous exercise several times a week).

Chronic conditions

Depressive symptoms were screened for using the 15-item Geriatric Depression Scale (Sheikh & Yesavage 1986). A score of 5 or more (range 0-15) was used to indicate the presence of depressive symptoms. Assessment of osteoarthritis and stroke was based on the baseline clinical examination and medical records. The presence of rheumatoid arthritis, chronic obstructive pulmonary disease, Parkinson's disease, diabetes, and cardiovascular disease was confirmed from the Special Reimbursement Register, which is maintained by the Finnish Social Insurance Institution and contains data on patients with specific chronic diseases. In this study, osteoarthritis and rheumatoid arthritis were combined to form a single arthritis variable. Similarly, stroke and Parkinson's disease formed a single neurological disease variable.

Muscle strength

Maximal isometric knee extension strength was measured unilaterally on both sides in a sitting position using an adjustable dynamometer chair (Good Strength, Metitur Oy, Palokka Finland). The measurements were performed at a knee angle of 60°. Participants were allowed to make three maximal efforts and the best performance with the highest value was accepted as the result. Five hundred and twenty participants completed the maximal isometric strength test. Participants were allocated into categories for age and sex, and each category was then divided into tertiles. In the logistic regression analyses, the highest tertile was compared with the middle tertile (moderate knee extension strength), lowest tertile (low knee extension strength) and with those with missing muscle strength values. People who were not able to participate in the strength test (n=102) were more likely to be older ($p<0.001$), to rate their health poor ($p<0.001$), and to have mobility limitation ($p<0.001$) than those who took part. For analytical purposes, people with missing muscle strength were included intthe poor muscle strength group.

Use of analgesics
Use of prescription and nonprescription analgesic drugs was assessed by trained nurse during the interviews. Drug information was obtained from the participants and/or their relatives and caregivers (prescriptions, drug packages), and from the medical records (the municipal health center, home nursing service, local hospitals, and Kuopio University Hospital).

4.4 The comprehensive geriatric assessment and individualized intervention

The individually tailored geriatric intervention was aimed at preventing disability in older people. An annual CGA was an integral part of the intervention. It involved a multidimensional team approach that determined an older person's biomedical, psychosocial, and environmental needs so that an appropriate treatment plan could be initiated. A physician, nurse, and physiotherapist assessed the participants annually, a dentist twice, and an ophthalmologist once during the study period. The CGA included commonly used standardized tools in the assessment of physical, cognitive, emotional, and functional status.

The individualized intervention consisted of a medical and a physical activity component. In the medical intervention the main focus was on the optimization of care and medication, and on the management of major medical problems commonly encountered in old age, such as inappropriate medication, malnutrition, declined cognition, and declined physical health, that increase the risk for institutionalized care. The multidisciplinary health professional team delivered the intervention, and referred the participant to other health professionals and community services when needed. The control participants did not receive any intervention but took part in the annual health and physical performance evaluation and used their usual healthcare services.

The physical activity component of the intervention consisted of individually tailored physical activity counseling and an opportunity to participate in supervised muscle strength and balance training. The counseling session started with a physical activity interview, the aim being to chart current as well as prior physical activity. To increase adherence, both the participant and physiotherapist signed the plan. The plan was revised and adjusted, if needed, annually.

Group-based progressive resistance training was offered to the intervention group once a week at a gym, and was supervised by a physiotherapist. The training included leg press, leg extension, leg curl, hip abduction, hip adduction, hip extension, and abdominal crunch. The intensity of training was determined by repetition maximums. Training was performed with a moderate intensity of 60-85% of 1 RM with 2-3 sets and 8-12 repetitions. Progression was done by increasing the load while maintaining the same number of successful repetitions. Each training session included a 15-minute period of combined warming-up and balance exercises.

4.5 Statistical methods

The descriptive statistics are expressed as proportions and means with standard deviations (SDs). The baseline comparisons of the discrete characteristics of the study groups were performed using Pearson's χ^2-test and comparisons for continuous variables were tested using independent sample Student's t-test and one-way analysis of variance (ANOVA). The assumption of normality was assessed graphically and tested with the Kolmogorov-Smirnov test.

Logistic regression model

The association of musculoskeletal pain with mobility limitation (Study I), and impaired balance (Study II) was studied using logistic regression models. The base models were adjusted for age and sex, and furthermore, known and postulated determinants of outcome variables were added to the model to examine in more detail the pathway between pain, mobility limitation and impaired postural balance. The adjusted models included BMI, living alone, chronic conditions, physical activity, and muscle strength.

Linear mixed model

Linear mixed models with a repeated measurements technique (unstructured covariance type), were used to analyze the effect of CGA and the individualized intervention on maximal walking speed, time to perform TUG, and the Berg Balance Test scores and the progress of these measures over time (Study III). The results of the linear mixed models are presented as estimated covariate effects (β parameters) with standard errors (SEs). The analysis yielded restricted maximum likelihood estimates for the effects of time, group, and time x group intervention. A statistically significant time x group interaction indicates that the two groups have different patterns of change in the outcome measurement over time.

Generalized estimating equation models

To analyze the effect of the intervention and 1-year follow-up data on our primary outcome, mobility limitation, generalized estimating equation (GEE) models were constructed. The GEE methodology allowed us to analyze whether the participants in the intervention group had a lower incidence of, or higher recovery from, mobility limitation, resulting in a lower prevalence of mobility limitation compared with the control group. The interaction term tested represents the difference between the groups in time-related change in the proportion of participants reporting mobility limitation. Results are expressed as odds ratios and their 95% confidence intervals. In a subgroup analysis, GEE models were applied to explore whether the prevalence of mobility limitation differed over time between the participants with pain and those without pain at baseline in the intervention and control groups. Number needed to treat (Cook & Sackett 1995) [NNT= 1/(proportion benefiting from experimental intervention in the intervention group – proportion benefiting in the control group)], was calculated to evaluate the efficacy of the trial the in whole sample after the 2-year intervention.

Statistical software

All data were entered into SPSS statistical software. In the analysis, the latest available version of this software was used. The SPSS statistical software for Windows (SPSS Inc., Chicago, US) was used to analyze the results of Studies I and II (version 15.0). The PASW statistical software (SPSS Inc., Chicago, US, version 18.0) was used in Studies III and IV.

5 RESULTS

5.1 Characteristics of the participants

Table 3 shows the baseline characteristics of the participants in the GeMS project. The participants were on average 81.8 ± 5.0 year-old, and the majority were women (70%, n=548). The most prevalent chronic conditions were cardiovascular diseases: approximately 64% of the participants (n=497) had cardiovascular disease. Almost 40% (n=299) of persons suffered from arthritis. Approximately half of the participants (47%, n=364) were categorized as having a sedentary lifestyle.

TABLE 3 Baseline characteristics of the participants in the GeMS project (n=781).

	Mean	(SD)
Age (years)	81.1	(5.0)
Education (years)	7.3	(3.3)
Body Mass Index (kg/m²)	26.4	(4.4)
Mini Mental State Examination (score)	24.6	(6.8)
	%	(n)
Women	70	(548)
Living arrangement		
at home with someone	38	298
at home alone	52	402
institutionalized	10	81
Poor self-rated health	15	120
Arthritis	38	299
Cardiovascular disease	64	497
Neurological disease	14	113
Chronic obstructive pulmonary disease	9	68
Cancer	4	29
Diabetes	16	128
Depressive symptoms	9	73
Sedentary	47	364

SD=Standard Deviation

5.2 Musculoskeletal pain in relation to mobility and postural balance

5.2.1 Musculoskeletal pain in the participants

A total of 251 (40%) community-dwelling persons reported persistent musculoskeletal pain. Of them, 62% (n=155) were classified as having severe or moderate pain, and 38% (n=96) as having mild pain. Pain was located in the lower extremities (40%), back (21%), lower extremities and back (17%), upper extremities (6%), and upper and lower extremities and back (16%).

Compared with participants without pain, those with pain were more likely to be women, to have a higher BMI, and to rate their health as poor. Participants with pain had a higher prevalence of osteoarthritis, chronic obstructive pulmonary disease, and depressed mood. In addition, they were more likely to be sedentary and have mobility limitation than those without pain. Participants with pain were also more likely to use analgesics. Table 4 shows the baseline comparisons between the pain severity groups.

TABLE 4 Baseline characteristics in relation to pain in the participants aged 75 years and over.

