STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH

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Cross-national Comparisons, Background Factors and Association with Mobility

Esitetään Jyväskylän yliopiston liikuntatieteellisen tiedekunnan suostumuksella julkisesti tarkastettavaksi yliopiston vanhassa juhlasalissa (S212) maaliskuun 26. päivänä 1994 kello 12.

Academic dissertation to be publicly discussed, by permission of the Faculty of Sport and Health Sciences of the University of Jyväskylä, in Auditorium S212, on March 26, 1994 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ

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URN:ISBN:978-951-39-7907-2
ISBN 978-951-39-7907-2 (PDF)
ISSN 0356-1070

ISBN 951-34-0225-8
ISSN 0356-1070

Jyväskylän yliopistopaino and
Sisäsuomi Oy, Jyväskylä 1994

"Älä kuluta aikaasi turhuuteen vaan itseesi, sillä elämä on lyhyt. Nauti elämästäsi, sillä sinun elämästäsi muut eivät voi nauttia. Tutki lakkaamatta sielusi tilaa, onko sillä hyvä vai huono olla."

"Tavoitteet voi asettaa hyvin korkealle ja siellä ne varmasti pysyvätkin. Todellisuuden kanssa ryömitään maassa."

-Erno Paasilinna-

Omistettu vanhemmilleni
Jouko ja Aira Rantaselle

ABSTRACT

Rantanen, Taina
Maximal isometric strength in older adults - Cross-national comparisons, background factors and association with mobility. Jyväskylä: University of Jyväskylä, 1994 -
(Studies in Sport, Physical Education and Health,
ISSN 0356-1070; 32)
ISBN 951-34-0225-8
Yhteenveto
Diss.

The aim was to study the levels and background factors of maximal isometric strength in older adults, as well as the association of strength with mobility. 75-year-old men and women were studied in three Nordic localities (Glostrup, Denmark; Gothenburg, Sweden; and Jyväskylä, Finland) to compare strength levels and anthropometric characteristics between populations. Socio-economic status, health and everyday physical activity as background factors of maximal strength were then studied among the 75-year-old residents of Jyväskylä. The association between life-long physical exercise, educational background and work history with strength were investigated in specially selected groups of women aged 50-60 years and 66-85 years. Altogether, 1113 individuals took part in the maximal isometric strength tests. Maximal isometric strength of hand grip, elbow flexion, knee extension, trunk flexion and extension were measured with the aid of specially constructed dynamometers. Significant differences in the strength were observed between the 75-year-olds in Glostrup, Gothenburg and Jyväskylä partly owing to differences in basic anthropometric characteristics. Poorer values in the state-of-health indicators correlated with lower strength and greater amount of everyday physical activity with better strength. Women with life-long history of physical exercise exhibited greater force values than their sedentary controls. Among the 50-60-year-old women a university level educational background was connected with greater muscle strength, whereas among the older persons education or former occupation were not associated with strength. Greater strength was connected with better locomotor abilities.

Keywords: muscle strength, aging, exercise, anthropometry, socio-economic status, health, mobility

ACKNOWLEDGEMENTS

Writing an academic dissertation is much easier if the "background factors" are in order. Professor Eino Heikkinen has tutored me since I started my master's thesis. He introduced the research into aging to me. Discussions with him were loaded with ideas and were an inspiration to me. He deserves a medal for long service. I have had the privilege to work with a colourful personality and true free spirit, whom I highly esteem, Docent Pertti Era, my other supervisor. I am indebted to him for guiding and spurring me on in my studies as well as for his wise practical and existential advice during the writing process.

I wish to express my warm gratitude to the official examiners of this thesis, Professor Juhani Ilmarinen and Docent Urho Kujala, for their useful comments on the manuscript, which especially improved the structure of this text. Their obvious professional qualifications combined with their gentlemanly manners made it a pleasure to me to have my work examined by them.

Mr. Markku Kauppinen and Mr. Jukka Jokela, two experts in statistics, deserve my gratitude for their valuable help in analysing the data. Both of them also have the rare ability to translate esoteric statistical concepts into the language of common people, which made the teamwork pleasant.

Mr. Michael Freeman has revised the language of the original publications as well as this thesis. Thank you, Michael. Ms. Pirjo Koikkalainen has given the finishing touches to the layout of this book. Thank you, Pirjo.

I would also like to express my gratitude to the colleagues, teachers and co-authors of mine for their contribution to the thesis. The efforts of the researchers of the NORA 75 project in Glostrup, Gothenburg and Jyväskylä should not be forgotten.

I appreciate the support and understanding I have experienced among my fellow post-graduate students. Spirited discussions took place in the official seminars, in the university cafeteria as well as in various pubs. In particular PhLic Taru Lintunen deserves acknowledgement for her readiness to make instant comments on anything.

My parents Aira and Jouko Rantanen have supported me and shown genuine interest in my work. I want to thank them for always being on my side. This book is dedicated to them. I warmly think of my partner Jorma, who came into my life and brought the music with him.

This study was carried out as a part of larger research projects going on in the Department of Health Sciences, University of Jyväskylä, and in the Foundation for the Promotion of Physical Culture and Health. The

NORA 75 project has been made possible by grants from The Nordic Research Policy Council. The Evergreen project has been funded by The Academy of Finland, The Ministry of Education, The Ministry of Social and Health Affairs, The City of Jyväskylä and The University of Jyväskylä. The Ministry of Education and Elna Kopponen Foundation have supported the projects on the association of intensive physical training with functional capacity of middle-aged and elderly women. I have received personal grants from the Ministry of Education.

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

(I) Era, P., Rantanen, T., Avlund, K., Gause-Nilsson, I., Heikkinen, E., Schroll, M., Steen, B., Suominen, H. 1994. Maximal isometric muscle strength and anthropometry in 75-year-old men and women in three Nordic localities. Scandinavian Journal of Medicine & Science in Sports, 4, 26-31

(II) Rantanen, T., Era, P., Kauppinen, M., Heikkinen, E. Association between maximal isometric muscle strength and socio-economic status, health and physical activity among 75-year-old men and women. Journal of Aging and Physical Activity, accepted.

(III) Rantanen, T., Sipilä, S., Suominen, H. 1993. Muscle strength and history of heavy manual work among elderly trained women and randomly chosen sample population. European Journal of Applied Physiology and Occupational Physiology 66, 514-517.

(IV) Rantanen, T., Parkatti, T., Heikkinen, E. 1992. Muscular strength according to level of physical exercise and educational background in middle-aged women in Finland. European Journal of Applied Physiology and Occupational Physiology 65, 507-512.

(V) Rantanen, T., Era, P., Heikkinen, E. 1994. Maximal isometric muscle strength and mobility among 75-year-old population. Age and Ageing, in press.

1 INTRODUCTION

The proportion of older people in Western societies has increased because a larger number of citizens survive till retirement age. The life-expectancy of old people has also increased (Valkenburg 1988). An important question is how many additional years of independent life will be gained as compared to years with disabilities and the need for external care. The extension of the life span does not seem to be a result of better health at advanced ages; instead people, in fact, live longer and have more diseases than during earlier decades (Roos et al. 1993) and a greater amount of disability associated with specific chronic conditions and symptoms (Kaplan 1991). The expected compression of morbidity (Fries 1980) may not happen. Moreover, on the basis of current age-specific estimates of disability in the years prior to death, it is projected that the shift in the distribution of age at death will lead to an increased number of years of disability prior to death for the total population aged 65 and older (Guralnik 1991).

Disability in motor activities becomes more common at higher ages, especially among women (Verbrugge 1984, Haug & Folmar 1986, Harris et al. 1989, Jylhä et al. 1992, Heikkinen et al. 1993). Longitudinal data on health event transitions for individuals have shown that the risk of becoming disabled is roughly the same for males and females (Manton 1988). This suggests that sex differences in the prevalence of disabilities arise from the greater longevity of females at any given level of age and functional impairment. In Finland the average life span of women is about 8 years longer than that of men. Consequently, at age 75-79 the number of women is roughly the double that of men, and at age 80-84 the relation is three to one (Valkonen 1986).

The burden on health service systems as well as the quality of life of an individual are in many cases strongly dependent on that individual's level of independency in daily life. The life of an elderly person who is able to transfer independently from a chair or a toilet seat and walk about indoors or outdoors may be very different from that of another who has partially or fully lost such capacities. Therefore, research on the conditions responsible for disability is of great importance in the interest of prevention.

Muscle strength may be one of the essential factors related to independent mobility. Muscle force and power are necessary for the performance of many everyday motor tasks, such as rising from a seated position or negotiating stairs. As humans age the ability of skeletal muscles to generate force decreases. A large number of elderly persons live below, at, or just above the threshold of the capacity needed for such tasks. Even a minor illness and the consequent bed-rest may render them dependent (Young 1986, Åstrand 1992).

The differences in life expectancy between the Nordic countries suggest that there might also be differences in functional capacities and biological aging between populations (Schroll et al. 1993). Cross-national interview studies have shown differences between countries and localities in the abilities of elderly persons to manage their daily life (Kozarević et al. 1989). So far, clinically measured cross-national epidemiological data on the functional capabilities of elderly people is lacking.

The purpose of this project was to study the levels of maximal isometric strength in representative population samples of elderly people as well as assess the background factors of strength. 75-year-old men and women were studied in three Nordic localities (Glostrup, Denmark; Gothenburg, Sweden; and Jyväskylä, Finland) to compare the strength levels and anthropometric characteristics between the populations (I). Socio-economic status, health and everyday physical activity as background factors of maximal strength in the elderly were then studied among the 75-year-old residents of Jyväskylä (II). The association of life-long physical exercise, educational background and work history with strength were investigated in specially selected groups of women aged 50-60-years (IV) and 66-85 years (III). These women lived in the environs of Jyväskylä, or were recruited from among the members of Finnish sports organisations and the Association of Physical Education Teachers. The maximal isometric strength test results as indicators of physical functioning among the elderly were studied by looking at the associations between maximal isometric strength and mobility in everyday life (V).

2 REVIEW OF THE LITERATURE

2.1 Physical functioning among elderly men and women

The occurrence of chronic diseases and multimorbidity are common among older persons (e.g. Heikkinen et al. 1993). In 1980 the World Health Organization (WHO) introduced a classification of the consequences of diseases which have a heavy impact on the life of the patient. This International Classification of Impairments, Disabilities and Handicaps provides a useful basis for planning rehabilitation programs (see Vermeer 1991). While many degenerative diseases are chronic and cannot be completely cured, other opportunities than treatment of diseases should also be considered to decrease the handicap. Especially among more advanced age-groups it is important to study a person's ability to function (Young et al. 1994).

Most important areas of physical functioning studied among the elderly can be included under the general categories of mobility and self-care ability. Mobility refers to a person's ability to walk and move independently indoors, on stairs and outdoors. Because no standard procedure for evaluation exists, it is important in planning a study to consider the relevance as well as sensitivity of a given test battery or scale in relation to the specific purposes of the study (Feinstein et al. 1986, Young et al. 1994). Mobility, for example, has been studied by interview techniques as well as performance tests (Jette 1985).

Inability or poor performance in the basic physical activities of everyday life is more common in the higher age groups and among women than men (Haug & Folmar 1986, Harris et al. 1989, Jylhä et al. 1992, Heikkinen et al. 1993, Laukkanen et al. 1993). In a Finnish survey of representative samples of 65-84-year-old men and women (N=1224) self-care abilities as well as mobility were studied by means of an interview (Laukkanen et al. 1993). In the 65-74-year-old age group, 68% of the men and 65% of the women had no difficulties in coping with going to the toilet, eating, bathing, getting in to and out of bed, dressing, getting about indoors, cutting their toenails and getting about outdoors. The corresponding figures in the 75-84-year-old age group were 58% for the men and 37% for the women.

According to an interview study conducted among a normal 70-year-old population, 67% of the men and 72% of the women experienced difficulty in negotiating stairs, although only 2% were unable to manage at all (Avlund & Schultz-Larsen 1991). In a study by Aniansson et al. (1980a) activities of daily living were studied among 70-year-old men and women using performance tests. All the men and women were able to climb up and down a 30 cm step without using a hand rail. 6.1% of the men and 3.7% of the women could rise from a stool only with difficulty. Only very limited number of probands reached the walking speed of 1.4 m/s, which was at the time the norm for pedestrians at signalled intersections.

In a two-year follow-up study of locomotor ability of the subjects aged 80 years and older (N=1791) 44% of the men and 28% of the women were physically able at the baseline (Harris et al. 1989). Physically able was defined as having no difficulty in walking 1/4 of a mile, lifting 10 pounds, climbing 10 steps, or in stooping, crouching and kneeling. Of those physically able at the baseline, 50% of the women and 42% of the men remained so at the end of the 2-year follow-up. Of all the 1453 survivors at the end of the follow-up 33% of the men and 22% of the women were physically able.

Even at very high levels of impairment, there are significant numbers of people who apparently manifest long-term improvement in functioning (Manton 1988). In a six-year prospective cohort study among persons 65 years old or older (N=508) 13% of men and 20% of women improved their physical functioning (Strawbridge et al. 1992).

2.2 Background factors of strength in older adults

2.2.1 Age: cross-sectional and longitudinal studies

The strength of a person can be defined as the maximum force which can be exerted against an immovable object (isometric strength), the heaviest weight which can be lifted or lowered (dynamic strength) or the maximal torque which can be developed against a pre-set rate-limiting device (isokinetic strength) (Frontera & Meredith 1989). The variation in maximal force developed by muscles during contraction with different speeds shows the well-known S-shape relationship, the classical force-velocity curve. The maximal force in a concentric activity is less than in an isometric contraction. Highest force can be attained in an eccentric contraction (see e.g. Åstrand & Rodahl 1986).

Aging is accompanied by both structural and functional changes in muscle leading to e.g. loss of dynamic and isometric muscle strength. To what extent this is a result of external (e.g. exercise, diseases) or internal (aging as such) factors or their interaction is not fully understood at the moment. Most of the data about strength with age is based on cross-sectional studies. Most studies deal with relatively small samples. Epidemiological studies focusing on the functional abilities of older adults have rarely included strength measurements other than hand grip.

Age differences have been found to depend on type of contraction. Isometric and dynamic measurements revealed a similar pattern of age differences in men (Larsson et al. 1979). Isometric and dynamic strength of quadriceps muscle was highest in those age groups between 3rd and 5th decades. Among the older men lower values were observed. Vandervoort et al. (1990) compared average and peak torque values between young (20-29 years) and elderly (66-89 years) women in eccentric and concentric knee flexion and extension. The values obtained under eccentric conditions were less affected by age factor than those obtained under concentric conditions.

The age-related decline in strength seems to be different in different muscle groups. The isometric strength difference between representative samples of 31-35- and 71-75-year-old men has been observed to be 47% for knee extension, 42% for hand grip and trunk extension, 35% for trunk flexion and 35% for elbow flexion (Viitasalo et al. 1985).

Men and women have been found to differ with respect to the age groups in which the highest values in strength tests are obtained. In a cross-sectional study among working age adults the greatest relative trunk extension torque values were observed in men among the 25-year-old age group with the successive age-groups exhibiting less strength up to age 55. Among the women the greatest value was measured for the 45-year-olds (Viljanen et al. 1991). Among both sexes the greatest difference between following 10-year-cohorts was found between the age-groups of 45 and 55 years in favour of the former. For trunk flexion torque smaller age differences were observed. According to Murray et al. (1985) the differences in strength between young and old subjects were smaller among the women than the men. The knee strength of the 70-86-year-old women was found to range from 56 to 78% of that of the women aged 29-35 years. The corresponding values for the men varied from 45 to 65% depending on the measurement (Murray et al. 1980).

In a 40-year follow-up study among former physical education students Asmussen et al. (1975) observed that the hand grip strength of the women declined 21% from age 23 to age 50. The corresponding figure for the men was 19%. A steeper decline was observed after that age especially among the women. At the age of 63 years women had retained 63% and men 72% of their values measured at the age of 23. Phillips et al. (1993) observed in a cross-sectional study that weakening of the muscles in women starts at the same age as the menopause, whereas in men those around 60 years were the youngest to exhibit muscle weakness.

The comparison of cross-sectional and longitudinal grip strength test results among large numbers of healthy men and women suggest that decline in physical strength is greater than that indicated by cross-sectional comparisons of different age groups (Clement 1974). In a four-year follow-up study of 920 men and women aged 65 and over the cross-sectional age-related decline in grip strength was 2%/year for men and women at the baseline. After four years 620 survivors were remeasured. Grip strength had declined by 12% in the men and 19% in the women (Bassey & Harries 1993). A steeper decline at higher ages was observed by Kallman et al. (1990) as well as Bassey & Harries (1993).

In other studies among older age groups the decline in strength in women has been found to be smaller than in men. Aniansson et al. (1983) found that 75-year-old women retained a greater percentage of isometric and isokinetic thigh muscle strength measured at the age of 70 than men of the same age. The annual loss in peak torque was 3.1% for the women and 4.1% for the men. The loss in hand grip strength has also been shown to be proportionately smaller among women than among men (Lundgren-Lindqvist & Sperling 1983).

However, not all individuals exhibit a constant decline in strength with aging. In a nine-year follow-up, 48% of men under 40 years, 29% of men 40-59 years and 15% of those over 60 years showed no decline in grip strength (Kallman et al. 1990). Greig et al. (1993) reported an annual median change in quadriceps strength of only 0,3% in healthy and active men and women over 80 years of age during an 8-year follow-up.

