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Muscle function in old age with special reference to muscle morphology, effect of training and capacity in activities of daily living

Amelie Aniansson

Göteborg 1980

MUSCLE FUNCTION IN OLD AGE WITH SPECIAL REFERENCE TO MUSCLE MORPHOLOGY, EFFECT OF TRAINING AND CAPACITY IN ACTIVITIES OF DAILY LIVING

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av

Amelie Aniansson

This thesis is based on the following papers,

I. Aniansson, A., Rundgren, Å. & Sperling, L.: Evaluation of functional capacity in activities of daily living in 70-year-old men and women. Scand J Rehab Med. Accepted to publication.

II. Aniansson, A., Grimby, G. & Rundgren, Å.: Isometric and isokinetic quadriceps muscle strength in 70-year-old men and women. Scand J Rehab Med. Accepted to publication.

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ABSTRACT

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Amelie Aniansson, Dept. of Rehabil. Med. I, Sahlgren's Hospital, S-413 45 Göteborg, Sweden.

Seventy-year-old men (n=195) and women (n=229) systematically selected from a population study were investigated with the aims to delineate their functional capacity in some essential activities of daily living (ADL). The performance in the different ADL-functions in the subjects was relatively well preserved in the movements ofimportance for hygiene and dressing activities and practical basic functions in the home. Regarding important ADL-functions outside the home, such as crossing the street at signalized intersections or using public transport, it appeared that even 70-year-olds had considerable problems.
Representative reference values for isometric and isokinetic quadriceps muscle strength are presented in "healthy" 70-year-old men (n=40) and women (n=32). Quadriceps muscle strength in women was on average 56% of that in men. The force-velocity showed a parallel decrease in peak torque values with increasing velocity in both sexes. Equations for calculation of normal values from the individuals' body height and weight are given.
Fifty-two men and 13 women in the seventies and apparently healthy without locomotor disturbances were investigated to obtain further information on muscle morphology and the importance of different variables for the muscle force in that age. The body cell mass correlated highly to muscle strength. The Type I and the Type II fibre composition as well as capillarization were fairly similar in the sexes and compared with younger groups.
The reduction in Type II fibre size and the lack of correlation between muscle strength and Type II fibre area compared with younger groups point to some loss of the functional importance of Type II (fast twitch) fibres in the elderly. The lack of more pronounced neuropathic changes speaks against a denervation process as a major cause of muscle strength decline with age. The enzymatic (Mg^{2+} ATPase, myokinase and LDH) and the phosphagen (ATP and CP) content values did not differ between the sexes and no correlations were found between these variables and muscle strength.
To investigate the effect of physical training on muscle strength and muscle fibre composition and area, 12 of the men, all untrained, participated in physical training, including strength training of the lower extremities for 45 min., three times a week for 12 weeks. Isometric and isokinetic quadriceps muscle strength increased significantly, as did the Type II A fibre proportion and relatively Type II A fibre area and myokinase activity. Heart rate decreased at submaximal loads, indicating an improvement of the cardiovascular function. There was no change in body cell mass or capillarization. The results indicate that the human muscle remains trainable at least into the seventies. The decline in muscle strength might at least up to that age, be due to a combined effect of inactivity and aging.

Key words: Muscle strength, quadriceps, isokinetic, muscle morphology, physical training, activities of daily living testing, elderly people.