	No pain	Pain		p-
		Mild	Moderate / severe	
	n=371	n=96	n=155	value*
	Mean (SD)	Mean (SD)	Mean (SD)	
Age (y)	80.0 (4.3)	80.9 (4.9)	80.9 (4.6)	.050
Education (y)	7.6 (3.2)	8.0 (4.2)	7.0 (2.9)	.061
BMI (kg/m²)	26.1 (4.1)	27.4 (3.9)	27.8 (4.9)	<.001
MMSE (score)	26.9 (2.9)	26.9 (2.9)	27.2 (2.4)	.527
	%	%	%	
Women	66	72	80	.004
Poor self-rated health	8	17	25	<.001
Arthritis	26	57	54	<.001
Cardiovascular disease	63	68	71	.178
Neurological disease	11	11	16	.255
Chronic obstructive pulmonary disease	7	8	15	.023
Cancer	4	2	3	.522
Diabetes	14	16	21	.116
Depressive symptoms	6	13	11	.039
Sedentary	32	43	50	.001
Mobility limitation	24	40	47	<.001
Analgesics	26	60	77	<.001

*Chi-square test and ANOVA
BMI=Body Mass Index
MMSE=Mini-Mental State Examination

5.2.2 Association of musculoskeletal pain with mobility limitation (I)

Musculoskeletal pain was associated with mobility problems among the community-dwelling participants. Time to perform the Timed Up & Go test was significantly higher among participants with pain (15.1±SE 0.5s) compared to those without pain (12.4±0.4s, p=0.003). Maximal walking speed was lower among participants with pain compared to those without pain (1.23±0.03m/s vs. 1.42±0.02m/s, p<0.001).

Participants who reported pain had over twice the risk (OR 2.35 95% CI 1.63–3.38) for a TUG result of over 13.5 s or inability to perform the test, indicating mobility limitation, than participants with no pain after adjusting for age and gender. After adjustment for body mass, living alone, self-rated health, chronic conditions, physical activity, and muscle strength, the association between pain and mobility limitation was attenuated but remained statistically significant (OR 1.83 95% CI 1.16–2.89). The results on the relationships between severity of musculoskeletal pain and mobility limitation in the logistic regression analyses are presented in Table 5. There was a gradient risk for mobility limitation according to pain severity. The risk was highest among those with severe or moderate pain (OR 2.53 95% CI 1.67–3.70). The association remained significant after further adjustment (OR 1.84 95% CI 1.10–3.13).

TABLE 5 Association between musculoskeletal pain and mobility limitation. Odds ratios (OR) and 95 % Confidence intervals (CI) for mobility limitation measured by Timed Up & Go test among community-dwelling persons aged 75 years and over, n=622.

	Risk for mobility limitation			
	Model I*		Model II†	
	OR	95% CI	OR	95% CI
Severity of pain				
No pain	1.00	-	1.00	-
Mild pain	2.07	1.26-3.42	1.58	0.84-2.97
Moderate or severe pain	2.53	1.67-3.70	1.84	1.10–3.13
Age ≥ 80 years	3.36	2.34-4.83	2.95	1.88-4.63
Female	1.76	1.15-2.70	1.49	0.86-2.58
Body mass index ≥ 30kg/m^2			1.22	0.71-2.09
Living alone			2.30	1.40-3.79
Poor self-rated health			1.99	1.06-3.73
Chronic conditions				
Arthritis			1.46	0.93-2.29
Cardiovascular disease			1.07	0.67-1.73
Neurological disease			4.43	2.41-8.12
Obstructive pulmonary disease			0.78	0.38-1.62
Diabetes			1.31	0.73-2.36
Depressive symptoms			1.28	0.58-2.79
Sedentary lifestyle			3.54	2.25-5.59
Poor muscle strength			4.49	2.87-7.03

*Model adjusted for age and gender.
†Model adjusted for age, gender, body mass, living alone, osteoarthritis, rheumatoid arthritis, cardiovascular diseases, neurological diseases, chronic obstructive pulmonary diseases, diabetes, depressive symptoms, sedentary lifestyle, and poor maximal isometric knee extension strength.

Analgesic medications were used by 71% (177/251) of persons with pain, and by 26% (98/371) without pain (Table 4). The most commonly used oral analgesic drugs were non-steroidal anti-inflammatory drugs (NSAIDs, 33.5%), followed by acetaminophen (29.1%), opioids (22.9%), and combinations of NSAIDs and acetaminophen (11.6%). Furthermore, 2.9% used topical NSAIDs only. Figure 2 shows that the proportion of those who reported difficulties in walking 400 m was higher (p<0.001) among persons who had pain and used analgesics than in the other groups.

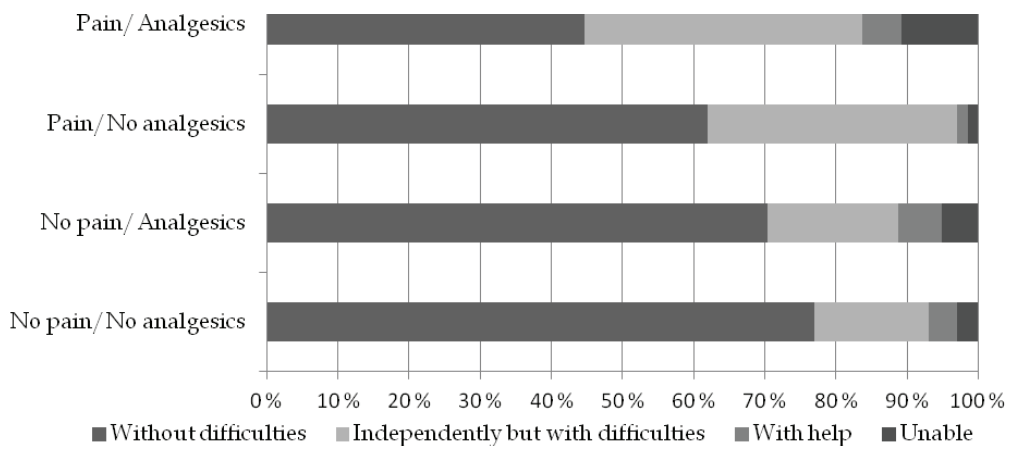

FIGURE 2 Percentages of persons according to self-reported ability to walk 400 m in groups formed on the basis of pain and use of analgesics.

Analgesic users who experienced pain had over three times the risk for mobility limitation (indicated as time to perform TUG over 13.5 s or inability to perform the test) (OR 3.19 95% CI 2.07–4.93) compared to pain-free persons who did not use analgesics. Further adjustment for potential factors on the pathway, such as body mass, living alone, self-rated health, chronic conditions, physical activity, and muscle strength, did not materially change the result (OR 2.37 95% CI 1.37–4.11). The risk of mobility limitation was not statistically significantly different between pain-free analgesic users (OR 1.20 95% CI 0.69-2.09), and non-users with pain (OR 1.29 95% CI 0.70-2.37) as compared to pain-free non-users (Figure 3).

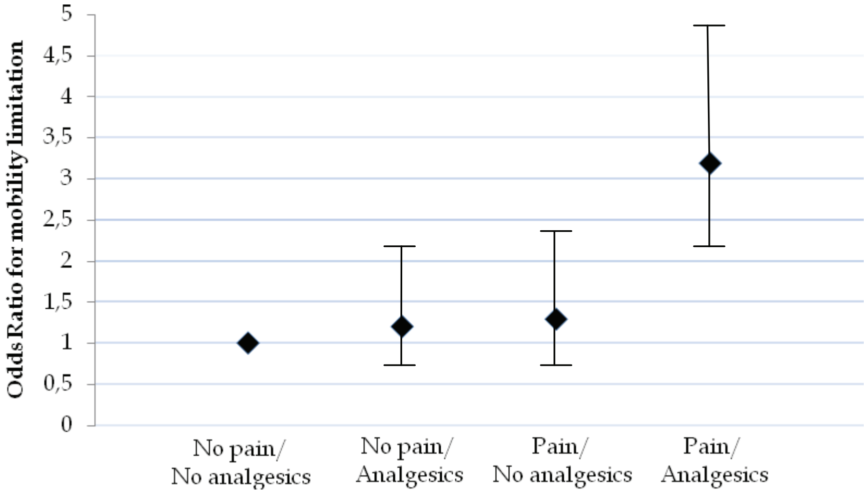

FIGURE 3 Odds Ratio and 95% Confidence Interval for having Timed Up & Go test result > 13.5 s or being unable to perform the test indicating mobility limitation in older persons stratified based on pain and analgesics use.