A critical issue in cross-sectional studies is the comparability of subjects of different ages. Metter et al. (1992) showed that 30% of healthy 60-year-old men could be expected to survive and be free of major diseases at the age of 80 years. In cross-sectional designs, although observed differences between two age groups are assumed to result from differences in age these may in part be related to factors connected with survival. According to Phillips (1986) poor grip strength was associated with greater mortality risk. Strength loss has been underestimated in cross-sectional models probably due to the relative underrepresentation in the older samples of weak individuals, especially if the health criteria have been similar for different age cohorts. On the other hand, the faster strength decline among women observed by e.g. Bassey & Harries (1993) may result from women's lower mortality risk at any age and level of impairment, thus causing a greater proportion of relatively weak individuals to survive (Manton 1988).

Thus, the present information about age-changes in strength is contradictory, probably partly due to the non-comparability of the study populations, designs and methods in different research projects as well as the absence of mortality analyses.

2.2.2 Anthropometry

Older persons have been found to have smaller body size than younger ones (Mitchell & Lipschitz 1982, Viitasalo et al. 1985, Lehmann et al. 1991). Especially among older women shorter body height is associated with age, probably due to degenerative changes in spine. In a study of 532 women and 358 men over 65 years of age body weight was also lower among the older individuals (Lehmann et al. 1991). In a cross-sectional study of men aged 31-35, 51-55 and 71-75 years Viitasalo et al. (1985) observed that body weight, estimated fat-free body weight, fat weight and body mass index showed the highest values for the middle-aged group and the lowest for the oldest group. Part of the age-related difference in body size may be due to secular trends and part to contraction in old age.

Age-related differences in strength have been studied in relation to changes in muscle cross-sectional area. In a study of healthy women the isometric knee extension strength of women in their 70s was found to be 35% weaker than that of women in their 20s. The difference in strength was of the same proportion as the difference in muscle cross-sectional area (Young et al. 1984). The knee extensor peak torques of 70-year-old men have been found to be 22% lower than those of 24 year-old men in isometric contraction and 32% lower at an angular velocity of 120°/s (Overend et al. 1992). The lower peak torques in the isometric tests among the older men could be accounted for by the decrease in muscle cross-sectional area. However, the 32% difference at angular velocity of 120°/s was greater than the difference in cross-sectional area. Phillips et al. (1993) noticed a difference in skeletal muscle maximal voluntary contraction/cross-sectional area between men and women of different ages. In the men the relation was maintained until age 60 but in the women a more pronounced decrease occurred around the time of menopause. Kallman et al. (1990) observed that grip strength decline among men was partially explained by declining muscle mass, but other factors beyond declining muscle mass remained to explain some of the strength loss observed with aging.

On the other hand, significant changes in body composition have been demonstrated among women over 60 years of age following a 24-week weight training program (Nichols et al. 1993). Lean mass increased by 1.5 kg, which was significantly associated with strength gain especially in the upper body. The effects of resistance training in older persons have been demonstrated also to include a decrease in body fat (Schaberg-Lorei et al. 1990, Nichols et al. 1993) and an increase in cross-sectional area in type II fibers and muscle size (Charette et al. 1991).

Cross-sectional studies have also shown muscle strength to correlate with body size. Height has been observed to be a major correlate of grip strength among elderly women (Cauley et al. 1987). The taller subjects exhibited greater strength. Greater body weight was found to correlate with greater strength, which was probably due to the training effect caused by lifting extra weight during normal daily activities (see Viitasalo et al. 1985). On the other hand heavier persons need more force for motor tasks, such as rising from a seated position. Consequently, body size and anthropometric characteristics should be considered when studying strength levels in different populations. So far, normative data about the body properties of older persons living in different areas remains scattered.

2.2.3 Health

In old age it is more common to have chronic diseases than to be healthy. The proportions of men and women aged 60-84 not reporting any medical diagnoses has been found to vary between countries from 5% (Tampere, Finland; Florence, Italy) to 50% (Kuwait) (Kozarević et al. 1989). Part of this cross-national variation is due to differences in the health care systems and well as study methods. In a large Finnish survey among 65-99 year-old men and women the proportions of those with chronic diseases varied between 80-90% (Aromaa et al. 1989). According to a study by Jylhä et al. (1992), 90% of persons aged 60-79 had at least one chronic disease or injury. The commonest diseases among the women were musculoskeletal disorders (44%), hypertonia (30%), ischemic heart disease (16%) and other cardiovascular diseases (30%). Among men the most prevalent diseases were musculoskeletal disorders (38%), hypertonia (24%), ischemic heart disease (21%) and other cardiovascular diseases (26%). According to Verbrugge (1984), at the age of 75 years and over, 55% of women reported peripheral joint complaints and 32% reported low back pain. Among men the corresponding figures were 24% and 14%.

Mälkiä (1993) has reviewed studies concerning muscle strength and health. Specific muscular and neurological diseases have been found to be associated with decreased strength. Nygård (1988) observed systematically lower isometric strength among middle-aged men with a musculoskeletal disease in comparison with healthy men. In a population study of Finnish adults under 65 years of age mental problems were connected with lower grip strength among the men but not the women (Mälkiä 1993). Among the women, however, when those with a lung, heart, vascular, joint, limb, back, mental or other disease were compared with healthy women the only significant difference was observed for cardiovascular diseases.

It was found that women aged 40-85 years with a documented diagnosis of osteoporosis and previous vertebral fractures exhibited lower back extension strength than controls. It is possible that the pain and discomfort following the initial vertebral fracture led to lack of proper recruitment of back muscles (Sinaki et al. 1993). If the disease has no direct influence on the biology of muscular performance, the lowered strength may, at least partly, result from the bed rest or restricted mobility and the disuse of muscles required for the cure and care of the disease. Moreover, the aches and pains commonly experienced in old age may lead to inactivity and disuse, which in turn lower strength (Svanborg 1988).

The ability to perform domestic work or the self-care ability of old people with chronic diseases has been under investigation. In particular elderly people with multiple diseases have had to give up or reduce their daily activities and home tasks (Aromaa et al. 1989). However, studies dealing with maximal strength have generally included only healthy (= no diagnosed disease) elderly people (e.g. Clement 1974, Young et al. 1984, Murray et al. 1985, Rice et al. 1989). As a result, relatively little is known about maximal strength and changes in it among elderly people with chronic diseases.

2.2.4 Physical activity and exercise

Before retirement, physical activity during leisure is more common among people of high occupational status and long educational background doing physically light work than among those doing heavy manual work and having shorter education (Aro et al. 1985, Vuolle et al. 1986). The proportion of people engaged in vigorous physical activities declines among men and women, especially after age 74 (Heikkinen et al. 1989, Pohjolainen & Heikkinen 1989). According to Grimby (1986) the activities of the majority of elderly people consist of light or moderate tasks like walking, gardening or domestic work. It has been observed that 70-73-year-old women spend more time than men on domestic activities, whereas men spend more time walking (Mattiasson-Nilo et al. 1990).

Great interindividual variation in strength has been observed among the elderly (see Heikkinen et al. 1984, Viitasalo et al. 1985, Svanborg 1988). It has been suggested that part of the age-related loss in physical capacity may be explained by declining levels of customary activity (Bassey 1985, Bassey & Harries 1993). The body will adapt to reduced demands on muscle activity by an accelerated rate of functional impairment and lowered physical fitness (see Åstrand 1992). Those elderly people who have maintained a physically active or "athletic" way of life have been shown to perform better than sedentary people in strength tests (Borkan & Norris 1980, Suominen et al. 1980, Bassey et al. 1988, Suominen et al. 1989, Sipilä et al. 1991, Era et al. 1992).

In 1945 Captain Thomas L Delorme published an article in the Journal of Bone and Joint Surgery dealing with the restoration of muscle power by heavy-resistance exercises. "Exercise is essential in restoring function to muscles, weakened and athrophied as a result of injury and disease." He also described his method of training, the ten-repetition maximum, which he had successfully used among men with war injuries (Delorme 1945).

During recent years strength training as a method of rehabilitating muscle function among old people has attracted increasing interest among scientists and clinicians. Trials have ended with positive outcomes and trainability has been verified among healthy, active, old people as well as frail institutionalised persons (Agre et al. 1988, Brown et al. 1990, Fiatarone et al. 1990, Brown & Holloszy 1991, Charette et al. 1991, Fisher et al. 1991, Grimby et al. 1992, Sauvage et al. 1992, Åstrand 1992, Nichols et al. 1993, Roman et al. 1993). Improved functioning has been demonstrated to result from neurological factors as well as muscle hypertrophy, even in nonagenarians (see e.g. Fiatarone et al. 1990).

The literature dealing with associations between physical exercise and muscle strength is substantial. However, until recent years, most research on leisure time physical exercise or veteran sports concentrated on studying men and only few reports including older women. Moreover, the significance of performing everyday or domestic activities in maintaining adequate strength levels among retired persons is not known. In the elderly, whose physical activity is normally at a reduced level, the relative importance of domestic activity may be increased (see Mattiasson-Nilo et al. 1990). Finally, no earlier studies have tried simultaneously to elaborate the associations of socio-economic status, health and physical activity with maximal strength among representative groups of elderly men and women.

2.2.5 Socio-economic status and work

Socio-economic status is frequently used as a background variable in epidemiological research and is generally defined according to educational background, occupation and income. High socio-economic status has been found to be connected with a lower prevalence of chronic diseases and musculo-skeletal impairments (Cunningham & Kelsey 1984, Fox 1990), lower mortality (Moser et al. 1988, Hasan 1989, Fox 1990), good functional capacity (Heikkinen et al. 1993), maintenance of good self-rated health and functional capacity (Harris et al. 1989, Hirdes & Forbes 1993), longer active life expectancy (Katz et al. 1983), "healthy aging" (Guralnik et al. 1989) and a lower risk of losing mobility (Guralnik et al. 1993). In the Nordic countries the proportion of older people with university education is relatively small (4% - 5%) in comparison with the younger cohorts (9% - 20%) (Schroll et al. 1993).

Clement (1974) found social class to be positively associated with strength. Occupation has also been found to correlate with muscle strength. The association, however, seems to vary between different age groups. Young male workers in physically strenuous occupations have been shown to have better maximal isometric muscle strength than workers in lighter occupations (Era et al. 1992). In middle-age the situation was reversed. Nygård et al. (1987, 1988) found that middle-aged women and men with a higher physical work load showed systematically lower muscle strength when compared to a group with a lower work load at the baseline. After a four-year follow-up, maximal isometric trunk flexion and extension strength had significantly declined in all work categories (Nygård et al. 1991), which suggest that heavy occupations and physical effort during work do not maintain strength. Lower musculoskeletal capacity among those doing physically strenuous work may be the combined result of prolonged physically heavy work and aging, as well as the higher prevalence of musculoskeletal diseases (Nygård 1988). The association between previous work and strength after retirement has rarely been studied. Aniansson et al. (1980b) found no correlation between quadriceps strength and previous occupational physical activity among 70-year-old women but among men those with heavy work histories exhibited lower strength.

Information about changing levels of strength in various occupations as well as about the selection processes involved is important, for example, in the interest of preventing impairments as well as in planning and implementing appropriate rehabilitation programs. Cross-sectional and longitudinal data exist on maximal strength and physical work load among those still in working life (e.g. Nygård 1988, Nygård et al. 1991). The long-term effects of physically heavy work on strength among retired, older persons are not known at the moment.

2.3 Strength as a determinant of mobility among elderly people

Muscle contractions are the basis for physical movement. The activities of daily life vary as to how much strength they require and as to which skeletal muscles are involved. For each activity the minimum amount of strength required to perform it normally can be designated as a strength threshold (Young 1986, Åstrand 1992, Young et al. 1994). Below the threshold functional impairment occurs (Buchner et al. 1991, 1992). According to Buchner et al. (1991) strength may be curvilinearly associated with functional status so that the most evident association would be expected among the very frail elderly near the threshold.

Among elderly persons the reserve in performance capacity may be so slight, that even a small additional decline in strength may render some everyday activities impossible (Young 1986, Åstrand 1992). An individual may due largely to muscle weakness become unable to perform a regular domestic physical routine, such as rising from a chair or climbing stairs (Bassey et al. 1992). Eventually with weakening of the major muscle groups an independent life may become impossible. Hyatt et al. (1990) found that maximal isometric strength of hand grip, quadriceps and biceps were positively associated with functional status as described by the Barthel Index among a group of men and women aged 65-89 years, and that poor strength was associated with the need of help and receipt of domiciliary services.

In studying the association of strength with functional capacity in elderly persons both isometric and dynamic strength measurements have been used. It has been suggested by Buchner et al. (1992) that relative rather than absolute measures of strength are more closely related to the ability to perform physical movements: muscles act to move weight. In tasks such as standing up, walking or climbing stairs a person has to carry his/her own body weight. Consequently body size should be taken into account. However, there is no standard measure of relative strength. In studies using absolute strength values consistent associations with mobility have not always been found. In a study by Dannenskiold-Samsoe et al. (1984) a statistically significant correlation was found between absolute isokinetic knee extension strength and step climbing performance among healthy 80-year-old men but not women.

Fiatarone et al. (1990) observed a statistically significant correlation between dynamic quadriceps strength (one repetition maximum), as measured by a functional test, and maximal walking speed as well as time taken to rise from a chair among frail, institutionalised subjects aged 86-96 years. In a study by Bassey et al. (1988) maximal isometric plantar flexion strength has been found to correlate with customary walking speed among independently living men and women aged 65 years and over.

Comfortable or customary walking speed has also been demonstrated to depend on factors other than maximal strength. According to Bendall et al. (1989) 44% of the variation in comfortable walking speed among men aged 65-90 could be explained by height, calf strength and the presence of health problems. Among women of the same age, 42% of the variance could be accounted for by height, calf strength, step-score and the presence of leg pain.

At the moment there is insufficient epidemiological data objectively verifying the curvilinear relationship between maximal strength and motor ability among elderly persons. Moreover, a validated strength threshold for any definable motor task has not yet been reported.

3 AIMS

The aim of this project was to investigate if there are cross-national differences in maximal isometric strength levels of old subjects, and what are the background factors explaining the variation in the strength levels. The purpose was also to assess the relevance of testing maximal isometric strength among elderly persons with respect to the ability to perform physical activities of daily life.

The questions addressed were:

1) Do cross-national differences exist in maximal isometric strength levels between representative groups of 75-year-old residents in Jyväskylä (Finland), Gothenburg (Sweden) and Glostrup (Denmark)?

   - What are the relations between the strength values and basic anthropometric characteristics within and between the three localities?

2) What are the background variables explaining the variation in maximal isometric strength among older adults?

3) Is maximal isometric strength associated with the ability to perform physical activities of daily life, such as walking or climbing stairs?

A schematic description of the study can be seen in Figure 1. In four of the original papers (I-IV) maximal isometric strength was the dependent variable. In those papers the explanatory variables were locality, sex, age, socio-economic status, health, physical activity and anthropometric characteristics. In paper (V) maximal isometric strength was studied as a factor explaining the variation in mobility.

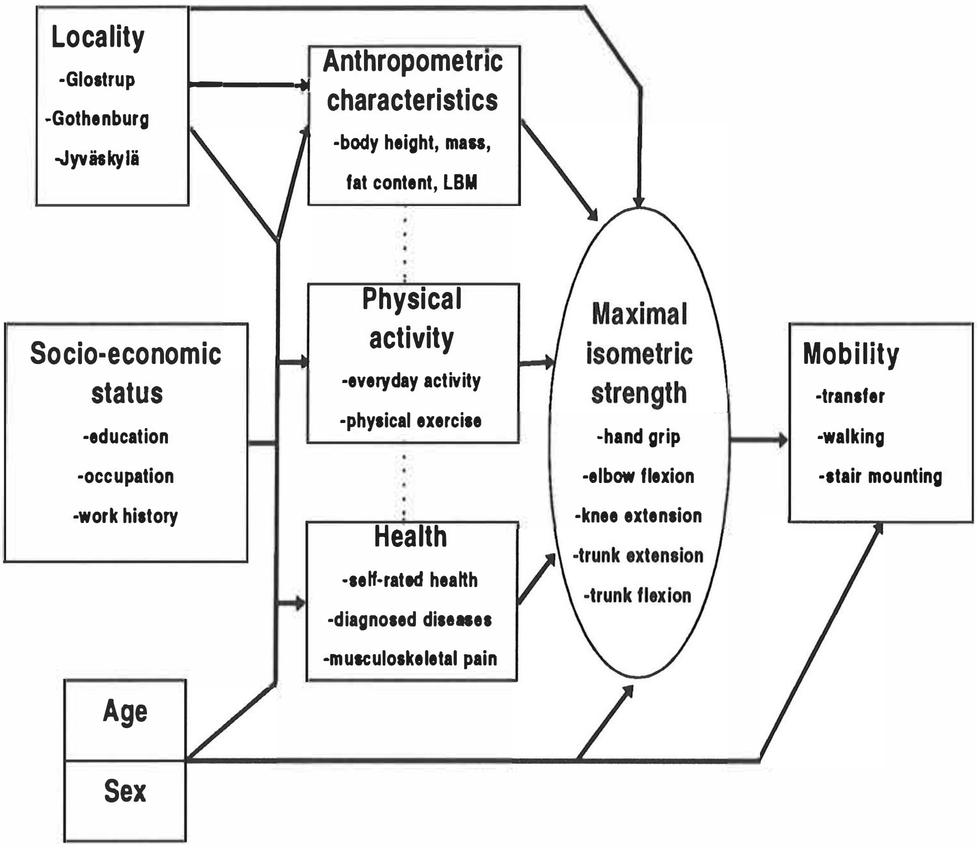


FIGURE 1 A schematic presentation of the variables and associations studied. The arrows describe the hypothetical direction of causality

4 PARTICIPANTS AND METHODS

4.1 The implementation of the study

In papers (I), (II) and (V) the subjects were contacted by post. Those who agreed to participate were visited by an interviewer in their homes. At the interview the subject was invited to participate in the laboratory tests approximately one week later.

In studies (III) and (IV) the participants were also contacted by post. The letter enclosed a questionnaire. The participants filled in the questionnaire before attending the laboratory. The forms were checked during the interview before the laboratory examinations, and possible gaps were then filled.

The participants were advised not to exercise vigorously, drink alcohol or smoke before entering the laboratory. The strength tests were performed as a part of a more extensive interdisciplinary project dealing with the functional capacities of older adults. In all cases the strength tests were preceded by a medical examination.

4.2 Participants

75-year-old residents of the cities of Glostrup, Gothenburg and Jyväskylä

The study (I) was implemented as part of the larger gerontological comparative study Nordic Research on Ageing (NORA 75) (Schroll et al. 1993). The study was based on representative samples of the 75-year-old residents of Glostrup, Denmark and Gothenburg, Sweden, whereas in Jyväskylä, Finland, all the residents aged 75 were invited to participate. The number of 75-year-olds in the Glostrup area was 1592, of which 550 were selected for the sample. In Gothenburg the corresponding figures were 3706 and 450. In Jyväskylä the total number of 75-year olds at the beginning of the data collection was 388. Participation in the different stages of the study is shown in Table 1.

TABLE 1 Participation rates in different stages of the study in Glostrup, Gothenburg and Jyväskylä

	GLOSTRUP	GOTHENBURG	JYVÄSKYLÄ
Data collection			
from	1.9.1989	1.10.1990	1.10.1989
to	31.1.1990	31.5.1991	31.1.1990
Sample	550	450	388
Eligible	541	446	382
Home visit	459 (85%)	368 (83%)	350 (92%)
Laboratory examinations	410 (76%)	298 (67%)	295 (77%)
Strength tests	404 (75%)	214 (48%)	291 (75%)
Proxy interview	70 (13%)	45 (10%)	5 (1%)
Refused	0	69 (16%)	27 (7%)
No contact	11 (2%)	9 (2%)	2 (1%)

The percentage participation rates were calculated in relation to the numbers of eligible subjects, i.e. those surviving and continuing to reside in the study area. The participation rate in the laboratory examination was somewhat lower in Gothenburg than in the other localities. Papers (II) and (V) are based on the data gathered among the residents of Jyväskylä.

Elderly trained women and control group (III)

A total of 60 active 66-85 year-old participants in various sports (long-distance running, cross-country skiing, track and field and traditional Finnish women's gymnastics) were selected on the basis of a preliminary postal questionnaire. It included questions about the subject's past and present levels of physical activity and was sent to 600 veteran members of Finnish sports organisations. 52 (87%) of the chosen subjects participated in the laboratory examinations.

The population sample consisted of 71 70-81-year-old women randomly drawn from the population register of the rural municipality of Jyväskylä. 42 (59%) of this sample participated in the laboratory examinations.

Physically active and sedentary middle-aged women with long or short educational background (IV)

The subjects were 50-60-year-old women selected on the basis of their educational background and physical activity levels from among graduates from the Gymnastics Department of Helsinki University during the 1950s and currently employed as physical education teachers, other teachers from various schools in Jyväskylä, from local women's gymnastics clubs and from the population register. An invitation was sent to 188 women of whom 60% participated. The final group sizes were as follows:

Group 1. (University education, physically active) n=32
Group 2. (University education, sedentary) n=23
Group 3. (Vocational education, physically active) n=26
Group 4. (Vocational education, sedentary) n=31.

4.3 Methods

The summary of the measurements reported in the original papers can be seen in Table 2.

TABLE 2 The variables measured in original papers and methods used.

Variable	Paper	Method/Reference
Maximal isometric strength of limbs and trunk	I-V	Viitasalo et al. (1977) Heikkinen et al (1984) Sipilä et al. (1991)
Capacity of abdominal muscles	III, IV	Sit up-tests
Anthropometric characteristics		
- Body height and weight	I-V	
- Body fat content	IV	Durnin & Womersley (1974)
	I, II	Lukaski et al. (1985) Lukaski & Bolonchuk (1987)
- Lean body mass	I, II	Lukaski et al. (1985) Lukaski & Bolonchuk (1987)
Mobility		
- Locomotor ability	V	Interview, Avlund & Schultz-Larsen (1991)
- Stair mounting	V	Aniansson et al. (1980a)
- Maximal walking speed	V	Aniansson et al. (1980a)
Health		
- Self-rated health	IV	Questionnaire
	II	Interview
- Musculoskeletal symptoms	II	Interview
- Chronic diseases	II	Clinical examination, American College of Sports Medicine (1986)
Physical activity	III, IV	Questionnaire
	II	Interview, Grimby (1986)
Socioeconomic status		
- Educational background	III, IV	Questionnaire
	II	Interview
- Occupational status	III	Questionnaire
	II	Interview
- History of heavy work	III	Interview

Maximal isometric strength measurements (I-V)

The maximal isometric strength of hand grip, arm flexion and knee extension were measured on the side of the dominant hand in a sitting position using an adjustable dynamometer chair constructed at the Department of Health Sciences (Heikkinen et al. 1984, Sipilä et al. 1991).

Hand grip strength was measured by a dynamometer fixed to the arm of the chair. Elbow flexion strength was measured at an angle of 90 degrees in a neutral position (thumb up) with the elbow supported comfortably and the wrist attached by belts to a strain-gauge system. Knee extension strength was measured at an angle of 60 degrees from full extension. The ankle was fastened by a belt to a strain-gauge system. Maximal isometric trunk flexion and extension strengths were measured in a standing position according to Viitasalo et al. (1977).

The subject was allowed two or three practice trials after which three formal trials were performed with a one-minute interval between each. The best result of the three actual trials was accepted as the result. The results were expressed as absolute values and body weight-related values.

The reproducibility of the maximal isometric strength measurements expressed as correlation coefficients between two successive trials has been observed to be quite high for hand grip (r=0.88-0.92, Mälkiä 1983), knee extension (r=0.98, Viitasalo et al. 1980) and trunk flexion and extension (r=0.95-0.97, Viitasalo et al. 1977) tests. The reproducibility of the tests of relative maximal isometric strength of the trunk muscles expressed as the coefficient of variation between duplicate measurements has been found to vary between 2.0% and 4.6% for the trunk extension and 2.6% and 4.6% for the trunk flexion test (Viljanen et al. 1991).

The distribution of the strength values of the 75-year-old residents of Jyväskylä can be seen in Appendices 1 and 2.

Anthropometric characteristics

Body weight and height were measured using conventional methods. Body composition (body fat content, lean body mass) was estimated using the biolectrical impedance method (Spectrum II, RJL Systems Inc., USA) (Lukaski et al. 1985, Lukaski & Bolonchuk 1987) (I, II, III, V). In (IV) the percentage of body fat was estimated from the sum of skinfolds taken at four sites: biceps, triceps, subscapular, and suprailiac (Durnin & Womersley 1974).

Physical activity

In the population study a six-point scale was used in assessing level of physical activity (II). On this scale a short period of moderate physical activity is considered equal to a longer period of easy physical activity

(Grimby 1986, Mattiasson-Nilo et al. 1990). The scale was validated by Mattiasson-Nilo et al. (1990) with the aid of heart rate recordings and is as follows:

1) Hardly any physical activity,
2) Mostly sitting, sometimes walking, easy gardening or similar tasks, sometimes light household tasks such as heating up food, dusting, or "clearing away",
3) Light physical exercise around 2-4 hours a week, e.g. walking, fishing, dancing, ordinary gardening, including walks to and from shops. Main responsibility for light domestic work, cooking, dusting, "clearing away", and making beds. Performing or taking part in weekly cleaning,
4) Moderate exercise 1-2 hours a week, e.g. jogging, swimming, gymnastics, heavier gardening, home maintenance, or easier activities more than 4 hours a week. Responsibility for all domestic activities easy as well as heavy. Weekly cleaning, washing floors and window-cleaning,
5) Moderate exercise at least 3 hours a week,
6) Hard or very hard exercise several times a week, e.g. jogging, skiing.

In papers (III) and (IV) specially selected physically active women (members of sports associations or clubs, physical education teachers) were compared with sedentary women. Current level of physical activity was also studied by means of a questionnaire concentrating on various sporting activities as well as time spent on exercise. In (III) physical activity was measured using the scale by Grimby (1986) with minor modifications. In (IV) the participants were shown a list of various sports activities for winter and summer separately. The activities were divided on a discretionary basis into brisk and moderate (brisk: skiing, jogging, basketball, gym training, cycling, rowing, swimming, tennis, gymnastics, etc.; moderate: bowling, home gymnastics, walking, folk dancing, table tennis, etc.). An index was constructed on the basis of the number of times per week brisk or moderate exercise was taken. Present and former habits of practising traditional Finnish women's gymnastics were elicited from the members of the gymnastics clubs and the physical education teachers by means of a separate questionnaire.

Health

Prior to the strength tests a physician evaluated contraindications according to the criteria of the American College of Sports Medicine (1986) (I-V). The physician obtained information about diagnosed chronic diseases by clinical examination and interview techniques (II).

Information about self-rated health and musculoskeletal symptoms (II) were elicited by means of a questionnaire. An index (range 0-6) describing overall musculoskeletal pain during past two weeks was calculated as the sum total of symptoms at three localities: shoulders and neck, back and hips and the extremities. A three-point scale was used: 0 = no pain, 1 = some pain; 2 = a lot of pain.

Education, occupation and work history

Information about education and former occupation was elicited by interview (II) and questionnaire (III, IV). Women with academic education were selected from among the school teachers (IV). Information about work history was elicited by a retrospective interview (III). The subject was asked to recall her employment during her life-span. She was asked if she had been employed in a job involving heavy muscular work such as lifting, moving or carrying heavy objects or chopping wood or digging. The jobs mentioned included working in farming, forestry, construction, factory, warehouse, bakery, hospital, services and cleaning, all of which were classified as physically heavy. Starting age and length of employment were recorded.

Mobility (V)

Mobility was studied in connection with the home interview. The mobility interview was based on the functional ability scale by Avlund & Schultz-Larsen (1991) originally covering wide range of physical and instrumental activities (see also Schultz-Larsen et al. 1992). The functions selected for this study were: 1) Getting out of bed or a chair, 2) Walking indoors, 3) Managing stairs, 4) Walking out of doors in good weather, 5) Walking out of doors in poor weather. The categories were: 1) Able, 2) Able with difficulty (tiredness afterwards or reduced speed), 3) Needs help, 4) Unable.

Maximal walking speed over 10 meters was measured in the laboratory corridor using a regular stop-watch. Climbing ability was measured using a stair-mounting test. The test was carried out using five 10 cm-high boxes, which could be combined to form steps with heights of 10, 20, 30, 40 and 50 cm. The probands were asked to step up and down each step once. The highest step managed without support from the hand rail was recorded as the result (Aniansson et al. 1980a).

Statistical methods (I-V)

The statistical significance of the differences between means was analysed by Student's t-test or one-way analysis of variance followed by Least Significant Difference -test (LSD). Two-way analysis of variance was used to compare the means between groups formed on the basis of two independent variables. The associations of the strength measures with the continuous background variables were analysed by Pearson's product-moment correlations. The associations between muscle force and the discrete variables were determined by estimating the polyserial correlation coefficients. Chi square-test was used with the crosstabulation. Multivariate linear structural equation models were used to analyse the simultaneous associations of the background variables with the indicators of maximal isometric strength. The models were constructed with the help of the LISREL VI program (Jöreskog & Sörbom 1986).

5 RESULTS

5.1 Levels and background factors of maximal isometric strength

5.1.1 Cross-national comparison of maximal isometric strength and anthropometric characteristics

Significant differences in maximal isometric strength between 75-year-old residents in Glostrup, Gothenburg and Jyväskylä were observed (I). In absolute units the 75-year-old men and women from Jyväskylä had significantly lower strength values for hand grip and elbow flexion than the residents of the other two localities. Moreover, the performance of the men from Jyväskylä was also inferior in the knee extension test (Figure 2). In the elbow flexion and knee extension strength tests men from Glostrup performed better than the men from Gothenburg. In the results of the trunk strength tests no differences between localities were observed among the men, whereas the women from Glostrup had lower values than those in Gothenburg and, particularly, Jyväskylä.

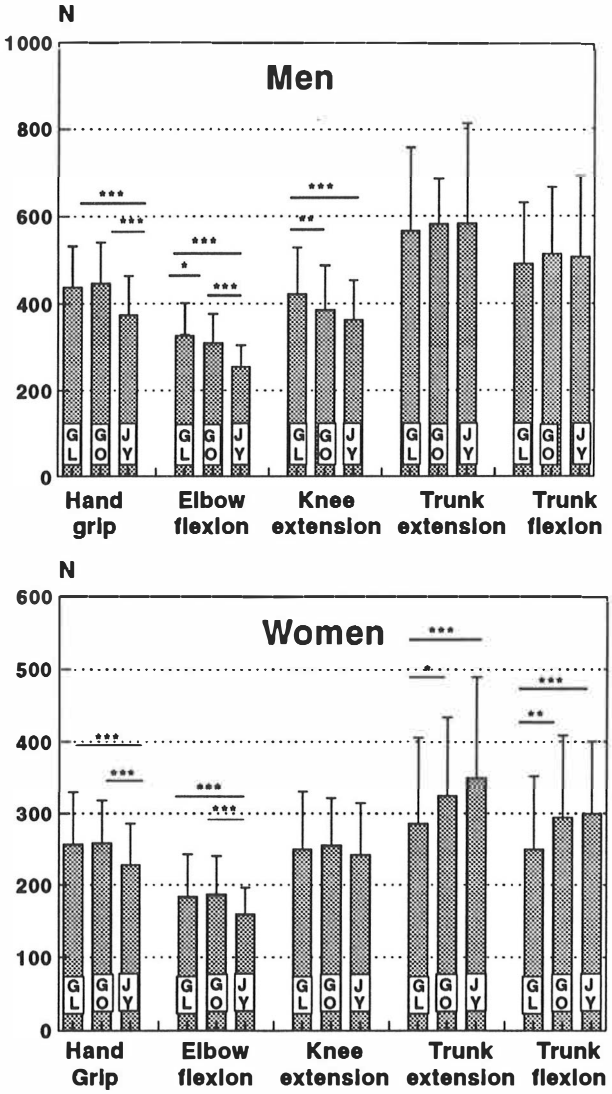


FIGURE 2 Maximal isometric strength (absolute values) of hand grip, elbow flexion, knee extension, trunk extension and trunk flexion in 75-year-old men and women in three Nordic localities (Glostrup, Denmark; Gothenburg, Sweden; and Jyväskylä, Finland). Means + standard deviations and the statistical significance of the differences (oneway analysis of variance) are shown. ***p<.001 **p<.01 *p<.05

Significant differences in the height, weight and body composition were also observed (Table 3). The men from Gothenburg were significantly taller than the men from Glostrup and Jyväskylä. The women from Gothenburg were significantly taller than those from Jyväskylä. The latter, however, had the greatest body mass as well as body mass index.

TABLE 3 Anthropometric characteristics of the 75-year-old persons in three Nordic localities (mean, SD) (oneway analyses of variance followed by least significant difference -test).

	GLOSTRUP 1	GOTHENBURG 2	JYVÄSKYLÄ 3	F-VALUE	1,2	1,3	2,3
MEN							
Body height, cm	170.4 (5.9)	174.1 (6.1)	169.3 (6.2)	17.8***	***		***
Body weight, kg	75.7 (10.8)	77.7 (11.3)	74.1 (10.7)	2.7			
Body mass index, kg/m^2	26.0 (3.2)	25.6 (3.1)	25.9 (3.6)	0.6			
Body fat, %	19.2 (6.7)	22.8 (5.3)	21.8 (5.9)	12.7***	***	***	
Lean body mass, kg	60.7 (6.8)	59.5 (6.7)	57.6 (6.3)	7.3***		***	*
WOMEN							
Body height, cm	157.6 (5.7)	161.3 (5.6)	155.8 (5.6)	36.1***	***	**	***
Body weight, kg	64.1 (11.8)	65.9 (10.3)	67.5 (11.6)	4.5*		**	
Body mass index, kg/m^2	25.8 (4.6)	25.3 (3.6)	27.8 (4.7)	15.6***		***	***
Body fat, %	27.1 (8.1)	31.3 (6.0)	32.8 (7.0)	32.0***	***	***	
Lean body mass, kg	46.0 (5.5)	44.7 (4.2)	44.8 (4.3)	4.0*	*	*	

*** p<.001 **p<.01 * p<.05

After adjusting the maximal isometric strength results for body weight the differences remained similar (Figure 3).