5.2.3 Association of musculoskeletal pain with postural balance (II)

Table 6 compares the measures of postural sway in the four different stances between the three groups according to severity of pain. In addition, the proportion of those unable to perform a test is presented by pain groups. Significantly higher AP velocities in all stances were observed for participants with moderate to severe pain compared to those without pain. A trend towards increased sway in the ML direction in those with pain was present but the differences between the groups were not statistically significant. Figure 4 shows that velocity moment increased with the increasing challenge of the test. In each test, participants with no pain performed significantly better than those with moderate to severe pain. For example, in the most challenging test position, semitandem stance, the mean of the velocity moment was statistically significantly higher (117.4 mm^2/s, SD 59.7) for those with moderate to severe pain than those without pain (104.4 mm^2/s, SD 46.9), p=0.011). Additionally, a significantly greater proportion of the participants with musculoskeletal pain were unable to perform the semitandem test compared to those without pain (Table 6).

Logistic regression analysis revealed that participants with moderate to severe pain had over twice (OR 2.55, 95% CI 1.67-3.91) the risk for impaired postural balance compared to those without pain. The multivariate adjustment, including age, gender, obesity, chronic diseases, joint replacement, muscle strength and level of physical activity, did not materially change the estimate (OR 2.33, 95 % CI 1.44-3.76). Mild pain was not associated with impaired postural balance (OR 1.08 95% CI 0.64-1.83).

TABLE 6 Indices of COP movement variables, mean (SD), in different standing conditions by pain groups.

Balance test/ COP movement	No pain n=314	Pain: Mild n=113	Pain: Moderate / severe n=178	Trend p-value†
Normal, eyes open				
ML velocity mm/s	5.6 (2.8)	5.7 (2.4)	6.2 (3.3)	.124
AP velocity mm/s	10.3 (4.9)	10.8 (4.9)	12.1 (6.9)*	.005
Velocity moment mm^2/s	22.2 (12.3)	22.6 (13.0)	26.1 (14.3)*	.049
Unable to perform, n (%)	18 (6)	11 (10)	18 (10)	.150
Normal, eyes closed				
ML velocity mm/s	7.8 (4.9)	8.2 (5.0)	8.8 (5.2)	.064
AP velocity mm/s	16.3 (6.8)	17.4 (7.4)	18.5 (8.4)*	.017
Velocity moment mm^2/s	33.7 (26.2)	37.0 (27.9)	43.5 (31.8)*	.012
Unable to perform, n (%)	22 (7)	13 (11)	20 (12)	.179
Feet together				
ML velocity mm/s	16.1 (5.7)	16.8 (5.8)	17.3 (6.4)	.234
AP velocity mm/s	13.2 (5.4)	14.4 (6.2)	15.7 (6.3)*	.001
Velocity moment mm^2/s	65.8 (34.6)	70.6 (34.5)	77.4 (38.1)*	.016
Unable to perform, n (%)	35 (11)	16 (14)	33 (19)*	.074
Semitandem				
ML velocity mm/s	24.4 (7.3)	25.5 (7.7)	26.2 (8.1)	.154
AP velocity mm/s	19.7 (8.0)	20.2 (7.7)	22.0 (8.3)*	.009
Velocity moment mm^2/s	104.4 (46.9)	107.2 (55.8)	117.4 (59.7)*	.055
Unable to perform, n (%)	79 (25)	38 (34)	68 (38)*	.008

COP=center of pressure
SD=standard deviation
ML=mediolateral
AP=anteroposterior
† test for linear trend across pain groups.
* p <0.017 determined from least significant difference post hoc test for differences between pain groups.

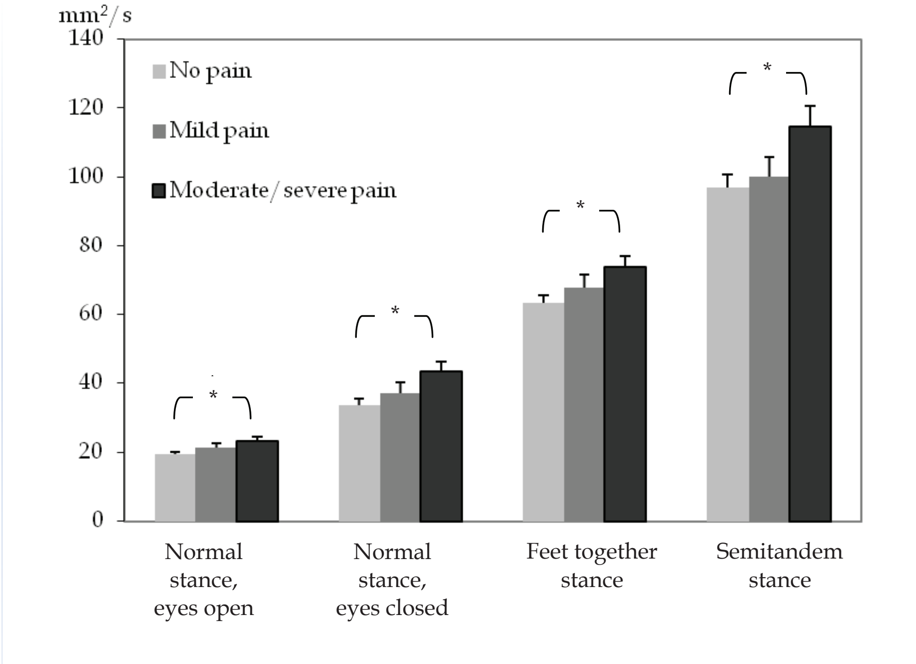

FIGURE 4 Mean center of pressure velocity moments and standard errors in four different stance positions by pain groups. * $p<0.017$ for comparison between those with moderate/severe pain and no pain determined from least significant test.

5.3 Effects of the comprehensive geriatric assessment and individualized intervention on mobility

In the GeMs data, the baseline characteristics of the intervention group and control group were comparable (Studies III and IV). The mean age of the both groups was 81 years and the majority were women (71% in the intervention group and 69% in the control group). There were no statistically significant differences between the study groups in the prevalence of chronic conditions, physical activity or maximal isometric knee extension strength at the baseline (Studies III and IV).

The geriatric intervention was based on the comprehensive geriatric assessment and multidisciplinary team approach. After the geriatric comprehensive assessment by a physician, nurse and physiotherapist, the interventions were tailored for each participant individually. The interventions are described in Table 7. The participants in the intervention group received on average three interventions (SD 1.6) during the GeMS project. In addition to the modification of medication and other activities optimizing health and well-being, the intervention emphasized physical activity. All the participants in the intervention group received annual physical activity counseling by a physiotherapist. They also had an opportunity to participate in supervised balance and strength training once a week during the years 2004-2006. 182 persons took part in the training offered by the GeMS project. The side effects related to the supervised strength and balance training were not systematically collected; however, according to the physiotherapists' reports, only a few persons discontinued training due to musculoskeletal problems or decreased motivation.

TABLE 7 Content of geriatric intervention by multidisciplinary team members and number of the participants who received the interventions during the years 2004-2006.

Team member and functions	n
Physician specializing in geriatric medicine	
- optimizing medication	277
- optimizing medical treatment	120
- new diagnoses and referral to specialized care	109
Trained physiotherapist	
- physical activity counseling	356
- supervised strength and balance training at gym	182
Trained nurse	
- targeted health counseling	120
- arranging services as a case manager	77
Nutritionist	
- targeted nutrition intervention	84
Dentist	
- clinical examination of oral health	354
Ophthalmologist	
- clinical and microscopic examination of eyes/ referral for surgery or specialized care if needed	304

5.3.1 Effects of the comprehensive geriatric assessment and individualized intervention on walking and balance (III)

Altogether 83% (n=552) of the participants who were able to participate in physical performance measurements at the baseline completed the Timed Up & Go test at the follow-up measurement at the end of the intervention. The corresponding proportion for walking speed was 75% (n=503), and for the Berg Balance Scale 85% (n=569). Those who dropped out were more likely to be older (83 vs. 80 years, p< 0.001), sedentary (57% vs. 37%, p<0.001), institutionalized (10% vs. 2%, p<0.001) and to report poor health (20% vs. 11%, p=0.008) than those who completed the measurements.