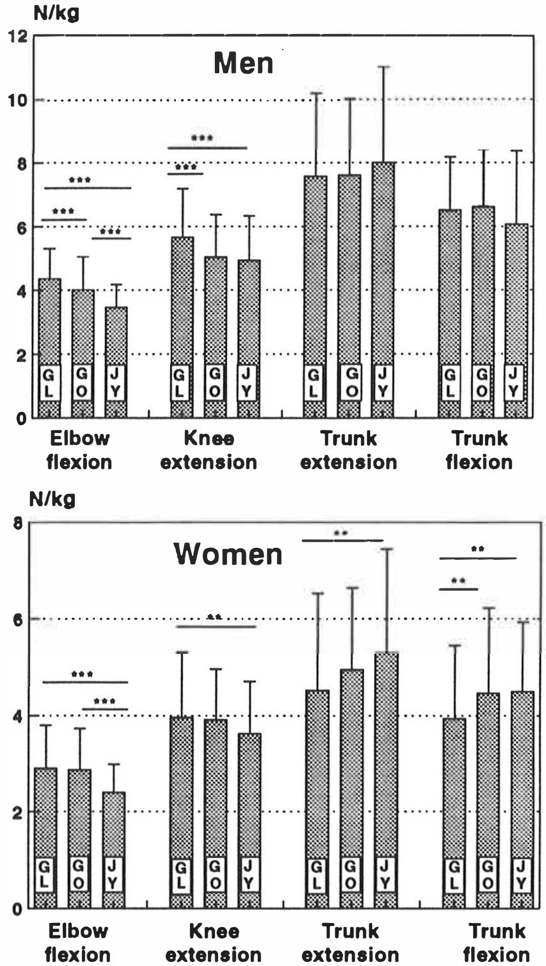


FIGURE 3 Maximal isometric strength (relative values) of elbow flexion, knee extension, trunk extension and trunk flexion in 75-year-old men and women in three Nordic localities (Glostrup, Denmark; Gothenburg, Sweden; and Jyväskylä, Finland). Means + standard deviations and the statistical significance of the differences (oneway analysis of variance) are shown. ***p<.001 **p<.01 *p<.05

The correlation analyses showed that body height, body weight, body mass index, percentage body fat and lean body mass correlated significantly with the absolute values of maximal isometric strength among both sexes from each locality (Table 4.). Lean body mass was the strongest correlate. In particular, among the women from Glostrup and Jyväskylä body height correlated positively with strength: the taller subjects were stronger. The few negative correlations between body fat

TABLE 4 Correlation coefficients between maximal isometric strength (absolute values) and anthropometric properties among 75-year-old men and women in Glostrup, Gothenburg and Jyväskylä.

	GLOSTRUP					GOTHENBURG					JYVÄSKYLÄ				
	Height	Weight	BMI	Fat%	LBM	Height	Weight	BMI	Fat%	LBM	Height	Weight	BMI	Fat%	LBM
MEN			(N=188-194)					(N=89-98)					(N=95-101)		
Hand grip	.280***	.347***	.396***	.006	.448**	.331***	.320***	.200*	-.188*	.493***	.270**	.192*	.032	-.221*	.392***
Elbow flexion	.211**	.396***	.340***	.057	.445***	.216*	.284**	.222*	-.086	.394***	.040	.228**	.201*	-.061	.333***
Knee extension	.053	.127*	.122*	.032	.198**	.064	.208*	.223*	-.150	.334***	.122	.159	.091	-.098	.261**
Trunk extension	.082	.122*	.100	-.043	.183**	.148	.178*	.140	.151	.330***	.204*	.101	-.007	-.115	.208*
Trunk flexion	.177**	.324***	.276***	.091	.366***	.178*	.418***	.395***	.026	.528***	.248**	.351***	.221*	.128	.366***
WOMEN			(N=197-209)					(N=100-115)					(N=180-190)		
Hand grip	.326***	.252***	.128*	.007	.419***	.188*	.204*	.133	.015	.246**	.320***	.130*	-.000	-.038	.311***
Elbow flexion	.304***	.353***	.244***	.071	.516***	.157*	.149	.083	-.118	.247**	.278***	.252***	.135*	.074	.397***
Knee extension	.215***	.191**	.114	.058	.279***	.141	.193*	.148	.066	.217*	.246***	.267***	.170**	.172**	.323***
Trunk extension	.243***	.158*	.071	.011	.273***	.168*	.223**	.163*	.106	.194*	.275***	.114	-.020	.030	.214**
Trunk flexion	.226***	.268***	.188**	.140*	.311***	.071	.240**	.217**	.127	.222*	.253***	.333***	.227***	.186**	.377***

***p<.001 **p<.01 *p<.05

content and maximal strength indicated poorer strength among persons with a greater proportion of fat tissue.

5.1.2 Health

The association of health with maximal isometric force was studied among the 75-year-old residents of Jyväskylä (II). 5 men (5%) and 15 women (8%) had no diagnosed chronic diseases. Diseases of the cardiovascular (e.g. ischemic heart disease, hypertension, cardiac insufficiency), musculoskeletal (arthritis, back pain) and nervous and sensory organs (parkinsonism, cataract, stroke) were the most common. 49% of the men and 51% of the women had a disease in one system, 31% of the men and women in two, and 4% of the men and 3% of the women had a disease in all three systems (Figure 4).

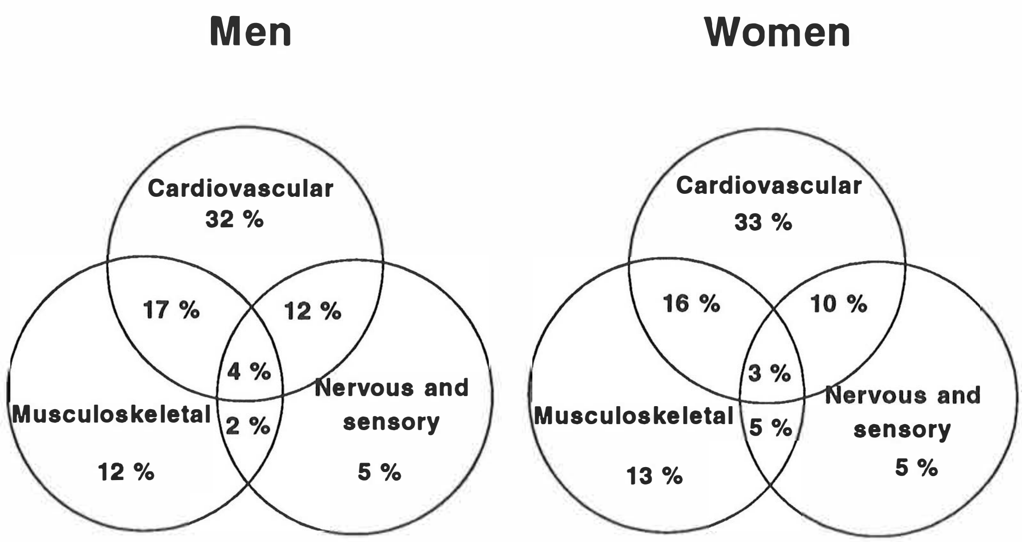


FIGURE 4 The prevalence of diseases in the cardiovascular, musculoskeletal and nervous and sensory systems and combinations of them among 75-year-old men (n=102) and women (n=199). 5 men and 15 women had no diagnosed diseases, and 12 men and 18 women had other diseases than those mentioned above.

The prevalence of these diseases and their combinations did not differ between the sexes. 12 men and 18 women had diseases other than those mentioned above (such as mental diseases, tumours, diseases of the digestive system and diabetes). Men had on average 2.0 and women 2.3 chronic diseases.

In comparing maximal isometric strength levels between the healthy women (no diseases) and those having a disease of the musculoskeletal, nervous or cardiovascular system or a combination of these, no systematic differences between the means were observed. The sole exception was elbow flexion force: the group of women with both nervous and musculoskeletal diseases performed worse ($p<.05$) than the healthy women. Among the men such comparisons were not possible as only five of them were healthy.

The majority of the participants rated their health as average (Table 5). No difference between the sexes in self-rated health or musculoskeletal symptoms were observed. Among both sexes self-rated health, index of musculoskeletal symptoms and number of chronic diseases were significantly intercorrelated.

TABLE 5 Health variables among 75-year-old men and women.

Variable	MEN (n=105)		WOMEN (n=200)		t-value	χ^2
Number of chronic diseases (mean, SD)	2.0	(1.4)	2.3	(1.7)	-0.37	
Index of musculoskeletal pain, range 0-6 (mean, SD)	2.2	(1.8)	.4	(1.7)	-1.09	
Self-rated health (%)						
-Good	13		15			
-Average	75		72			0.65
-Poor	12		13			

Among the men poorer values in the state-of-health indicators (number of chronic diseases, index of musculoskeletal symptoms, and self-rated health) were associated with low elbow flexion and trunk forces (Table 6). Among the women bad self-rated health correlated with poor values in all the force variables, whereas number of chronic diseases and index of musculoskeletal symptoms correlated negatively with trunk extension strength only.

TABLE 6 Correlations between health and force variables among 75-year-old men and women. Depending on the level of measurement for each pair of variables product moment or polyserial correlation coefficients are used.

Variable	1.	2.	3.	4.	5.	6.	7.
MEN (n=91-119)							
1. Number of chronic diseases							
2. Index of musculoskel. symptoms	0.340***						
3. Self-rated health	0.707***	0.543***					
4. Hand grip force	-0.157	-0.095	0.002				
5. Elbow flexion force	-0.199*	-0.133	0.270***	0.638***			
6. Knee extension force	-0.120	-0.053	-0.046	0.524***	0.638****		
7. Trunk extension force	-0.367***	-0.306**	-0.592***	0.515***	0.564****	0.696***	
8 .Trunk flexion force	-0.252*	-0.218*	-0.280**	0.427***	0.505***	0.648***	0.719***
WOMEN (n=175-263)							
1. Number of chronic diseases							
2. Index of musculoskel. symptoms	0.366***						
3. Self-rated health	0.359***	0.558***					
4. Hand grip force	-0.022	-0.090	-0.199*				
5. Elbow flexion force	-0.073	-0.121	-0.211**	0.672***			
6. Knee extension force	-0.117	-0.109	0.336***	0.514***	0.536***		
7. Trunk extension force	-0.155*	-0.158*	-0.420***	0.541***	0.552***	0.614***	
8. Trunk flexion force	-0.053	0.029	-0.240**	0.524***	0.547***	0.662***	0.650***

***p<.001, **p<.01, *p<.05

5.1.3 Physical activity and exercise

The association of physical exercise with maximal isometric strength was studied by comparing selected 50-60-year-old and 66-86-year-old women with a life-long history of physical exercise with control groups of corresponding ages (III, IV). The association of everyday physical activity with strength was studied among a representative group of 75-year-old men and women (II).

The physically active 50-60-year-old women had practised traditional Finnish women's gymnastics (a special creative form of movement exercise in which the emphasis is on fluctuations between tension and relaxation) for an average of 31 years and were currently training on an average three hours per week during winter and one hour per week during summer. The index describing the brisk physical activities practised was significantly lower in the sedentary control group (1.3) than among the physically active group (4.1).

Among the veteran sportswomen aged 66-85 years (mean age 73.9 years) the average history of habitual physical exercise was 50 years (range 3-74). At present 70% were still training intensively (meaning breathlessness and sweating) more than three times per week. The population sample (mean age 74.6 years) was rather sedentary with none of the group taking any specific physical exercise. Among the majority (90%) current physical activity consisted of everyday household activities or light walking.

The physically active 50-60-year-old and 66-86-year-old women exhibited greater absolute and body weight-related maximal isometric strength than the sedentary women of corresponding age (Figure 5). The absolute strength tests results (excluding grip strength) of the older active group varied from 73% (trunk extension) to 95% (elbow flexion) of those of the younger group. In the sedentary groups the corresponding range was from 68% (trunk extension) to 89% (knee extension). Adjusting the strength results to body weight diminished the difference between the older and middle-aged active women (75% - 100%). Among the sedentary women the weight-adjustment increased the age difference (64% - 85%) due to higher body weight among the older group.

It was also observed, that the body weight-related elbow flexion, knee extension and trunk extension and flexion forces of the 66-86-year-old physically active women were on about the same level as the values of the sedentary women twenty years younger than them (Figure 5).

The association of everyday physical activity with strength was studied among 75-year-old residents of Jyväskylä with the help of correlation analyses (II). 63% of the men and 71% of the women were currently engaged in light physical activities (e.g. light walking, dancing, easy gardening or similar tasks) at most for 2-4 hours a week. 11% of the men and 3% of the women claimed to be moderately active at least 3 hours a week (e.g. playing tennis, swimming, jogging) (Table 7).

TABLE 7 Amount of physical activity among 75-year-old men and women

Variable	Men (n=104) %	Women (n=191) %	χ^2
1. Hardly any physical activity	9	3	
2. Mostly sitting, sometimes walk, light tasks	20	22	
3. Light physical exercise about 2-4 h/week, walks	34	46	
4. Moderate exercise 1-2 h/week or easier exercise more than 4 h/week	26	26	
5. Moderate exercise at least 3 h/week	11	3	
6. Hard or very hard regular exercise several times/week	0	0	13.6**

** p<.01

The amount of general physical activity correlated positively with the body weight-related maximal isometric forces (Table 8).

TABLE 8 Correlation coefficients between physical activity and force variables among 75-year-old men and women in Jyväskylä.

Variable	MEN (n=95-101) r	p	WOMEN (n=178-186) r	p
Hand grip	0.296	***	0.292	***
Elbow flexion	0.473	***	0.329	***
Knee extension	0.396	***	0.253	***
Trunk extension	0.530	***	0.219	***
Trunk flexion	0.435	***	0.385	***

***p<.001, **p<.01, *p<.05

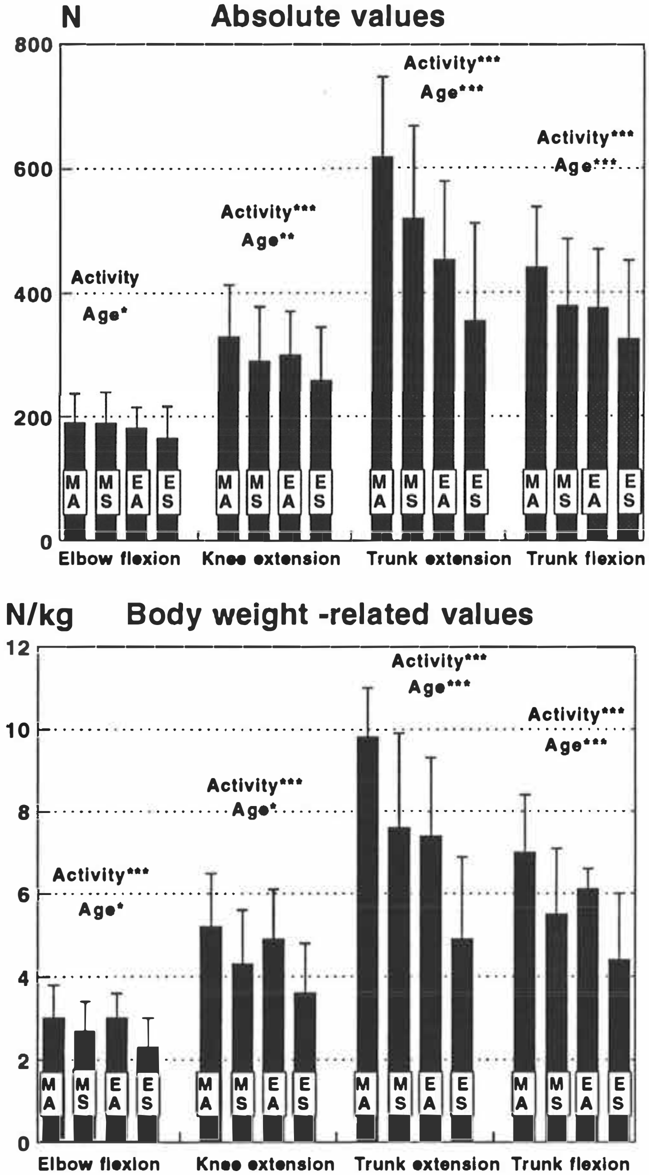


FIGURE 5 The absolute and body weight-related maximal isometric strength of elbow flexion, knee extension and trunk extension and flexion in 50-60 and 66-85-year-old women grouped according to physical exercise level (two-way analysis of variance). M = 50 - 60 years, E = 66-85 years, A = active, S = sedentary. ***p<.001 **p<.01 *p<.05

5.1.4 Education and work

The association of educational background and occupational status with maximal isometric strength was studied among 50-60-year-old women (IV) and among 75-year-old men and women living in Jyväskylä (II).

The maximal isometric strength test results of the 50-60-year-old women with university education and employed as teachers (higher managerials) were compared with women having a vocational or lower educational background and employed as lower managerials (40%), manual workers (30%), higher managerials (10%) or not employed (20%). Even though the level of physical activity was controlled, those with university level educational background exhibited greater strength in knee extension and trunk flexion and extension tests.

TABLE 9 Maximal isometric strength of five muscle groups (Mean, SD, F) among 50-60-year-old women grouped according to habitual physical activity and educational background (two-way analysis of variance).