The results of the TUG and walking speed tests, and the Berg Balance Scale score over time are presented for the two study groups in Table 8. There were no statistically significant differences between the intervention and control group at baseline in the Berg Balance Scale score (p=0.069), TUG time (p=0.256), or walking speed (p=0.867). The changes in mobility between the study groups over the 2-year trial, however, were significantly different. The interaction term for the TUG test was -0.97 ± 0.26 seconds, suggesting that the difference in the change in the time needed to complete the test was 0.97 s in favor of the intervention group. In the control group, the time to complete the TUG worsened from the baseline values, whereas the intervention group showed no decline during the 2-year trial. In maximal walking speed, the difference in the change was 0.05 ± 0.01 m/s in favor of the intervention group. Walking speed improved in the intervention group over the 2-year trial, but decreased in the control group. The NNT for clinically significant change in walking speed was 6. This indicates that to obtain a meaningful change (0.05 m/s) in walking speed in one person, 6 persons would have to receive a comprehensive geriatric assessment and individualized intervention. The intervention group showed increases in the Berg Balance score, whereas the control group scores decreased. When comparing the changes in balance between the study groups, the difference was 1.13 ± 0.19 points in favor of the intervention group. (Table 8.)

The results for the 2-year trial and one-year post-intervention are also shown in Table 8. When the one-year follow-up was included in the analyses, the differences in the changes in mobility over time between the study groups remained significant, although smaller, for both TUG (-0.57 ± 0.23), walking speed (0.03 ± 0.01) and balance (0.61 ± 0.13) At follow-up, the participants' performance in the mobility tests had slightly worsened, although they remained better in the intervention group than control group, whose values were approximately stable during the follow-up. (Table 8.)

TABLE 8 Means and standard deviation (SD) for the physical performance tests, and the linear mixed model estimates for change in mobility over the 2-year intervention (interaction 1) and one-year post-intervention (interaction 2) by study group among persons aged 75 years and over.

	BL 2004 mean±SD	Year 2005 mean±SD	Year 2006 mean±SD	Interaction 1 β (SE) p-value	Year 2007 mean±SD	Interaction 2 β (SE) p-value
Berg Balance Scale, score						
Intervention group	47.7±9.6	48.1±9.0	48.4±8.6	1.13 (0.19)	47.7±9.7	0.60 (0.13)
Control group	46.4±10.7	45.2±11.9	45.3±11.3	<0.001	45.3±11.9	<0.001
Walking speed, m/s						
Intervention group	1.23±0.40	1.29±0.46	1.27±0.47	0.05 (0.01)	1.29±0.49	0.03 (0.01)
Control group	1.23±0.48	1.22±0.50	1.21±0.51	<0.001	1.20±0.50	<0.001
Timed Up & Go test, s						
Intervention group	13.9±9.6	13.2±9.0	14.0±10.5	-0.97 (0.26)	14.9±14.1	-0.57 (0.23)
Control group	14.8±10.3	15.0±9.6	15.9±11.9	<0.001	15.9±15.3	0.014

BL=Baseline
SE=Standard error

5.3.2 Effects of the comprehensive geriatric assessment and individualized intervention on perceived mobility (IV)

All the participants who were studied at every annual follow-up point (Figure 1) completed the mobility interview about their ability to walk 400 meters. The proportion of participants reporting limitation in walking 400 meters is shown in Figure 5. The proportion of participants reporting mobility difficulties in walking decreased in the intervention group during the intervention, whereas corresponding proportion increased in the control group. The proportions of participants with mobility limitation in the intervention group were 16%, 15%, 12%, and 14% across the 3-year study period, whereas in the control group, the corresponding proportions were 19%, 19%, 23%, and 26%. The treatment effect was significant after the 2-year intervention (OR 0.82, 95%CI 0.70-0.96) and remained significant at the 1-year-post-intervention follow-up (OR 0.84, 95%CI 0.75-0.94, Table 9).

Among the persons followed over the whole study period, about 77% (n=262) of those without mobility limitation at baseline remained so in the intervention group versus 69% (n=211) of those in the control group (p<0.001), whereas recovery was reported by 17% (n=11) of those with mobility limitation at baseline in the intervention group versus 14% (n=10) in the control group (p=0.887). The proportion of those who reported mobility limitation at each measurement point over the 3-year study period or who developed new mobility limitation during the study were 13% (n=42) in the intervention group and 25% (n=73) in the control group (p<0.001). At the end of the intervention study, the NNT for mobility limitation was 12. In other words, to prevent one person from developing mobility limitation or to recover from baseline mobility limitation, 12 persons had to receive the CGA and an individualized intervention.

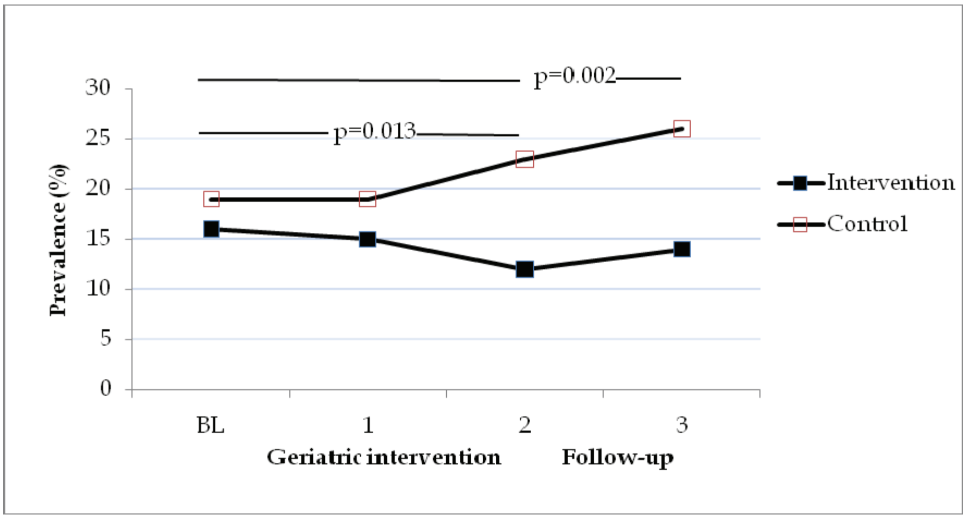

FIGURE 5 Proportion of participants with mobility limitation in the intervention and control group at baseline, at the annual follow-up points during the geriatric intervention, and at the one-year post-intervention follow-up. Note: p value indicates the statistical significance of the treatment effects (group x time interaction) observed in the generalized estimating equation models. BL=baseline

TABLE 9 Treatment effects of the comprehensive geriatric assessment and individualized intervention on perceived mobility after the 2-year intervention (2-year follow-up) and 1-year post-intervention (3-year follow-up). Odds Ratio (OR) represents the extent of the treatment effect (group x time interaction).

	2-year follow-up			3-year follow-up		
	OR	95% CI	p	OR	95% CI	p
Difficulties in walking 400 m independently	0.82	0.70-0.96	.013	0.84	0.75-0.94	.002

5.3.3 Effects of the comprehensive geriatric assessment and individualized intervention on mobility among persons with pain (IV)

Among persons with pain, the proportion of participants reporting mobility limitation was 18% in the intervention group and 19 % in the control group (p=0.892) at baseline. In control group, the proportion of participants reporting mobility limitation gradually increased over the years (22%, 26%, 31%) whereas in the intervention group, the proportion of participants reporting mobility limitation decreased during the 2-year intervention (17%, 15%), and slightly increased at the 1-year post-intervention follow-up point (18%). The treatment effect of the intervention on mobility was significant (OR 0.75, 95%CI 0.59-0.96) at the end of 2-year intervention among persons with pain. The effect remained significant (OR 0.79, 95%CI 0.67-0.93) when the 1-year post-intervention follow-up was taken into account, while no statistically significant effects (OR 0.86, 95% CI 0.72-1.03) were observed among pain-free persons (Figure 6).

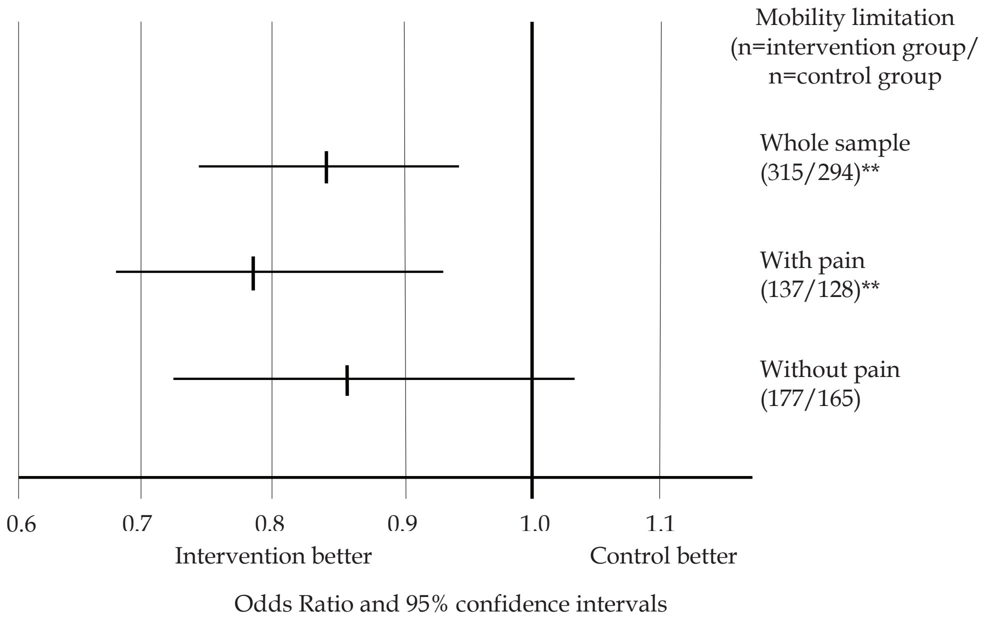

FIGURE 6 Estimated treatment effects of the comprehensive geriatric assessment and individualized intervention on mobility after the 2-year intervention and 1-year post-intervention follow-up. Treatment effects (group x time interaction) are expressed as Odds Ratios and their 95 % confidence intervals and illustrated by bars. **p<0.01.

6 DISCUSSION

The aim of this study was to gain insight into the associations between musculoskeletal pain, mobility and postural balance. Additionally, the effects of a comprehensive geriatric assessment and individualized intervention on mobility in older people, and in persons with musculoskeletal pain were investigated.

The results supported the view that musculoskeletal pain is common in older persons, and compromises their ability to walk and maintain balance, especially in more challenging mobility tasks. There was a clear association between musculoskeletal pain, mobility limitation, and impairment in postural balance, and the association was accentuated when considering the severity of pain. Persons with moderate or severe pain had approximately twice the risk for mobility and balance problems than those without pain. The present study also showed that the 3-year comprehensive geriatric assessment and individually targeted interventions had a positive effect on mobility. Specifically, the intervention effect on perceived mobility was significant among persons with musculoskeletal pain.

6.1 Musculoskeletal pain as a determinant of mobility limitation and postural balance impairment

According to the results of this study, musculoskeletal pain was associated with mobility limitation and balance impairment among older community-dwelling people. The results showed a steep dose-response relationship: the highest risk for mobility limitation and balance impairment was observed among persons who had severe or moderate pain.

The present results are in line with the findings by Lamb et al. (2000) and Eggermont et al. (2009) both of whom have shown an association between pain severity and performance-based mobility limitation. According to Lamb et al. (2000), older women with severe knee pain had over twice the risk for mobility limitation measured by walking speed and chair rising tests. Similarly, a study by Eggermont et al. (2009) showed that severe pain was associated with poor performance in walking speed and chair rising tests. Furthermore, they found that the total number of pain sites was even more strongly associated with mobility deficits than pain severity. In the study by Leveille et al. (2007), persons with widespread pain did not perform worse in mobility tests than those without pain at baseline, but widespread pain predicted onset or worsening of self-reported mobility difficulties during the 3 year follow-up. A recent study by Shah et al. (2011) extended knowledge about the consequences of pain by showing that musculoskeletal pain also predicted the development of performance-based mobility disability as well as the perceived problems in mobility tasks.

There are several possible explanations for the associations, although the precise pathway between pain and mobility and balance is not clear. First of all, pain may be a marker for an underlying pathology that could contribute to mobility limitation, such as osteoarthritis with deformities. In this study, the associations between musculoskeletal pain, mobility limitation, and balance impairment were independent of osteoarthritis and several other chronic conditions. However, we cannot be certain that some unmeasured or undiagnosed pathology could be a contributing factor to the observed associations. Severe pain may indicate higher severity or longer duration of the underlying pathology that has resulted in physical activity restriction over years.

One explanation for mobility and balance problems could lie in the neuromuscular effects of pain. These effects may lead to lower extremity muscle weakness or slowed neuromuscular responses to an unexpected displacement of COP. Muscle weakness could result from lack of physical activity (Rantanen & Avela 1997, Rantanen et al. 1999) or as a direct effect of pain on muscle, referred to as reflex muscle inhibition (Graven-Nielsen et al. 2002). Another factor may be gait alterations or adaptations in order to restrict painful movements (Henriksen et al. 2010). These changes and adaptations may induce additional pain, resulting in further physical activity restriction in the long run (Keefe et al. 1991, Hurwitz et al. 1997).

In the present study, the associations between musculoskeletal pain, mobility limitation, and balance impairment were independent of knee extension strength. This suggests that the relationship between pain and mobility problems is at least partly independent of the generally assumed muscle strength deficit-related pathway. However, there are a wide range of neuromuscular factors, such as leg power, that were not measured and may explain the relationship observed in this study. For instance, previous studies have suggested that, although leg muscle power is related to muscle strength, it has a greater influence than strength on mobility tasks of daily living (Bean et al. 2003, Sayers et al. 2005). Power is representative not only of limb force production, as is the case with leg strength, but also limb speed of movement. Therefore, power plays an important role in the maintenance of balance and thus of several mobility tasks (Bean et al. 2003, Mayson et al. 2008). It is possible that high speed movements that require leg power are painful for persons with lower limb or back pain. Chair rising, for example, requires rapid force production and may be more burdensome than regular walking for persons with painful musculoskeletal conditions in the lower limbs or back (Eggermont et al. 2009). Thus, severe pain may lead to the restriction of movements, or abnormal changes in movement patterns. This may lead to a vicious circle where older people affected by pain reduce their physical activity, thereby accelerating the development of further mobility limitation (Guralnik et al. 2001, Visser et al. 2005). For instance, persistent severe pain may indicate higher severity or longer duration of the underlying disease, resulting in physical activity restriction over the years. Unfortunately, no data on leg power, which would have allowed us to examine whether it contributes to the association between pain, balance and mobility, were available in the present study. In addition, we did not include data on nutritional status, for example malnutrition or vitamin D deficiency, which may also be on the pathway from musculoskeletal pain to mobility and balance problems (Janssen et al. 2002, Milaneschi et al. 2010).

It is possible that the correlation between musculoskeletal pain and observed mobility limitation, measured by the TUG test, was mediated by postural balance. The TUG test requires good postural balance in addition to the other physical characteristics needed in standing up, walking, turning around and sitting down (Podsiadlo & Richardson 1991). Persons with moderate or severe pain showed greater COP displacement and velocity than persons without pain. Greater COP movement indicates poorer postural balance (Pajala et al. 2008), as does the inability to maintain posture while standing on a narrow base of support.

Pain-related interruption of cognitive functions may be one of the important factors underlying mobility and balance problems. Executive function, for example, includes a set of cognitive abilities that are necessary for effective, goal-directed actions and for the control of attentional resources (Solberg Nes et al. 2009). Compared to younger people, older persons have to allocate a greater proportion of their attention to the maintenance of postural balance during walking and other mobility tasks (Lundin-Olsson, Nyberg & Gustafson 1997). Pain may disturb or in other way interfere with the executive function needed to maintain balance and perform mobility tasks (Vancleef & Peters 2006). Recent imaging studies have shown that persons with persistent pain exhibit changes in both brain structure and function consistent with changes observed through neuropsychological testing (Neugebauer et al. 2009, Apkarian et al. 2011). In previous studies persons with pain have shown poorer executive function and decreased attentional resources compared with healthy controls (Karp et al. 2006, Weiner et al. 2006). Poor attention has also been associated with gait changes and increased risk of falls (Springer et al. 2006, Herman et al. 2010). Factors underlying the cognitively mediated pathway between pain, mobility and balance problems may be partly mediated though fatigue and mood disorders, which are commonly linked to persistent pain (Kato et al. 2006).