Variable	University degree Active (n=32)	University degree Sedentary (n=22)	Vocational or lower Active (n=26)	Vocational or lower Sedentary (n=26-29)	*Source of variance* Activity F	Activity p	Education F	Education p
Hand grip (N)	385 (78)	343 (86)	367 (74)	320 (89)	7.9	**	1.7	
Elbow flexion (N)	201 (58)	170 (54)	205 (47)	198 (38)	5.7	**	1.3	
Leg extension (N)	378 (85)	286 (87)	317 (92)	277 (92)	14.1	***	4.5	*
Body extension (N)	670(117)	538(164)	621(141)	476(142)	30.1	***	6.0	*
Body flexion (N)	501 (92)	388(112)	429 (90)	348(111)	24.5	***	8.7	**

*** = p<.001 ** = p<.01 * = p<.05

Among 75-year-old men and women no differences in strength according to educational background or former occupational status were observed.

A history of heavy work as a modulator of maximal isometric strength was studied among 66-85-year-old physically active women and controls (III). The mean history of heavy work was 36 years (SD 20) among the population sample and 24 years (SD 24) among the trained group. The median value for the trained women was 14 years (range 0-73) as against 38 years for the population sample (range 0-66). The correlation coefficients between the number of years of heavy work and muscle force were calculated for the trained women and population sample separately. A statistically significant positive correlation was observed among the population sample for trunk extension force, ($r=.425$ $p<.01$). Among the trained women the correlation coefficients were not statistically significant.The simultaneous association of current physical exercise during leisure and history of heavy work with maximal strength were studied in more detail using two-way analysis of variance. No significant associations between work history and any of the strength variables were observed (see paper III, Table 5).

5.1.5 Multivariate analyses of the associations between socio-economic status, health, physical activity and maximal isometric strength

The background factors of maximal isometric strength were intercorrelated among the 75-year-old residents of Jyväskylä (II). Consequently multivariate analyses were performed in order to study their simultaneous associations with strength. The construction of the multivariate LISREL-models was based on previous correlation analyses between the force and the background variables as well as information received from earlier literature and logical reasoning.

Force factors were constructed in the interest of combining the original test results into two factors describing maximal strength as an entity. The structure of the force factors differed somewhat between the sexes. Among the men the limb force factor was based on the measurements of hand grip, elbow flexion and knee extension strength (Figure 6). Knee extension strength also had a loading on the trunk force factor as well as the measurements of trunk extension and flexion. Among the women the limb force factor was based on the upper limb strength measurements (Figure 7). The trunk force factor was based on measurements of the knee extension and trunk flexion and extension forces. Among both sexes the limb and trunk force factors were intercorrelated.

The regression analytical sections of the LISREL models also differed between the sexes. Initially, physical activity, number of chronic diseases, self-rated health and index of musculo-skeletal pain were introduced into the models for the men and the women in order to study their explanatory power simultaneously. The variables, which had statistically significant effects, can be seen in Figures 6 and 7. Among both sexes level of physical activity explained the variation in the limb and trunk force factors. Among the men the trunk force factor was explained by number of chronic diseases and index of musculoskeletal pain, whereas among the women the explanatory variables were self-rated health and index of musculoskeletal pain.

In the model for the men the determination coefficient (R^2) for the trunk force factor was 0.60 and for the limb force factor 0.50, indicating that 60% of the variation in the trunk force factor and 50% of the variation in the limb force factor were explained by the independent variables. The determination coefficient (D) of the whole model for the men was 0.59 and for the women 0.55. Among the women also a greater amount of the variation in the trunk force factor (64%) than that in the limb force factor (56%) was be explained by the background factors.

Occupational and educational background was not directly associated with the force factors. However, those of higher socioeconomic status tended to be physically more active.

It was concluded that higher level of everyday physical activity and good values in the state-of-health indicators were the most important variables explaining greater strength among the elderly people.

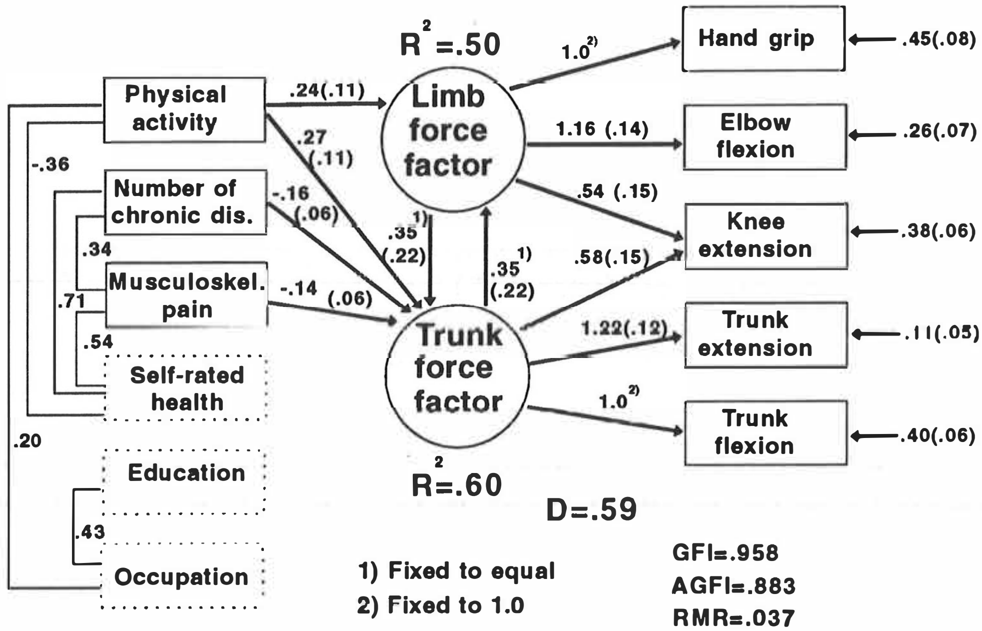


FIGURE 6 The determinants of body weight-related maximal isometric muscle force among 75-year-old men. Isometric strength is described by the limb force factor based on the measurements of the hand grip, elbow flexion and knee extension forces, and the trunk force factor based on the measurements of knee extension and trunk flexion and extension. The variance in these factors is explained by a regression model using the background variables as independent variables. The R^2 values indicate the determination coefficient for each force factor separately and D the corresponding coefficient for the whole model. The mutual correlations between the force factors as well as between the background factors are shown. The explanatory variables marked with broken lines were not significant and were not introduced into the final model. GFI, Goodness of fit index. AGFI, Adjusted goodness of fit index. RMR, Root-mean-square residual.

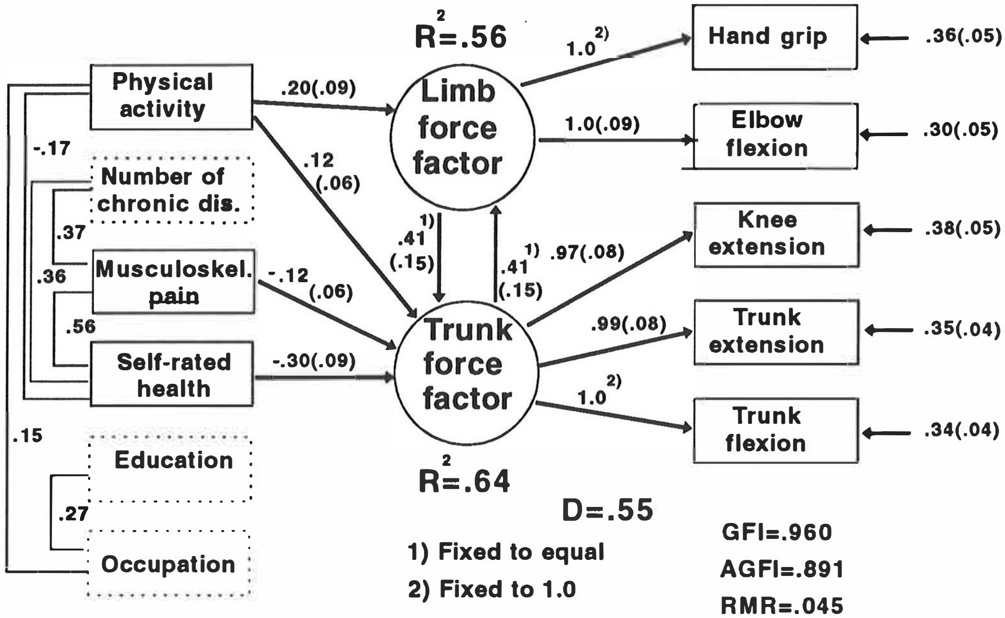


FIGURE 7 The determinants of body weight-related maximal isometric muscle force among 75-year-old women The explanatory variables marked with broken lines were not significant and were not introduced into the final model. For details and definitions see Figure 6.

5.2 Maximal isometric strength and mobility

Mobility was studied in connection with the home interview among the 75-year-old residents of Jyväskylä (IV). The strength tests were not performed by 18 men and 47 women: these subjects took part in the home interview only. The prevalence of poor mobility was greater among this group than among those who participated in the strength measurements. The proportion of those not able to perform the mobility functions independently varied from 0 to 15% among the participants and from 3 to 50% among the drop-outs, depending on the task examined. No statistically significant mobility differences between the sexes were observed on the basis of the interview. Because only few of the strength-tested subjects needed help or were unable to perform the mobility functions at all, strength comparisons could be made only between mobility function categories 1. (Able) and 2. (Able with difficulty). Among both sexes greater strength was exhibited by those who claimed to be able to perform the requested tasks without difficulty (Figure 8). The strength differences were consistently statistically significant for all the muscle groups studied. However, among the men, hand grip strength was associated only with the ability to get out of bed or a chair.

The majority (76%) of the men could step up on to a 50 cm high box. Among the women greater variation in climbing performance was observed: 28% managed the highest step, and 26% were able to climb to 40 cm, and about every second woman (46%) managed 0-30 cm. Those who performed better in the stair-mounting test exhibited greater maximal isometric strength (Figure 9).

Maximal walking speed was on average 1.8 m/s (SD 0.5) among the men, and 1.5 m/s (SD 0.5) among the women. Walking speed correlated positively with all the strength test results in the women ($p<.001$). Among the men the corresponding correlations were significant ($p<.05$) for all the other tests except hand grip.

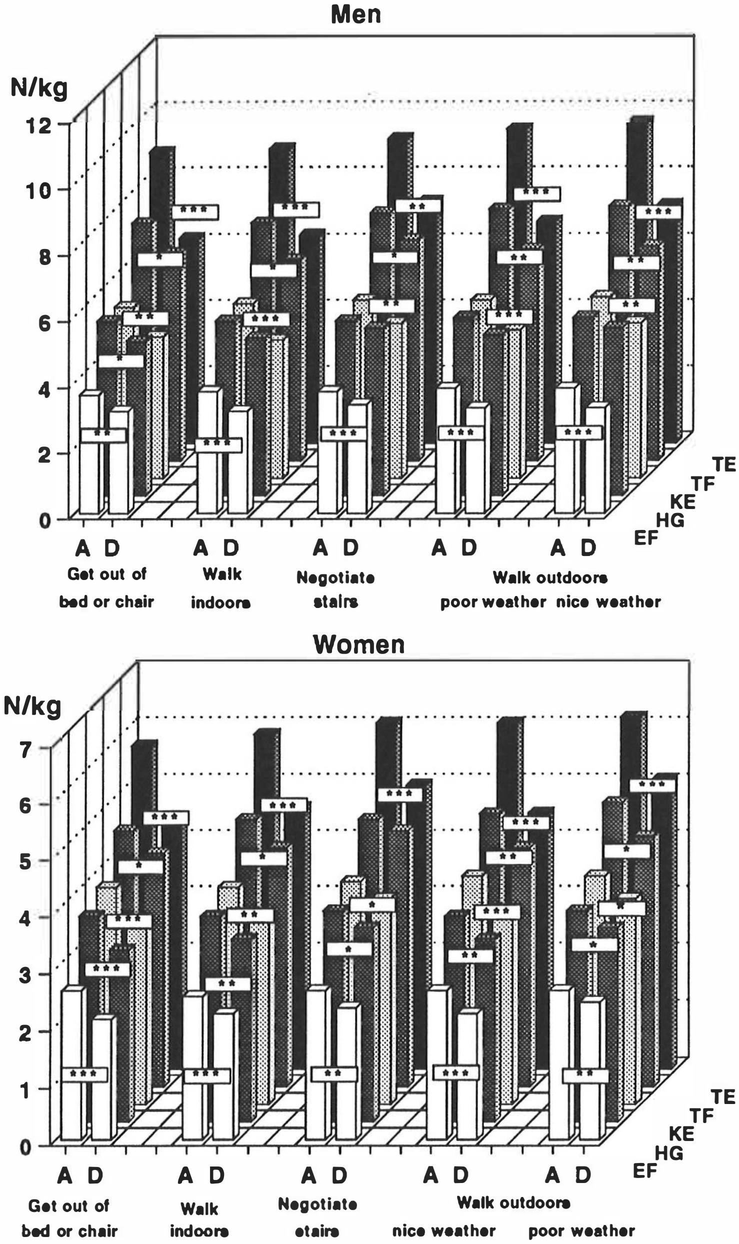
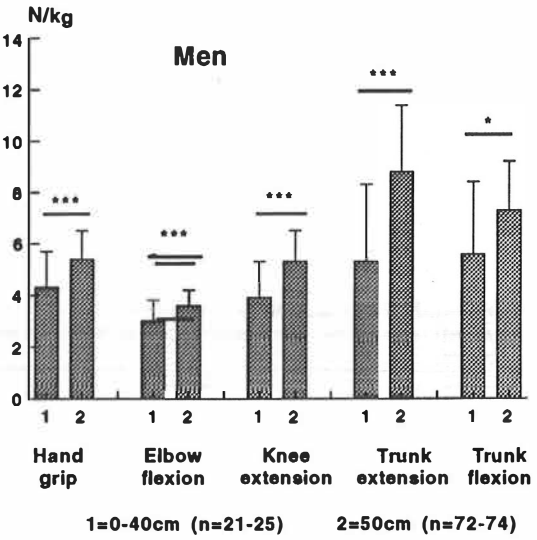


FIGURE 8 Maximal isometric strength (relative values) of elbow flexion (EF), hand grip (HG), knee extension (KE), trunk flexion (TF) and trunk extension (TE) among 75-year-old men and women grouped according to their ability to manage daily motor tasks (A=able, D=difficulties, t-test). ***p<.001 **p<.01 *p<.05



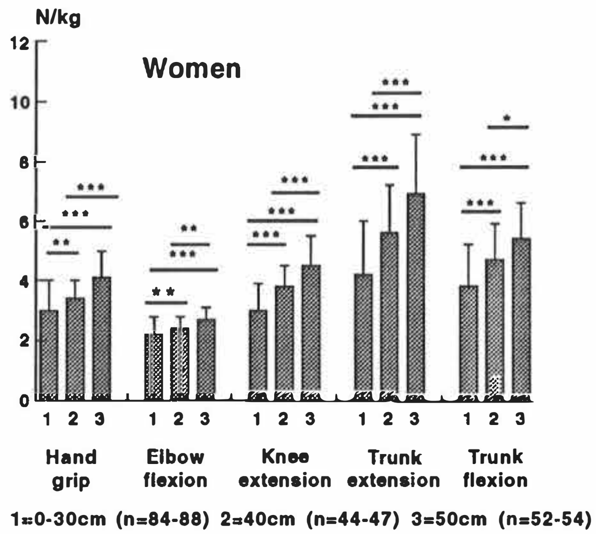


FIGURE 9 Maximal isometric strength (relative values) among 75-year-old men and women grouped according to their performance in stair mounting-test (t-test or oneway analysis of variance followed by LSD-test). ***p<.001 **p<.01 *p<.05

To study the association between maximal strength and walking speed in more detail the participants were divided into two mobility groups for the men and women separately: those with good mobility were represented by participants who expressed no difficulty in negotiating stairs, whereas those with impaired mobility were represented by persons who expressed reduced speed or tiredness while climbing stairs. The correlation coefficients were calculated separately for both groups (Table 10).

TABLE 10 Correlation coefficients between maximal walking speed and isometric strength among 75-year-old men and women grouped according to their mobility in stairs.

Variable	MEN				WOMEN			
	No difficulty (n=41-43)		Some difficulty (n=52-55)		No difficulty (n=56-59)		Some difficulty (n=119-124)	
	r	p	r	p	r	p	r	p
Hand grip	.156		.502	***	.363	**	.485	***
Elbow flexion	.226		.408	**	.384	**	.470	***
Knee extension	.383	*	.508	***	.417	***	.436	***
Trunk extension	.531	***	.644	***	.445	***	.590	***
Trunk flexion	.339	*	.572	***	.443	***	.551	***

***p<.001 **p<.01 *p<.05

The maximal force variables and walking speed tended to be more strongly associated among those with impaired stair climbing capacity, particularly among the men (see Appendices 3 and 4).

6 DISCUSSION

6.1 Maximal isometric strength and background factors

Cross-national comparison of maximal isometric strength and anthropometric characteristics

Although great interindividual variation in strength has been observed among the elderly in previous studies (see Heikkinen et al. 1984, Viitasalo et al. 1985, Svanborg 1988), such studies have not looked at the differences cross-nationally. For this reason maximal isometric strength and its association with anthropometric properties was studied among representative samples of 75-year-old persons in Glostrup, Denmark and Gothenburg, Sweden as well as all residents of Jyväskylä, Finland (I).

The greatest limb forces were observed among the women from Glostrup and were accompanied by the greatest lean body mass. Lean body mass was the most significant correlate of maximal strength within each locality. However, the same group exhibited the lowest values in the trunk force tests. The highest values observed in the trunk strength tests were among the women from Jyväskylä. This may partly be explained by the stockier body shape indicated by a greater body mass index. Persons with a heavier build may have stronger trunk muscles than those more slenderly built. The body mass index correlated significantly with, in particular the trunk flexion test values within each locality. Among the men the trunk forces did not differ between the residents of the three localities. The correlations between anthropometric characteristics and strength were logically consistent within each locality. Nonetheless, the strength differences between the localities remained similar even after standardization for body weight.

The results indicated significant differences in strength levels expressed in absolute units as well as in anthropometric characteristics between the localities. Part of the differences in strength observed between the residents of the three localities are explained by anthropometric factors. On the basis of this data, no conclusions concerning the rate of biological aging in the localities can be drawn. The statistically significant association between weight-related muscle strength and locomotive abilities (V) suggests that some of the differences in the functional capacities observed between the residents of the different localities (Kozarević et al. 1989) using interview techniques may be due to differences between the populations in fitness characteristics, like maximal strength.

Health

Among the 75-year-old residents of Jyväskylä 5 men (5%) and 15 women (8%) had no medically diagnosed chronic diseases (II). Similar proportions (ranging between 5-20%) of healthy elderly people have been observed in other Finnish epidemiological surveys (Aromaa et al. 1989, Jylhä et al. 1992). In old age it is more common to have chronic diseases than to be healthy. Nonetheless, generally only healthy (= no diagnosed disease) elderly people have been selected for studies of strength or physical performance capacity (e.g. Clement 1974, Young et al. 1984, Murray et al. 1985, Rice et al. 1989). Consequently, relatively little is known about the association between chronic diseases and strength in elderly populations.

In the present study no consistent statistically significant differences in strength between the healthy women and those having one or more diseases of cardiovascular, musculoskeletal or nervous system were observed. In addition, the correlations between number of chronic diseases and the force variables were not statistically significant among the women, except for trunk extension force. These data suggest that the existence of diagnosed chronic diseases as such is not necessarily connected with lower muscle strength among elderly women. According to the follow-up study by Bassey & Harries (1993) loss of grip strength was mainly due to diminished activity rather than loss of health.

Because in the present study only five men were healthy, similar comparisons could not be undertaken. Among the men the number of chronic diseases correlated negatively with the elbow flexion and trunk flexion and extension forces.

Apart from the direct effects of specific muscular and neurological diseases on muscle (see Jones & Round 1990), the loss of strength may, at least partly, be a result of the restricted mobility caused by various symptoms (as in cardiovascular diseases), or required for the care of a disease. For example, Sinaki et al. (1993) suggested that the poorer back extension strength found among 40-85-year-old women with diagnosed osteoporosis and previous vertebral fractures was the result of the pain caused by the injury leading to the improper recruitment of back muscles and the ensuing disuse of the muscles. The present study also showed those with more musculoskeletal pain to have lower strength values in the trunk muscle tests.

The shortcoming here is the lack of information concerning the seriousness of diseases. In a population-based study design a great number of different diseases and combinations of diseases may be found. This approach does not ensure that healthy persons or persons with specific diseases are found in sufficient numbers to enable comparisons in even a relatively extensive data set. Comparative experimental studies among groups with specific diseases of known severity would be one approach to shedding more light on the association between diseases and strength in old age. The changes in physical activity caused by the disease should also be known.

Good self-rated health correlated with greater strength among both sexes. The ability to manage daily life has been found to be a significant determinant in self-rated health (Jylhä 1986). Consequently, the association between self-rated health and maximal strength may be due to the superior ability at managing daily tasks of those with greater strength (Young 1986).

Physical exercise and maximal isometric strength in different age groups

The strength of physically active 50-60-year-old and 66-85-year-old women was compared with "normal" women of corresponding age (III, IV). The physically active women in both age-groups exhibited greater absolute and body weight-related strength values.

The absolute strength tests results of the physically active 66-86-year-old women varied from 73% (trunk extension) to 95% (elbow flexion) of the results of their 50-60-year-old counterparts. In the sedentary groups the corresponding range was from 68% (trunk extension) to 89% (knee extension). Adjusting the strength results for body weight diminished the difference between the older and middle-aged active women (75% - 100%). Among the sedentary women adjustment for weight increased the age difference (64% - 85%) due to the higher body weight of the older group.

In a previous study employing similar methodology among representative samples of men aged 31-35, 51-55 and 71-75 years (Heikkinen et al. 1984, Viitasalo et al. 1985) the results of the older group of men varied from 68% (knee extension) to 76% (hand grip) of the results of the middle-aged group. The results of Murray et al. (1985) and Aniansson et al. (1983) suggest that women retain a greater proportion of their maximal strength towards the higher age groups. The present cross-sectional data is indirect evidence for that.

In fact, the weight-adjusted results of the physically active older women were on the same level as the results of the sedentary women about 20 years younger. The youthfulness of the strength values of the physically active 66-85-year-old women supports the common assumption that physical exercise is useful in the prevention of premature frailty. This may also imply that exercise even counteracts the age-related decline in strength.

Everyday physical activity

The majority of the 75-year-old persons in Jyväskylä were not in the habit of practising any specific exercises (II). The amount of everyday physical activity was observed to correlate positively with the body weight-related maximal isometric forces. Those busier in their everyday activities were observed to be stronger than the more passive participants. This is in accordance with the suggestion by Grimby (1986) and Mattiasson-Nilo et al. (1990) that daily activities such as domestic tasks and walking may have a training effect among older people with reduced capacities.

Socioeconomic status and work history

The 50-60-year-old women with an academic education exhibited greater maximal isometric strength than those with vocational or less education, even after controlling for physical exercise (IV). The reason for the greater muscle strength among those with a university degree remains unclear. One explanatory model is offered by social causation theory according to which differences in health between the social classes are seen to be due to the differences in living and working conditions as well as living habits associated with social class (see Townsend & Davidson 1983). An abundance of intellectual and economic re sources makes it easier to lead a life with reduced serious health risks (Aro et al. 1985, Aukee et al. 1985, Vuolle et al. 1986). In our study living habits (i.e. smoking, alcohol consumption, rest) varied between the groups only to a limited extent. Consequently work and working conditions could explain some of the variation. The higher educated women teachers were regarded as higher managerials (100%). The less educated were employed as lower managerials (40%), manual workers (30%) and higher managerials (10%) or not employed (20%). The interaction between aging and physically tiring work probably lowers muscle strength.

The association of heavy work with maximal strength was studied among 66-85 year-old trained women and a random population sample aged 70-81 years (III). The main result was that length of heavy work history was not systematically associated with strength in either group.

The association between occupation and muscle strength seems to vary in different age groups. Era et al. (1992) found greater strength among young men doing physically heavy work. Among middle-aged persons the situation was reversed. Nygård et al. (1988) found that middle-aged women with a high physical work load showed systematically lower muscle strength when compared to a group with a low work load. After a four-year follow-up strength had declined in all the work categories, which indicated that physical effort during work does not maintain nor increase maximal strength among employees aged 50 years and over (Nygård et al. 1991).

The present results support those of Aniansson et al. (1980b) who also found no correlation between quadriceps strength and previous occupational activity among 70-year-old women. In this study physically heavy work referred to jobs which had included lifting or moving heavy objects. Consequently, a training effect on maximal strength would be expected. However, after retirement a detraining effect would occur. Thus, the hypothetical association between previous heavy workload and strength measured after retirement would be caused by a third factor. It would be logical to assume, that those doing heavy work and having lower strength and more musculoskeletal conditions in their 50s would be even more disadvantaged in their later life. These cross-sectional comparisons did not, however, accord that supposition.

The changes in the association between physical occupational work load and strength in different age groups may, at least partly, be explained by selection factors. One type of selection factor operates at the time of entering employment. It is likely that a heavy job will attract those whose health and strength fall above some threshold for such work. A secondary selection factor intervenes later when a worker changes his/her occupation because he/she is no longer fit or healthy enough for the previous heavy job (for review see Östlin 1989). The selection factor theory is supported by the finding of Ilmarinen (1989) that a high physical work load was a risk factor for coronary heart disease among men. Moreover, mortality has been found to be greater among individuals at lower socio-economic levels (Clement 1974, Hasan 1988).

Women who have not been forced to transfer into lighter professions may be innately stronger. On the other hand, persons who are familiar with strenuous physical work may have some advantage in maximal performance measurements as compared to those who are not used to performing feats of strength in their lighter jobs. However, two-way analysis of variance with heavy work history and exercise during leisure as independent variables revealed no significant the associations between any of the strength variables and heavy work.

Multivariate analyses on the association of socioeconomic status, health and physical activity with maximal isometric strength

The simultaneous associations of socio-economic status, health and physical activity with maximal isometric strength were studied among 75-year-old men and women (II) with the help of LISREL models. The construction of the models was based on the information presented in the literature, logical reasoning and analyses showing correlations between the force variables and the background variables.

The force factors differed between the sexes. Among the men the knee extension strength had a loading on both limb and trunk force factors whereas among the women it was connected with the trunk force factor. However, among both sexes all the strength test results were significantly intercorrelated. Reason for the differences in the structure of force factors between the sexes is partly unknown. One reason could be the genetically determined differences in the physique between men and women. The age-related strength change in different muscle groups may also differ between the sexes. Lundgren-Lindqvist & Sperling (1983) observed a proportionately smaller decline in hand grip strength among the women than men. This was suggested to result from the greater use of hands in domestic work among the women than the men.

Among both sexes the amount of physical activity explained the variation in both the limb and trunk force factors, whereas the state-of-health indicators explained the variance only in the trunk force factors. Some difference between the sexes was also observed with respect to the health variables as explainers of trunk force. Among the men number of chronic diseases and among the women self-rated health explained the variation in the trunk force factor. Self-rated health and number of chronic diseases were significantly intercorrelated in both sexes. In multivariate analysis the intercorrelation of two independent variables may cause an effect to be transmitted through one or the other. Nevertheless, one explanation for this is offered by a finding of Verbrugge (1984): older women have more aches and pains which are bothersome but not life threatening, whereas men tend to be bothered in their daily life by precisely the diseases that often cause their deaths.

Socio-economic status was not directly associated with the maximal force variables in either sex. Instead it correlated significantly with the amount of physical activity. This may suggest that after retirement higher socio-economic status is associated with living habits that enhance the maintenance of better functional capacity.

The determination coefficients of the models were relatively high: 59% among the men and 55% among the women. It was concluded that indicators of health status and level of everyday physical activity were the most important variables explaining variation in maximal force.

However, a considerable amount of the variation observed in the force factors was not explained by the models. There would seem to be other factors involved in determining the variation in maximal strength. Genetic influence on strength has been found to be marked. According to a study of twins by Pérusse et al. (1987) of 1630 subjects from 375 families, biological inheritance had greater effect on muscle strength than on the other physical fitness components, explaining 30% of the variation in strength. The study by Reed et al. (1991) among 127 pairs of male identical twins and 130 pairs of male fraternal twins suggested that the estimate of hereditability was 65% for grip strength adjusted for significant effects of weight, height, age, fatness, muscle mass and frame size.

The contribution of psychological factors to the decline and variation of strength with age is difficult to evaluate. According to a review of the literature by Holloway & Baechle (1990), the beliefs and expectations individuals have about their behaviours, including the ability to perform feats of strength, are powerful determinants in performance. The elderly may be unfamiliar with the meaning of maximal strength performance or consider it improper for their sex or age, as strength is usually associated with masculinity and youth. Consequently, older people may be more reluctant to participate in all out strength measurements. These learned, psychological factors may be limiting factors in the expression of maximal strength. Lack of motivation or fear of overstrain may result in a decreased neural drive, altering the recruitment of motor units and force production (Frontera & Meredith 1989).

6.2 Strength and mobility

Body weight-related maximal isometric strength showed a significant positive association with mobility among 75-year-old residents of Jyväskylä (V).

The majority of participants were mobile, they were able to get out of bed or a chair, walk about indoors and outdoors in good and poor weather, and negotiate stairs independently. However, a large proportion of them experienced reduced speed or tiredness afterwards as a reaction to such tasks. Reduced speed and tiredness were consistently associated with lower strength in both sexes.

Maximal isometric strength correlated significantly with maximal walking speed among both sexes, which accords with the results of Fiatarone et al. (1990). Also, in a study by Bassey et al. (1988), maximal isometric plantar flexion strength was found to correlate with customary walking speed among men and women aged 65 years and over.

In the present study the stair-mounting performance was more strongly associated with strength among the women than the men. Some of this difference may be explained by the smaller body height of the women. Climbing performance is associated among other things with the length of the lower extremities. In the current study the results of the women were normally distributed, indicating that the scale used was suitable for discriminating their climbing capacities. However, among the men the "ceiling-effect" was observed, probably due to greater body height and knee extension strength. The test was too "easy" with 76% of the participants managing the highest step. If higher steps had been tested among the men the results might have been more evenly distributed, and a stronger association between strength and climbing capacity observed.

Also, the correlations between strength and walking speed were stronger for the women than the men. To look at the associations in more detail two groups were formed: 1) those with good mobility, who were represented by persons who experienced no difficulty in climbing stairs, and 2) those with impaired mobility, who were represented by participants who experienced reduced speed or tiredness while negotiating stairs. The correlations were greater among the groups with difficulties in mobility, which is in accordance with the suggested curvilinear association between functional status and strength (Buchner et al. 1991) and also provides indirect support for the existence of strength thresholds as suggested by Young (1986).

Moreover, a greater proportion of women may be near the strength threshold for stair mounting or adequate walking speed because of the lower average strength among the females. Muscle weakness may be a more common reason for poor mobility among women than men. Consequently, in particular the older women would benefit from strength training.

According to the present study, isometric measurements provide useful information about a person's ability to move.

6.3 Methodological issues

Participation

In the NORA 75 -study (I) some differences in participation rates which may affect the generalizability of the findings, existed between the localities. In Gothenburg the participation rate for the laboratory examinations was lower (67%) than in Glostrup (76%) and Jyväskylä (77%). The drop-out may be selective, e.g. in Jyväskylä the participants rated their locomotive ability as good more often than the drop-outs. Consequently, the greater drop-out rate in Gothenburg may mean a relatively fitter group of participants. However, the most usual reason given in Gothenburg for not participating was 'too healthy'; these persons felt no need for a medical check-up. On the other hand, of the 298 persons who entered the laboratory in Gothenburg 41 were excluded from the strength tests due to medical contraindications. Assuming similarity in the prevalence of medical contraindications to strength tests in the three localities, the interpretation of the criteria for excluding subjects seemed to be stricter in Gothenburg. The corresponding figures were 5/410 in Glostrup and 5/295 in Jyväskylä. These two facts may have led to a relatively healthier test group in Gothenburg.

In Jyväskylä (II, V) the home-interview was carried out among 92% of the 75-year-old population, and in five cases a proxy-interview was performed. The participation rates for both sexes in the laboratory tests were also relatively high (81% for men and 75% for women). Persons needing help or unable to perform the mobility functions were more common among the strength test drop-outs than participants. Even though transportation was arranged, those with the poorest mobility in particular failed to attend the laboratory tests. The current results should therefore be considered representative of mobile 75-year-old persons only.

Besides concentrating on population samples, more extreme discretionary groups were also chosen for study (III, IV). The benefit of such designs is that enough subjects with the desired characteristics can be expected to participate. For example, physically very active elderly women are rare; among the 75-year-old population of Jyväskylä no veteran athletes were located. Therefore, answers to questions which cannot be found doing population-based samples may be found by more discrete sampling methods. The problem is that highly active older persons may also differ from their controls in many other respects, such as education, health status and psychological factors. In the study of 50-60-year-old women educational background was controlled so that no differences in that respect occurred. Among the 66-85-year-old women a greater proportion of the veteran athletes had secondary education in comparison to the control group. Psychological factors were not studied here.

The association between strength and physical exercise was studied among women with life-long physically active way of life. The elderly group of trained women (age range 66-85 years, average exercise history 50 years) was recruited from among the veteran members of Finnish sports organisations (III). The 50-60-year-old women were recruited from women's gymnastics clubs and the Association of Physical Education Teachers (IV). The physical activities of the control groups were similar to those of the general population of their age, consisting of domestic tasks, home gymnastics, walking and outdoor recreation (Laakso 1986). Their participation rate in the older control group was 59% and in the middle age group the corresponding figure was 50%. However, no differences in the occupations between participants and drop-outs were observed.

The groups selected on the basis of their educational background were compared among the 50-60-year-old women (IV). Among Finnish middle-aged women university graduates constitute an elite with good economic resources. For example, in the current study personal monthly income among the graduates was twice as high as among the less educated groups. The heterogeneous group with vocational or lower education represented the average middle-aged woman.