From the psychological-behavioral point of view, fear of pain, by contributing to the avoidance of certain movements and activities, might be among the predictors of mobility limitation (Leeuw et al. 2007). Pain-related fear has been shown to be associated with decreased walking speed in younger persons with low back pain (Al-Obaidi et al. 2003). Fear of pain may be a result of poor self-efficacy, a construct that refers to subjects´ beliefs in their personal capacity to execute the actions required to satisfy specific situational demands (Bandura 1977). It has been suggested that reduced self-efficacy is associated with activity restriction (Rejeski et al. 2001) and thus mediates the effect of pain on walking performance among older people with knee osteoarthritis (Maly et al. 2007). In addition, chronic pain and mood disorders, such as depression, often co-exist. Previous studies have shown that depressive symptoms are also related to poor self-efficacy (Lopez-Lopez et al. 2008), activity restriction (Wilkie et al. 2007), and mobility decline (Penninx et al. 1998, Hirvensalo et al. 2007). Thus, the associations between pain, depression and mobility problems are multifactorial and bi-directional (Landi et al. 2005, Arola et al. 2010). This suggests that chronic pain and depression should be carefully co-managed in order to prevent mobility limitation among older people. Further study is needed in order to deepen understanding of the factors on the pathway between pain and mobility problems.

The fact that the risk of mobility limitation was highest among persons with pain, who used analgesics, may reflect inadequate pain control. In addition, severe pain could be considered a marker of decreased vitality among older people owing to its strong correlation with poor mobility regardless of pain medication. It has been reported that almost half of older people who reported severe pain were using extremely low doses of analgesics (Pahor et al. 1999), and that analgesics were used occasionally rather than on regular basis (Pokela et al. 2010). It is possible that analgesics were not properly and appropriately used, and also that analgesics may not result in the desired response in some chronic diseases underlying the pain, such as severe osteoarthritis. Pharmacological pain management in older people is challenging as older persons are more likely to experience drug-related adverse effects. Ensuring the safe and effective pharmacological management of pain requires accurate pain assessment and regular monitoring of adverse events (AGS Panel on Pharmacological Management of Persistent Pain in Older Persons 2009).

In conclusion, pain was associated with mobility limitation and postural balance impairment. The association was not fully explained by the pathophysiological processes commonly thought to underlie pain, such as diseases and decreased muscle strength. It would appear that alleviating pain and developing multidimensional pain management strategies could potentially interrupt the negative effect of pain on mobility and further improve quality of life in older people. Thus there is a need for the development of easily adjustable interventions to promote mobility in everyday clinical practice among older people. For example, a multifactorial individualized approach, using both pharmacological and nonpharmacological methods to reduce pain, could be a key factor in maximizing mobility and hence quality of life in old age. It is important that sufficient attention be paid to comprehensive pain and mobility assessments and to the development of strategies for alleviating pain, particularly in older people who are already at increased risk for mobility decline.

6.2 Effects of the comprehensive geriatric assessment and individualized intervention on mobility

Mobility is important for independence in old age (Guralnik et al. 2000). A large body of evidence supports physical activity and exercise, in the form of resistance strength training, balance and aerobic exercises, as effective means to promote mobility and enhance health among older populations (American College of Sports Medicine et al. 2009, Manini & Pahor 2009). However, decline in mobility is aggravated by the complex interaction of several other factors in addition to a sedentary lifestyle. Thus, physical activity and exercise may be more effective when applied alongside a multifactorial intervention that is customized according to the personal risk profile. Recent guidelines for preventing falls recommend that multifactorial interventions for community-dwelling older people should include an exercise component (Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society 2011). This recommendation should be applied in all multifactorial interventions that aim at maintaining mobility and preventing disability in older people. According to the American College of Sport Medicine's (2009) position statement on exercise for older adults, exercise prescription for older frail people is more beneficial than any other intervention. It also recommends that resistance strength and/or balance training should precede aerobic training for this population. In the present study, all the participants in the intervention group received physical activity counseling and were offered an exercise program incorporating progressive resistance strength and balance training. Other parts of the interventions were customized according to personal needs.

According to the results of the present study, CGA with individualized interventions had positive effects on perceived mobility, and walking and balance. Little research has been conducted on the effects of a CGA and individualized intervention on physical performance and self-reported mobility among older people. A recent study by Melis et al. (2008) showed that it was possible to prevent deterioration of functional abilities in daily activities by a CGA and fairly simple home-based individually targeted intervention in vulnerable community-dwelling persons. However, the intervention did not improve objectively measured physical performance. This may be due to the fact that the intervention did not include physical activity counseling or a supervised training program. The positive effect of an intervention on walking and balance in our study is consistent with the outcome reported by Shumway-Cook et al. (2007). In both of these studies, the participants in the intervention group were given an opportunity to participate in supervised group exercise classes as an important part of a multifactorial intervention.

Previous studies have demonstrated that improvements in mobility are achieved by specific training programs, such as progressive resistance strength training (Bean et al. 2004, Portegijs et al. 2008), balance training (Wolf et al. 2001, Steadman et al. 2003, Sihvonen et al. 2004), walking (Li et al. 2005, Marsh et al.

2006a), and a combination of aerobic, strength, balance, and flexibility exercise (Means et al. 2005, LIFE Study Investigators et al. 2006). Physical activity counseling has also been found to have positive effects on perceived mobility among older people (Mänty et al. 2009). Our results supported the findings of previous multifactorial trials (Gill et al. 2004, Luukinen et al. 2007, Shumway-Cook et al. 2007) by showing that an individualized intervention program with a specific emphasis on physical activity had positive effects on mobility among older people with wide range of functional abilities.

The positive effects of the present comprehensive geriatric intervention were evident both in self-reported mobility and objectively measured physical performance. These measures are inter-related and there probably are several factors that mediate the positive effects of the intervention on them. However, it is not possible to determine whether specific parts of the intervention might be more effective for mobility than others in a multifactorial approach of this kind. Some parts of the intervention may be seen as more proximal for the outcome of the study, such as the promotion of physical activity and supervised strength and balance training, which are widely recognized as having beneficial effects on mobility. On the other hand, factors such as modification of medication or nutrition may also have had a positive effect on mobility in some persons. For example, special emphasis was placed on the use of calcium/vitamin D supplements (Lampela et al. 2010), which may have had beneficial effects particularly among the participants with pain (Al Faraj & Al Mutairi 2003, Bischoff-Ferrari et al. 2004). Thus, it seems likely that this individualized intervention met the needs of target persons and that its different components interacted effectively with respect to maintaining mobility. In addition to its positive effects on physiological characteristics, such as general health, neuromuscular performance, and balance, the intervention may also have had indirect psychological and social benefits. For example, possible improvements in self-confidence (McAuley et al. 2000, McAuley et al. 2007, Peduzzi et al. 2007) may partly explain the positive effects of the comprehensive intervention on mobility. These mediating factors clearly merit further investigation.

After this primary-care-based geriatric intervention, a significant 8% reduction in the risk for perceived limitation in walking 400 meters was found with a NNT of 12. By comparison, it has been estimated in older community-dwelling people aged 75 -81 years that to prevent one person from developing mobility difficulty or to recover from baseline difficulty, 15 persons would have to receive a single physical activity counseling session with supportive telephone contact every 4 months for 2 years (Mänty et al. 2009). In the present study, the individually modified intervention included annual physical activity counseling for 3 years, and the participants were also offered an opportunity to engage in supervised training in a gym.

We performed ancillary analyses on the effects of the intervention among persons with persistent musculoskeletal pain in order to construct hypotheses for future studies. The subgroup analysis indicated that the comprehensive geriatric assessment and individualized intervention had a beneficial effect among persons with persistent musculoskeletal pain. No statistically significant effect was observed among persons without pain at baseline. It is possible that the intervention may have had a specific impact on some factors pertinent to mobility in persons with pain. Persons with pain are known to be vulnerable to disability due to a diminished ability to respond effectively to the stress of persistent pain (Karp et al. 2006, Karp et al. 2008). Frail and disabled older adults are probably the most likely groups to benefit from comprehensive geriatric assessment and care (Reuben et al. 1995, Rubenstein 2004). The observations of present study suggest that older persons with pain need a comprehensive geriatric assessment and individualized interventions to maintain their mobility. This intervention did not specifically include pain management strategies, although medication was modified and referral for specialized care implemented when needed. In addition, counseling for self-care was offered as part of the intervention, but the intervention did not involve any specifically designed strategies for pain management, such as cognitive behavioral education. Further studies are needed to determine what interventions would be effective in alleviating pain in older people. The underlying mechanisms need to be considered in detail in future studies.