Strength measurements

Considerable effort was made to standardize the measurements in each locality in the NORA 75 project. The test equipment was transported from one locality to the other two. The testers had to be different in each locality for language reasons, and despite tutoring, differences in carrying out the tests may have persisted. However, the strength testers were tutored by the same person (Dr. P Era), who spent one week in each laboratory in the interest of standardizing the situation-oriented factors, such as instructions, motivation and previous activity as well as measurement techniques. The differences between the populations were not identical for all the muscle groups studied. The women from Glostrup yielded the best values for limb muscles and the poorest values for trunk muscles.

The strength measurements among the 50-60-year-old women and the 66-85-year-old women were performed using the same equipment except for a minor modification in respect to the hand grip force test. Consequently, the elbow flexion, knee extension and trunk flexion and extension force test results may in these two studies be considered comparable.

Isometric strength testing does not, of course, provide information about force production across the entire range of motion in a joint. However, it has been observed to be a good indicator of the ability of the knee extensors to emit torque throughout the range of motion in healthy and injured knee joints (Kannus & Järvinen 1990).

Other measurements

Work history was studied using a retrospective interview technique (II). In a situation like this, one can argue about the preciseness of the memory of the subjects. Work is, however, one of the major determinants of a person's everyday living. It can be assumed, therefore, that at least the main jobs were accurately remembered. The participant was asked to tell about her previous jobs which had included lifting or moving heavy objects. In an interview like this, the criteria of the heaviness of a job is, in the end, subjective and based on the subject's perception of the demands of the work in relation to her capacities.

The amount of physical activity was measured by a scale developed and validated by Grimby (1986) and modified by Mattiasson-Nilo et al. (1990). That score describes person's general level of everyday activity. Tasks that would have an effect of maximal strength were not specified.

The questionnaires used were mainly based on experience from previous studies performed in Glostrup, Gothenburg and Jyväskylä.

6.4 Main findings

The study was based on cross-sectional designs. Conclusion on causal relations cannot therefore be drawn.

1. Significant differences in strength levels existed between men and women living in different localities partly owing to differences in basic anthropometric characteristics.

2. Good self-rated health correlated with greater strength. The association between diseases and strength remained somewhat unclear, and seems to be different for men and women. Among the 75-year-old women the existence of chronic diseases as such was not associated with decreased strength. Among the men multimorbidity was connected with lower strength.

3. The selected individuals with life-long histories of physical exercise were observed to obtain greater values than their more sedentary counterparts. However, the ordinary physical activity performed in everyday life like domestic work and gardening also correlated positively with strength in nonselected population.

4. A history of heavy work was not associated with maximal strength among retired women.

5. Maximal isometric strength tests can be performed safely among nonselected elderly populations. The results of the body weight-related strength tests were found to be useful indicators of the locomotor abilities of the older persons.

6.5 Future research

At the moment only a limited number of studies on the age-changes in maximal strength exist. The cross-sectional analyses performed here suggest that it would be of interest to locate people with increasing, stable or decreasing strength in older age using follow-up designs. Investigating the factors associated with these conditions, like changes in health or exercise habits, would provide valuable information for the planning of preventive and rehabilitation programs to counteract premature frailty in old age. Experimental studies would then go on to provide more information dealing with the associations between health and strength. For example, training studies or follow-up studies among persons with specific diseases would be useful.

The association between maximal isometric strength and mobility would also be worth studying in more detail. For example, strength training as a method of improving mobility among elderly persons with limited capacities could provide new approaches to the care of this section of the population.

SUMMARY

Muscle strength has been observed to decrease with age. Disability in motor activities also becomes more common at higher ages. Moreover, the proportion of older people in Western societies has increased. An important issue for elderly individuals as well as for the health care system is the level of independent functioning a person is capable of in everyday life. A certain amount of muscle force and power are necessary for the performance of motor tasks such as rising from a seated position or climbing stairs. Many older persons live below, at, or just above the threshold of capacity needed to accomplish such tasks. Cross-national interview studies have indicated differences between the functional abilities of older people living in different localities. However, functional capacities have never been measured clinically in a cross-national design.

The purpose of this research was to study the levels of maximal isometric strength in representative population samples as well as to assess the background factors of strength. 75-year-old men and women were studied in three Nordic localities (Glostrup, Denmark; Gothenburg, Sweden; and Jyväskylä, Finland) to compare strength levels and anthropometric characteristics between populations (I). Socio-economic status, health and everyday physical activity as background factors of maximal strength were then studied among the 75-year-old residents of Jyväskylä (II). The association between life-long physical exercise, educational background and work history with strength were investigated in specially selected groups of women aged 50-60-years (IV) and 66-85 years (III). The maximal isometric strength test results as indicators of physical functioning among the elderly were studied by looking at the

associations between maximal isometric strength and mobility in everyday life (V).

Maximal isometric strength of hand grip, elbow flexion, knee extension, trunk flexion and extension were measured with the aid of specially constructed dynamometers. Body weight and height were measured using conventional methods. Body composition was estimated from the sum of skinfolds, or measured using the biolectrical impedance method. Information about physical activity, education, occupation, work history, self-rated health, musculoskeletal symptoms and mobility was elicited with the help of questionnaires and interviews. The studies also included standardised tests on maximal walking speed and stair mounting.

The population samples included 75-year-old residents of the city of Jyväskylä during 1989 (295 participated in laboratory tests, which is 77%), and random samples of the 75-year-old residents of Gothenburg (298, 67%) and Glostrup (410, 76%). In addition, 112 50-60-year-old and 92 66-85-year-old women selected on the basis of their physical exercise levels or educational backgrounds took part in the studies. Prior to the strength tests contraindications were evaluated by a physician. Altogether, 1113 individuals took part in the maximal isometric strength tests.

Significant differences in the strength and anthropometric variables were observed between the 75-year-olds in Glostrup, Gothenburg and Jyväskylä (I). The men and women from Glostrup exhibited greatest force in the limb strength tests expressed both in absolute and body weight-related units. They also had the lowest body fat content and greatest lean body mass. Lean body mass was also the most significant correlate of maximal strength within each locality. Among the men the trunk forces did not differ between the residents of the three localities. However, among the women, those from Jyväskylä showed the best results in the trunk strength tests. At the same time they were also shorter than the other women and had a greater body mass index. The body mass index was correlated significantly with, in particular, the trunk flexion test values.

Health as a modulator of strength was studied among the 75-year-old men and women resident in Jyväskylä (II). Poorer values in the state-of-health indicators (number of chronic diseases, index of musculoskeletal symptoms, and self-rated health) correlated with low elbow flexion and trunk forces among the men. Among the women bad self-rated health correlated with inferior values in all the tests, whereas number of chronic diseases and index of musculoskeletal symptoms correlated negatively with trunk extension strength only. Among the women no differences were observed in the strength test results between the healthy individuals (no diagnosed diseases) and those having a disease of the cardiovascular, musculoskeletal or nervous system or a combination of these.

The association of physical exercise with maximal isometric strength was studied by comparing the results of 50-60 (IV) and 66-85 year-old women (III) selected on the basis of their life-long history of physical exercise with corresponding sedentary control groups. The middle-aged and elderly active women exhibited greater absolute and body-weight-related force values than their sedentary controls. The relative strengths of elbow flexion, knee extension and trunk flexion and extension of the older active women were roughly on the same level as those of their sedentary counterparts twenty years younger.

Significant correlations between everyday physical activity and strength were also observed among the 75-year-old residents of Jyväskylä (II).

Among the 50-60-year-old women, those with a university level educational background exhibited greater results in the strength tests even after controlling for level of physical activity. Among the 75-year-old men and women educational background was not associated with strength.

The association of history of heavy work with strength was studied among trained women aged 66-85 and a corresponding population sample (III). The number of years of heavy work correlated positively with trunk extension force in the population sample, whereas among the trained women no such association was evident. However, two-way analyses of variance revealed no significant effects of work history on strength.

Because of the intercorrelation between the background factors, the simultaneous connections of socio-economic status, physical activity and health with strength were studied with the aid of multivariate structural equation models (LISREL VI) among the 75-year-old residents of Jyväskylä (II). The maximal force test results were condensed into limb and trunk force factors. The amount of everyday physical activity was positively associated with the force factors in both sexes. Among the men a smaller number of chronic diseases but not self-rated health correlated with greater trunk strength. Among the women the situation was vice versa: self-rated health was positively associated with trunk force. The multivariate analyses suggested the existence of some differences in the associates of strength as compared to the univariate analyses. This was probably due to strong intercorrelations within the independent variables. If two independent variables are correlated an effect may be transmitted through one or the other.

The association of maximal isometric strength with mobility was studied among the 75-year-old residents in the city of Jyväskylä (V). Those who rated their locomotor abilities as good (no difficulties in transferring from chair or bed, walking indoors or outdoors in good or poor weather or negotiating stairs) manifested better strength in all the tests. Greater strength was also connected positively with maximal walking speed and stair mounting capacity among both sexes.

These results suggest that maximal isometric strength tests can be performed safely among nonselected elderly populations. Significant differences in strength levels existed between men and women living in different localities partly owing to differences in basic anthropometric characteristics. The selected individuals with life-long histories of physical exercise were observed to obtain greater values than their more sedentary counterparts. In fact, the weight-adjusted results of the physically active older women were on the same level as the results of the sedentary women about 20 years younger. However, the ordinary physical activity performed in everyday life like domestic work and gardening also correlated positively with strength. Good self-rated health correlated with greater strength. The association between diseases and strength remained somewhat unclear; among the 75-year-old women the existence of chronic diseases as such was not associated with decreased strength. A history of heavy physical work was not associated with strength among retired women. The results of the body-weight-related strength tests were found to be useful indicators of the locomotor abilities of the older persons.

TIIVISTELMÄ

Lihasvoiman on todettu heikkenevän iän myötä. Samalla liikkumisongelmat yleistyvät. Myöskin iäkkäiden ihmisten osuus väestöstä on lisääntynyt länsimaissa. Keskeinen seikka ikäihmiselle itselleen sekä terveydenhoitojärjestelmälle on, miten itsenäisesti henkilö suoriutuu jokapäiväisistä tehtävistä. Tavanomaisiin motorisiin toimintoihin, kuten tuolilta nousuun tai portaissa liikkumiseen, tarvitaan tietty määrä lihasvoimaa. Monien vanhojen ihmisten lihasvoima on lähellä kynnystasoa, jonka alapuolella suorituskyky ei enää riitä. Haastattelututkimuksissa on todettu eroja eri maissa asuvien ihmisten toimintakyvyssä. Eri maissa asuvien iäkkäiden miesten ja naisten toimintakyvystä ei kuitenkaan ole tähän mennessä ollut saatavissa kliinisiin mittauksiin perustuvaa vertailukelpoista tietoa.

Tämän tutkimuksen tarkoituksena oli verrata kolmella eri paikkakunnalla (Glostrupissa Tanskassa, Göteborgissa Ruotsissa, ja Jyväskylässä Suomessa) asuvien 75-vuotiaiden miesten ja naisten isometrisen maksimivoiman tasoja sekä antropometrisia ominaisuuksia (I). Kullakin paikkakunnalla tavoitteena oli edustava väestöotos. Sosioekonomisen aseman, terveyden ja fyysisen aktiiviisuuden yhteyksiä maksimivoimaan tutkittiin 75-vuotiailta jyväskyläläisiltä (II). Elinikäisen liikuntaharrastuksen, koulutustaustan ja työhistorian merkitystä isometriseen maksimivoimaan tutkittiin harkinnanvaraisesti valittujen 50- 60- (IV) sekä 66-85-vuotiaiden naisten keskuudessa (III). Lisäksi isometristen maksimivoimamittausten tuloksia verrattiin liikkumiskykytesteissä saatuihin tuloksiin (V).

Tutkimuksen kohderyhminä olivat kaikki vuonna 1989 Jyväskylässä kirjoilla olleet 75-vuotiaat (295 osallistui eli 77 % kutsutuista), sekä satunnaisesti valitut otokset Göteborgin (298, 67 %) ja Glostrupin (410, 76 %) 75-vuotiaista asukkaista. Lisäksi tutkimuksiin osallistui 112 50-60-vuotiasta ja 92 66-85-vuotiasta naista, jotka valittiin liikunta-aktiivisuutensa tai koulutustaustansa perusteella. Ennen voimamittauksia lääkäri arvioi mahdolliset vasta-aiheet. Yhteensä 1113 henkilöä osallistui testeihin. Maksimaalinen isometrinen käden puristusvoima, kyynärvarren koukistusvoima, polven ojennusvoima sekä vartalon ojennus- ja koukistusvoima mitattiin erityisvalmisteisilla dynamometreillä. Pituus ja paino mitattiin tavanomaisesti. Kehon koostumus arvioitiin ihopoimumittausten tai biolektristen impedanssimittausten perusteella. Fyysisestä aktiivisuudesta, koulutuksesta, ammatista, työhistoriasta, koetusta terveydestä, tuki- ja liikuntaelinten oireista sekä liikkumiskyvystä kerättiin tietoa haastattelemalla sekä kyselomakkeilla. Kävelynopeutta ja portaalle nousukykyä mitattiin standardoiduilla testeillä.

Isometrisessa maksimivoimassa sekä antropometrisissa ominaisuuksissa havaittiin tilastollisesti merkitseviä eroja Glostrupin, Göteborgin ja Jyväskylän 75-vuotiaiden asukkaiden välillä (I). Raajojen voimamittauksissa glostrupilaiset miehet ja naiset saivat parhaat tulokset sekä absoluuttisina että painoon suhteutettuina yksikköinä ilmaistuna. Heillä oli myös matalin kehon rasvaprosentti ja suurin rasvaton kehon paino. Rasvaton paino oli tilastollisesti merkitsevin maksimivoiman korrelaatti kaikilla paikkakunnilla. Eri paikkakunnilla asuvien miesten välillä ei havaittu vartalovoimissa eroja. Sen sijaan jyväskyläläiset naiset olivat vahvimpia vartalon voimiltaan. He olivat myös lyhyempiä kuin muiden paikkakuntien naiset ja heillä oli suurin kehon massaindeksi. Kehon massaindeksi korreloi merkitsevästi erityisesti vartalon koukistusvoiman kanssa.

Terveyden yhteyttä maksivoimaan tutkittiin 75-vuotiailta jyväskyläläisiltä (II). Miehillä huonot arvot terveysindikaattoreissa (kroonisten sairauksien lukumäärä, tuki-ja liikuntaelinten oireindeksi ja koettu terveys) olivat yhteydessä heikkoon kyynärvarren koukistusvoimaan sekä huonoihin vartalovoimiin. Naisilla terveyden kokeminen hyväksi oli yhteydessä hyviin tuloksiin kaikissa voimamittauksissa, kun taas kroonisten sairauksien lukumäärä ja oireindeksi olivat yhteydessä ainoastaan vartalon ojennusvoimaan. Verrattaessa terveiden naisten (ei diagnosoitua sairautta) voimatuloksia niihin, joilla oli sydän- ja verenkiertoelimistön, tuki- ja liikuntaelimistön tai hermoston sairaus tai jokin näiden yhdistelmä, ei havaittu tilastollisesti merkitseviä eroja.

Ikänsä liikuntaa harrastaneiden 50-60-vuotiaiden (IV) ja 66-85-vuotiaiden (III) naisten maksimivoimat olivat merkitsevästi paremmat kuin vastaavanikäisten vertailuryhmän naisten. Lisäksi 66-85-vuotiaiden liikuntaa harrastavien naisten painoon suhteutetut maksimivoimat olivat suunnilleen samanlaiset kuin passiivisten keskimäärin 20 vuotta nuorempien naisten.

Myöskin runsas tavanomainen fyysinen aktiivisuus, esimerkiksi kotitöiden tekeminen ja kävely, korreloi hyvien maksimivoimien kanssa valikoitumattomassa väestössä (II).

Yliopistotasoisesti koulutettujen 50- 60-vuotiaiden naisten todettiin olevan voimakkaampia kuin vastaavanikäisten vähemmän koulutusta saaneiden naisten, vaikka liikunta-aktiivisuuden määrä vakioitiin (IV). Sen sijaan 75-vuotiailla koulutustausta ei ollut yhteydessä lihasvoimaan (II).

Raskaan ruumiillisen työn yhteyttä lihasvoimaan tutkittiin 66-85-vuotiailla liikuntaa harrastavilla naisilla sekä vastaavassa kontrolliryhmässä (III). Raskaiden työvuosien lukumäärä korreloi positiivisesti vartalon ojennusvoiman kanssa kontrolliryhmässä, mutta liikunnan harrastajilla yhteyttä ei ollut. Kun asiaa tutkittiin tarkemmin kaksisuuntaisella varianssianalyysillä, työhistorian ja lihasvoiman välillä ei havaittu yhteyttä.