Overall, the evidence on the effectiveness of a comprehensive geriatric assessment and individually tailored intervention among older persons is highly encouraging. This study suggests that beneficial effects of a comprehensive geriatric intervention can also be achieved in everyday clinical practice among older persons with wide range of functional abilities.

6.3 Methodological considerations and limitations

This study is based on a population-based research project (GeMS) conducted over the period 2004-2007. The data gathered for this study project were appropriate for investigating the research questions of the present PhD study.

The experimental design offered an opportunity to study the effects of comprehensive geriatric assessment and individualized intervention on mobility (Studies III and IV). Approximately one sixth of those in the target population were randomly assigned to the study, and thus can be considered to constitute a sample large enough to provide good representativeness of the target population (Strom 2006).

For practical reasons, this trial could not take fully into consideration all the factors necessary for a traditional randomized controlled trial with highly selected participants and highly controlled conditions. For example, randomization was done before the baseline measurements. However, the randomization process was successful because the baseline characteristics of the intervention and control groups were comparable. It should be noted that this was an “effectiveness” rather than “efficacy” study. Efficacy trials determine whether an intervention produces the expected results under ideal circumstances whereas effectiveness trials measure the effects of the intervention in a “real world” setting (Godwin et al. 2003). The participant in the trial represented the full spectrum of the population aged 75 years and over as age was the only eligibility criterion for participation in the GeMS. In addition, the intervention differed from an efficacy study, which typically is highly fixed (e.g a fixed number of physical training sessions in the short term). In this study, the intervention was initiated at different time points, and the participants were involved in it (e.g in physical training) for varying lengths of time. Interventions shown to be effective in strictly standardized efficacy studies do not necessarily yield similar effects when delivered on a large scale in community settings (Glasgow et al. 2003). Thus, the present study offers important knowledge about the effectiveness of a comprehensive intervention among a broadly defined older population where the level of participation varies on the basis of real-world conditions. However, explicit description of the intervention is challenging in highly individualized comprehensive trials of this kind, and makes the reproducibility of the study difficult. The subgroup analyses we performed are intended to serve as hypothesis for future studies, and consequently the conclusions are indicative only.

All in all, it should be emphasized that the CGA and individualized intervention was sustainable, and could easily be adapted to practice in various health care settings. Good representativeness of the study samples and a high participation rate allow the results to be generalized to the results to the target population. Compared to previous CGA programs, the intervention and follow-up in the present study were considerably longer. The participation rate was equal in both study groups, with attrition rates of 17% during the intervention and 22% over the entire 3-year study period. Because of their high age, loss of participants occurred mainly due to death. In older people, attrition typically is not random because those with more disabilities tend to drop out. In general, the reason most widely cited for non-participation in physical activity programs is poor health (Hirvensalo et al. 1998), and persons with poor physical performance also tend to have more negative attitudes towards exercise (Bean et al. 2007). In addition, persons with pain may have adapted fear-avoidance behavior (Leeuw et al. 2007) and have thus doubts about physical activity as treatment (Thorstensson et al. 2006).

The concept of musculoskeletal pain integrated information about pain presence and duration. It should be noted that the pain assessment was not based on a standardized pain questionnaire but included several single questions commonly used in clinical practice and also in previous studies. The validity and reliability of single questions concerning whether the respondent is experiencing pain, have not been studied, but as pain is a subjective experience, self-report is the starting point for any epidemiological study. Asking older people to recall pain experiences can result in an over- or underestimation of the true magnitude of this problem. Some older people may not report feeling pain because they view pain as a normal part of aging. Furthermore, information on clinically important characteristics in relation to mobility, such as pain sites and the prevalence of pain according to specific types or causes, was unavailable in this study. A single summary assessment of pain severity may have some limitations in older people given that they often have pain in multiple sites and that the impact on mobility may vary according to pain location and severity (Eggermont et al. 2009).

The GeMs project was not specifically designed to address pain issues, and thus the geriatric intervention was not specifically targeted at pain management. Older people who have severe pain also have mobility difficulties, and hence all of them were probably not able to participate in the physical performance measurements. Thus the results of the present study may somewhat underestimate the effects of pain on mobility and postural balance. However, the study design of the GeMS project enabled cross-sectional analyses on topics that have not been widely studied.

In the present study, self-reported ability to walk 400 meters was used as an outcome measure in Paper IV to study the effect of the comprehensive geriatric assessment and individualized intervention on mobility over the 3-year follow-up. Previous studies have reported that self-reported mobility is sensitive to changes in functioning over time (Latham et al. 2008), and that the ability to walk 400 meters is an important threshold for classifying mobility limitation (Sayers et al. 2004). This is supported by the findings of the present study, where the intervention also showed a beneficial effect on objective measures of mobility.

The strengths of this study include a population-based and large dataset including a trial with annual assessment of previously validated mobility outcomes. Identifying and treating the factors underlying mobility limitation, such as pain, may be highly beneficial not only for the individual but also for the health care system as a whole, given the objective of promoting independent living in old age. This study offers important information on pain, mobility, and the use of a comprehensive geriatric assessment and management program among older people.

6.4 Implications and future directions

Pain is highly prevalent among older people, but often remains untreated and can cause multiple adverse physical, emotional, psychological and social outcomes. In seeking to prevent pain-related abnormalities, attention should be paid to the early assessment and treatment of pain and related problems in primary care. According to this study, musculoskeletal pain is associated with poor mobility and impaired postural balance, and thus has a direct effect on independent functioning in daily life. Persistent pain may cause fear of pain during movement and reduce physical activity, leading to a sedentary life with development of further disability. The results of this study together with the previous evidence indicate that pain is an important determinant of mobility limitation, and identification of mobility problems is needed among high-risk persons with persistent pain. The Timed Up & Go test (TUG), and Short Physical Performance Battery (SPPB), for instance, consist of mobility and balance components and could thus serve as easy-to-use clinical tools to detect those who are prone to further development of disability. Not only the use of appropriate assessment tools for pain and mobility but also targeted treatment and rehabilitation with regular follow-up are at great importance. Thus, an individualized management plan should be prepared, implemented and periodically reviewed among older people with pain and at risk for mobility limitation.

Based upon the subgroup analyses, it is reasonable to suggest that the use of a comprehensive assessment and individualized intervention may slow mobility decline, particularly among vulnerable persons such as persons with pain. Further randomized controlled trials are needed to ensure that comprehensive geriatric programs are likely to succeed among persons with pain. In addition, it would be important to study whether comprehensive geriatric intervention have effects on pain. Even a small alleviation of pain may delay mobility problems. Thus, finding an appropriate pain management strategy as part of a comprehensive health care program should be one of the priorities where the objective is to promote the mobility and well-being of older persons with pain. Further studies are needed to clarify the mechanisms between pain and mobility and balance impairments. This knowledge would be important for planning effective interventions to prevent mobility and balance decline and for developing appropriate pain management strategies among older people. In the future, it would also be interesting to study whether pain is a direct cause of mobility limitation and, in particular, balance impairment. This should be addressed in prospective follow-up studies with multiple controlled factors.

The evidence of the efficacy of geriatric interventions, which include physical activity and other individually tailored components, on mobility is highly encouraging. The design and delivery of effective health care for older people are issues of increasing importance in the western countries, where the number of persons suffering from pain and mobility decline is expected to increase. Current health assessment and rehabilitation approaches aiming at promoting mobility may be inadequate, and should be reviewed. Ideally, approaches to the promotion of mobility will include a comprehensive geriatric assessment and appropriate, individually tailored, interventions. The present study indicates that a comprehensive geriatric assessment and an individualized intervention that heavily emphasizes physical activity are effective means to delay mobility limitation among older people. In particular, comprehensive geriatric assessments and individualized care should be targeted at groups that are most at risk for developing disability, such as persons with pain or other health problems.

A comprehensive intervention requires multidisciplinary team cooperation and awareness of the wide range of risk factors for disability in old age. This may be challenging in today's health care context, where lack of resources is often a reality in health centers (Tinetti et al. 2006). Thus, the viability of introducing a comprehensive geriatric intervention into everyday primary practice merits further study. In addition, future studies should evaluate the cost effectiveness of comprehensive geriatric assessments and multifactorial programs.

7 MAIN FINDINGS AND CONCLUSIONS

The main findings and conclusions can be summarized as follows:

1. Moderate to severe musculoskeletal pain was associated with mobility limitation in a general population of community-dwelling persons aged 75 years and older. It is possible that pain is a marker of an underlying pathology that will contribute to independent walking and other mobility tasks. However, when adjusted for several of these potentially confounding factors, moderate and severe pain remained a strong independent risk factor for mobility limitation.

2. One of the most important factors underlying the association between pain and mobility limitation seems to be poor postural balance. Moderate to severe pain was independently associated with impaired postural balance. More specifically, persons with moderate to severe pain showed increased sway on a force platform, and were at greater risk for impaired balance in standing on narrow base of support.

3. An annual comprehensive geriatric assessment with a highly individualized intervention that promoted physical activity improved walking speed and balance and maintained performance in the Timed Up & Go test.

4. The geriatric intervention had a positive effect on perceived mobility in older people. The positive effect of the intervention on mobility was strong particularly among persons with musculoskeletal pain. These results suggest that a comprehensive geriatric assessment and individualized intervention may offer an effective means to promote mobility, which is highly important for maintaining independence in the community.

YHTEENVETO (FINNISH SUMMARY)

Iäkkäiden henkilöiden kipujen yhteys liikkumiskykyyn ja tasapainon hallintaan sekä laaja-alaisen geriatrisen intervention vaikutukset liikkumiskykyyn

Itsenäinen liikkumiskyky on jokapäiväisistä toiminnoista suoriutumisen perusedellytys. Käveleminen ja asennosta toiseen siirtyminen edellyttävät tasapainon hallintaa, joka ikääntyessä heikentyy pystyasennon säätelyyn osallistuvissa elinjärjestelmissä tapahtuvien muutosten ja sairauksien seurauksena. Myös kipu voi vaikuttaa liikkumisessa tarvittavien elinjärjestelmien toimintaan ja johtaa liikkumiskyvyn ongelmiin. Erityisesti tuki- ja liikuntaelimistön kivut ovat yleisiä iäkkäillä ihmisillä. Kotona asuvista jopa puolet ja laitoshoidossa olevista henkilöistä jopa 80 % kärsii pitkäaikaisista kivuista. Kipujen taustalla ovat monet iän myötä yleistyvät sairaudet sekä erilaiset psykososiaaliset tekijät. Hoitamaton kipu aiheuttaa kärsimystä, heikentää kognitiivista ja fyysistä toimintakykyä, huonontaa elämänlaatua sekä lisää terveyspalvelujen käyttöä ja kustannuksia. Kipua saatetaan virheellisesti pitää vanhenemiseen kuuluvana ilmiönä, eikä kivun ja sen seurausten arviointiin ja hoitoon ole panostettu tarpeeksi. Myös aikaisempi tutkimustieto on puutteellista erityisesti iäkkäiden henkilöiden kivun ja liikkumiskyvyn sekä tasapainon hallinnan välisten yhteyksien ja niitä selittävien tekijöiden selvittämisessä.

Pitkittäistutkimukset ja satunnaistetut kontrolloidut kokeet ovat osoittaneet, että progressiivisella ja säännöllisellä liikuntaharjoittelulla voidaan ylläpitää ja parantaa iäkkäiden henkilöiden liikkumiskykyä. Liikkumiskyvyn heikentymiseen, kipuihin ja moniin muihin iäkkäiden kohtaamiin terveysongelmiin vaikuttavat kuitenkin useat eri tekijät, ja siksi tarvitaan kokonaisvaltaisempaa terveyden arviointia ja monitekijäisiä interventioita. Esimerkiksi laaja-alaisen geriatrisen arvioinnin ja sen perusteella yksilöllisesti kohdennettujen interventioiden vaikuttavuudesta liikkumiskykyyn tiedetään vasta hyvin vähän.

Tämän tutkimuksen tarkoituksena oli selvittää kivun yhteyttä liikkumiskykyyn ja tasapainon hallintaan. Lisäksi tutkittiin laaja-alaisen geriatrisen arvioinnin ja yksilöllisesti kohdennetun intervention vaikutuksia iäkkäiden henkilöiden liikkumiskykyyn. Tutkimuksessa hyödynnettiin Hyvän Hoidon Strategia – tutkimuksen aineistoa. Alkumittauksiin osallistui 781 kotona tai laitoksessa asuvaa 75-vuotiasta tai iäkkäämpää henkilöä, jotka oli satunnaistettu koe- ja kontrolliryhmiin. Koeryhmäläiset osallistuivat vuosittain laaja-alaiseen geriatriseen arviointiin ja saivat yksilöllisiä tarpeita vastaavia interventioita, liikuntaneuvontaa sekä mahdollisuuden osallistua ohjattuun tasapaino- ja lihasvoimaharjoitteluun vuosina 2004–2006. Tutkittavien henkilöiden liikkumiskyvyssä tapahtuvia muutoksia seurattiin vuosittain intervention ajan ja vuosi sen päättymisen jälkeen. Alaryhmäanalyysein selvitettiin intervention vaikutuksia kivuista kärsivien henkilöiden liikkumiskykyyn. Kotona asuvien henkilöiden alkumittausaineistoa käytettiin kivun, liikkumiskyvyn ja tasapainon hallinnan yhteyttä selvittäviin poikkileikkausanalyyseihin.

Tutkimuksen tulokset osoittavat, että tuki- ja liikuntaelimistön kipu on yhteydessä rajoittuneeseen liikkumiskykyyn ja heikentyneeseen tasapainon hallintaan. Yhteys oli riippumaton lukuisista liikkumiskyvyn ongelmien riskitekijöistä kuten iästä, pitkäaikaissairauksista, fyysisestä aktiivisuudesta ja alaraajojen lihasvoimasta. Tutkimuksessa havaittiin, että liikkumiskyvyn rajoittuminen oli todennäköisintä henkilöillä, joilla oli kipuja mutta myös lääkitys niihin. Pitkäaikaisia tuki- ja liikuntaelinkipuja raportoi 40 % tutkittavista, ja heistä kaksi kolmesta käytti kipulääkkeitä. Henkilöillä, jotka kokivat vähintään kohtalaisen voimakasta kipua, oli yli kaksinkertainen rajoittuneen liikkumiskyvyn ja heikon tasapainon hallinnan riski verrattuna kivuttomiin henkilöihin.

Kokeellinen tutkimus osoitti, että laaja-alaisella geriatrisella arvioinnilla ja yksilöllisesti kohdennetuilla interventioilla voidaan ylläpitää iäkkäiden henkilöiden liikkumiskykyä. Geriatrinen interventio ehkäisi koettujen kävelyvaikeuksien kehittymistä kolmen vuoden aikana. Interventio paransi myös objektiivisesti mitattua liikkumiskykyä: myönteiset vaikutukset ilmenivät kävelynopeudessa, dynaamisessa tasapainon hallinnassa sekä tuolista siirtymistä, kävelyä ja kääntymistä mittaavassa Timed Up & Go-testissä. Laaja-alaisen geriatrisen arvioinnin ja intervention vaikutukset havaittiin selkeimmin henkilöillä, jotka raportoivat kipua alkumittauksissa.

Yhteenvetona voidaan todeta, että iäkkäiden henkilöiden tuki- ja liikuntaelimistöön kohdistuvat kivut ovat yhteydessä rajoittuneeseen liikkumiskykyyn ja tasapainon hallinnan vaikeuksiin. Lisäksi havaittiin, että laaja-alaisella geriatrisella interventiolla ja yksilöllisesti kohdennetulla interventiolla voidaan ylläpitää liikkumiskykyä. Laaja-alaisella geriatrisella arvioinnilla, yksilöllisellä hoidolla ja kuntoutuksella sekä säännöllisellä seurannalla saattaakin olla myönteisiä vaikutuksia paitsi iäkkäiden henkilöiden liikkumiskykyyn myös itsenäiseen selviytymiseen ja kotona asumisen mahdollistumiseen. Erityisen tärkeää ongelmien oikea-aikainen tunnistaminen ja niihin puuttuminen on henkilöille, joiden liikkumiskyky uhkaa heikentyä esimerkiksi kipujen takia. Jatkossa tarvitaan seurantatutkimuksia kivun ja liikkumiskyvyn sekä tasapainon hallinnan ongelmien kehittymisen yhteyksistä ja yhdistävistä mekanismeista. Tarpeellista on myös selvittää geriatrisen intervention vaikutuksia kipuun ja itsenäiseen selviytymiseen jokapäiväisistä toiminnoista. Lisäksi on tärkeää tutkia laaja-alaisen geriatrisen arvioinnin ja yksilöllisesti kohdennettujen interventioiden soveltamismahdollisuuksia perusterveydenhuollossa sekä kustannustehokkuutta.

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