Koska käytetyt taustatekijät korreloivat keskenään, sosio-ekonomisen aseman, terveyden ja fyysisen aktiivisuuden samanaikaisia yhteyksiä tutkittiin monimuuttujamenetelmällä eli muodostamalla lineaarisia rakenneyhtälömalleja (LISREL VI). 75-vuotiaiden jyväskyläläisten maksimivoimatulokset tiivistettin raaja- ja vartalovoimafaktoreiksi (II). Malleissa runsas fyysinen aktiivisuus oli positiivisesti yhteydessä voimafaktoreihin sekä miehillä että naisilla. Miehillä kroonisten sairauksien vähäisyys oli yhteydessä hyviin vartalovoimiin, mutta koetun terveyden ja voimafaktoreiden välillä ei ollut yhteyttä. Naisilla tilanne oli päinvastainen: hyvä koettu terveys liittyi vartalon hyvään voimakkuuteen, mutta kroonisten sairauksien ja voiman välillä ei ollut yhteyttä. Monimuuttujamenetelmällä analysoiden havaittiin maksimivoimaa selittävissä tekijöissä eroja yksisuuntaisilla analysointimenetelmillä saatuihin tuloksiin verrattuna. Syynä saattaa olla taustatekijöiden voimakas keskinäinen korrelaatio, jolloin yhteys voi välittyä kumman tahansa tekijän kautta. Toisaalta selityksenä voi olla miesten ja naisten erilainen sairastavuus.Isometrisen maksimivoiman ja liikkumiskyvyn yhteyttä tutkittiin 75-vuotiailla jyväskyläläisillä (V). Ne, jotka arvioivat liikkumiskykynsä hyväksi (ei vaikeuksia vuoteesta tai tuolista siirtymisessä, liikkumisessa sisällä ja ulkona hyvällä tai huonolla säällä tai portaiden nousemisessa), saivat voimamittauksissa parempia tuloksia kuin ne, jotka kokivat vaikeuksia liikkumisessaan. Myös kävelynopeus ja portaalle nouseminen olivat positiivisesti yhteydessä isometriseen maksivoimaan.

Glostrupissa, Göteborgissa ja Jyväskylässä asuvien miesten ja naisten välillä oli merkitseviä voimakkuuseroja, mitkä osittain selittyivät antropometristen ominaisuuksien erojen perusteella. Ikänsä liikuntaa harrastaneiden naisten todettiin olevan voimakkaampia kuin naisten, jotka eivät erityisesti harrastaneet liikuntaa. Itse asiassa 66-85 -vuotiaiden veteraaninaisurheilijoiden todettiin olevan suunnilleen yhtä voimakkaita kuin keskimäärin 20 vuotta nuoremmat liikunnallisesti passiiviset naiset. Valikoitumattomassa väestössä myös runsas tavanomainen fyysinen aktiivisuus sekä hyväksi koettu terveys olivat yhteydessä hyvään lihasvoimaan. Kroonisten sairauksien ja lihasvoiman yhteys jäi hieman epäselväksi: terveiden 75-vuotiaiden naisten lihasvoima ei poikennut kroonisia sairauksia sairastavien naisten lihasvoimasta. Raskaan ruumiillisen työn tekeminen ennen eläkeikää ei ollut yhteydessä lihasvoimaan iäkkäillä naisilla. Tämä tutkimus osoitti, että isometrisiä maksimivoimamittauksia on mahdollista turvallisesti tehdä valikoitumattomille, suhteellisen korkean iän saavuttaneille ihmisille, ja että painoon suhteutetut testitulokset ovat hyödyllisiä liikkumiskyvyn indikaattoreita.

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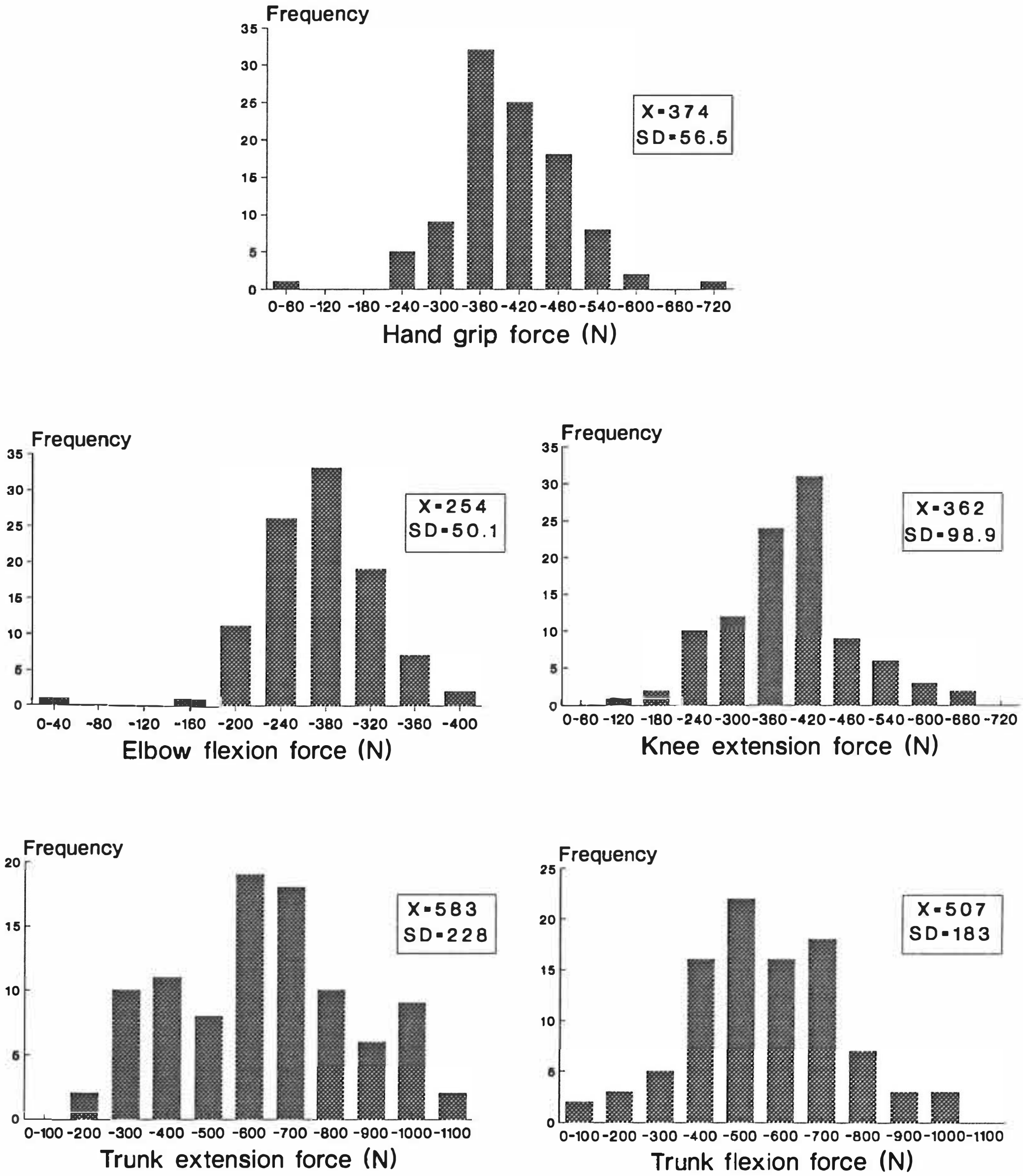
APPENDIX 1

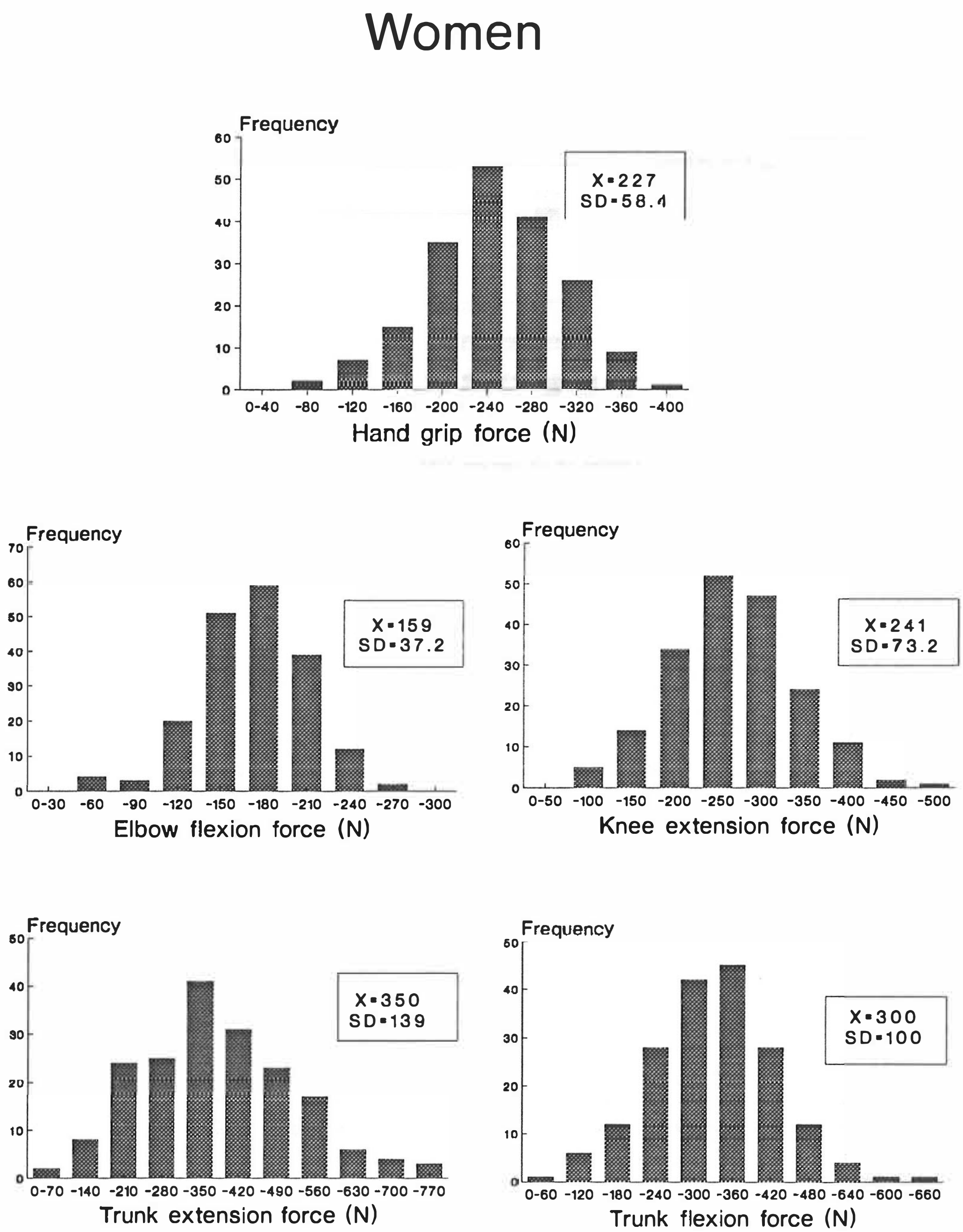
Appendix 1. The distribution of the strength test results in 75-year-old men (101-95) living in Jyväskylä.

Men



APPENDIX 2

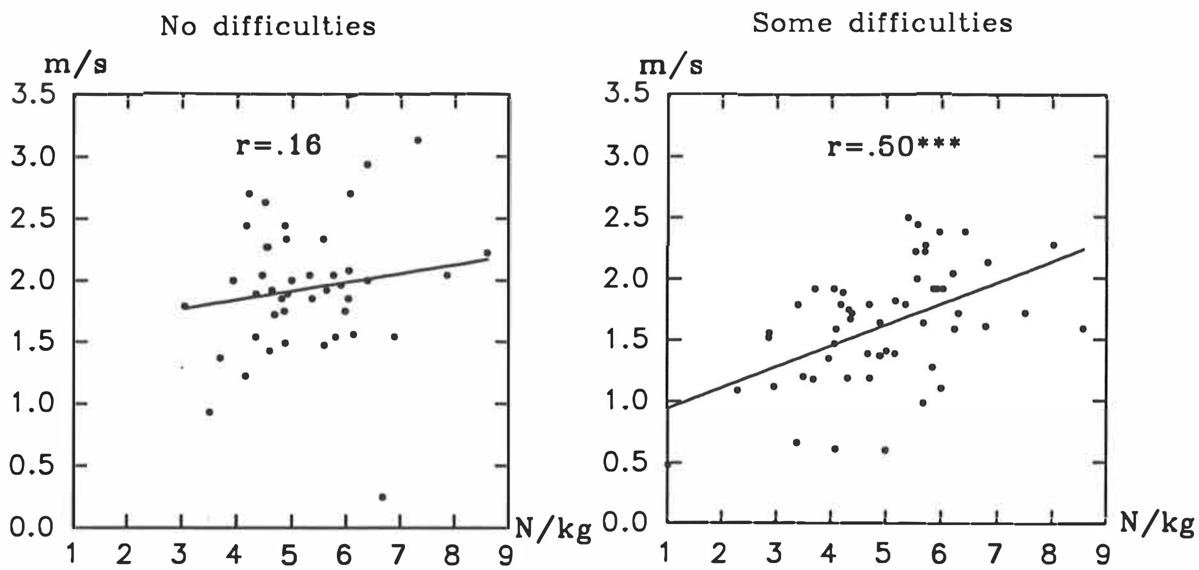
Appendix 2. The distribution of the strength test results in 75-year-old women (178-186) living in Jyväskylä.



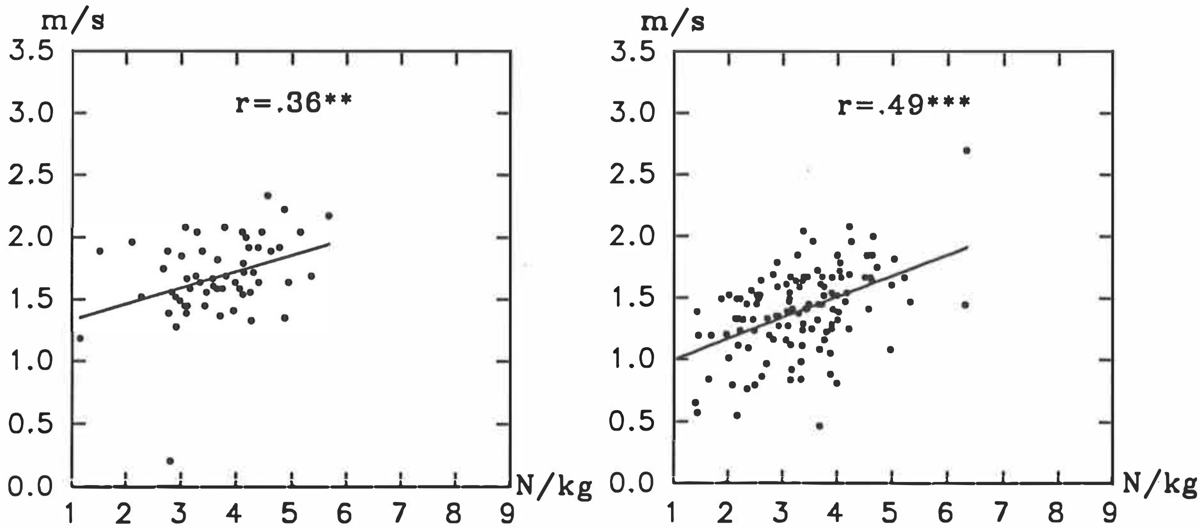
APPENDIX 3

Appendix 3. The relationship between maximal walking speed and body-weight-related maximal isometric hand grip force among 75-year-old men and women grouped according to their mobility.

Men



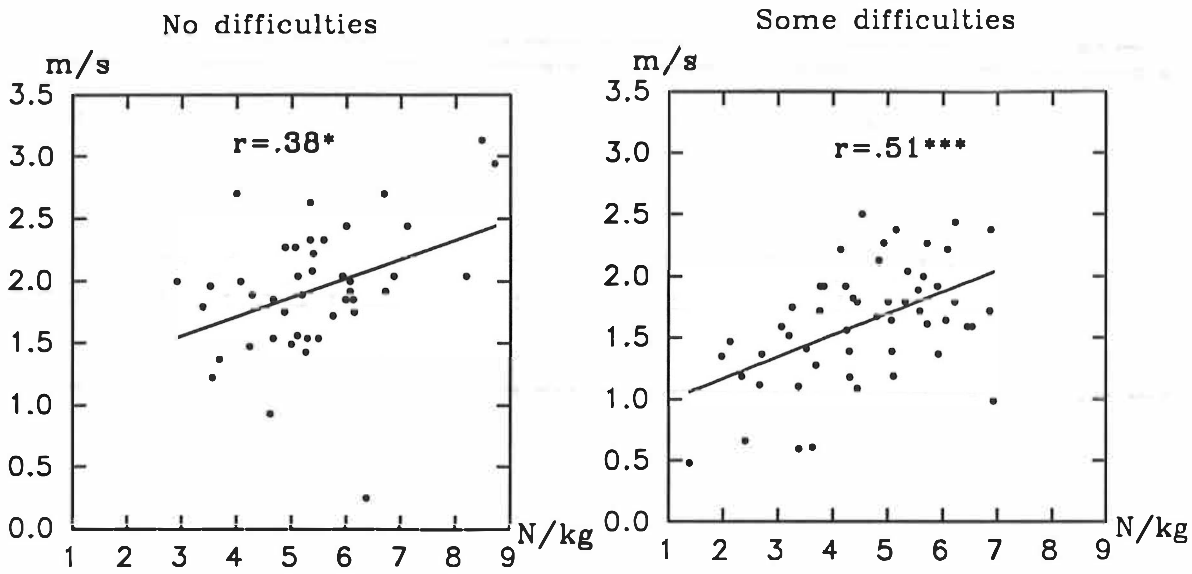
Women



APPENDIX 4

Appendix 4. The relationship between maximal walking speed and body-weight-related maximal isometric knee extension force among 75-year-old men and women grouped according to their mobility.

Men



Women