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ERRATA

p 11,Fig I: The figures in the first drop-out squares should be corrected to 37 and 57 for males and females respectively.
p 12, line 7 and 10: for "randomly" read "systematically".
p 16, line 10: delete "out".
p 20, bottom line: Add after analyses: The tests of paired observations were performed by use of a linear, nonparametric permutation test for paired observations (Bradley, 1968).
p 21, line 17: Add: "In this study all but one subject could climb up and down a 40 cm step....." etc.
p 30, after line 17: Add: "In this study of basal ADL-tasks the greatest reduction....." etc.
p 31, line 29: "In this" should be followed by "study".
p I: 3, Fig I: The figures in the first drop-out squares should be corrected to 37 and 57 for males and females respectively.
p I: 4, lines 6 and 7: For 39 (17.0%) read 37 (16.3%) and for 54 (19.1%) read 57 (19.9%).
p I: 5, Table II: The figures , reading from top to bottom should be 16, 161, 13 and 0 in the male column and 36, 189, 1 and 0 in the female column.
p I: 5, lines 17 and 18: "of the examining physician had clinical contra-indications participation" should be deleted.
p I: 9, line 10: Delete "cut".
p I: 15, Table V: For 73 in the male column read 72.
p II: 9, Table V a: Delete the minus sign before the constant 30, 77.
p II: 10, line 3: "Table I" should read "Table I a".
p II: 13, line 22: For "that" read "than".
p III: 4, line 35: For "standard error" read "methodological error".
p III: 6, line 4: Delete "and".
p III: 9, bottom line: For men read women.
p III: 10, line 1: For women read men.
p III: 10, line 5: Delete "0,001".
p IV: 7, line 5: For Type II read Type II B.
p IV: 9, Table III: Fig.text. For "μ moles x g^{-1}" read "μ moles x g^{-1} x min^{-1}".
p IV: 11, line 28: For "may be due to principally" read "indicate a major influence of".
p IV: 12, line 30: After "(Bass et al, 1969)" insert " increased significantly".

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To my husband Gunnar
and my children Helena,
Gustav, Johan, Per and Hans.

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CONTENTS

INTRODUCTION

The average length of life is increasing in Sweden according to demographic calculations (63) as is the number of persons in whom inactivity and different handicaps may necessitate rehabilitation measures. For the individual as well as society it is of great importance that people are able to lead an independant and active daily life in their old age.

As malfunction of the locomotor system usually makes people dependent on others, it seems essential to find out more about the function and trainability of the musculo-skeletal system in elderly people. Better knowledge about these factors would make it possible to take better care of the elderly and adapt the environment better to their needs. The value of physical training for prevention of unnecessary falls and fractures could also be elucidated. Furthermore, information about basal muscle function and the effect of physical training in muscles in the elderly would make it easier to provide adequate physicotherapy in connection with inactivity and disorders.

A decline in muscular performance with advancing age has been demonstrated in several studies (e.g. 6,25,44,74). A reduction in muscle mass has also been found (e.g. 2,64,73). The decline in muscle strength with age may be due to primary aging of the skeletal muscle, but also to secondary changes induced in muscle by aging of other body systems, such as the nervous, vascular and endocrine systems. A reduction in physical activity with age may be another reason for the decline in muscle strength. Motivation of the subject to perform maximal effort must also be taken into account.

Representative reference values for muscle strength in the elderly are lacking. Such values should be based on as representative population samples as possible. The population study of 70-year-olds in Göteborg has provided an opportunity to obtain muscle strength values for representative "healthy" men and women of that age. The concept "healthy" is, however, difficult to define because it may not be easy to distinguish between symptoms and signs of aging processes per se and those of disease in elderly individuals.

Morphological changes in skeletal muscle in elderly persons have been reported (69,70) whereas changes before 60-70 years of age (45) appear more disputable according to results for various age-groups summarized by Aniansson et al. (5). Gutmann & Hanzlikova (29) proposed that the senile muscle atrophy combines features of both a decline in nerve-impulse activity, related to progressive disuse, a specific long-term neurotrophic disturbance resembling denervation in some functional respects ("functional denervation") and/or actual nerve atrophy which act relatively independent. Few morphological data are available in the literature with respect to elderly and especially female subjects. This study provides further information on morphological and enzymatic data in the elderly. The importance of these factors for the muscle force and differences in them between the sexes are also analyzed.

Present knowledge of physical performance and possible effects of physical training on muscle strength in elderly persons is sparse, whereas several studies have reported increase of the aerobic capacity with training (1,11,67). This investigation aims to give further information about the influence of physical training on age-related changes in muscle strength, and muscle morphology and its value as a preventive measure against disability and dependence on others. The ability to look after oneself is aspired after at all ages and not least by the elderly, and is important for peoples´ enjoyment of life. It might be easier to achieve if the functional needs of elderly people were given more consideration when planning housing as well as the surrounding physical environment. There is a general lack of information, however, about the functional capacity of the elderly in essential activities of daily living, such as basal ADL-functions, function in the kitchen, getting on and off public transport and the comfortable walking speed, with special reference to pedestrian crossings. In this study 70-year-old subjects from the population study are investigated with suitable methods for evaluation of ADL-functions and the results are correlated to muscle strength. By obtaining more information about the capacity in ADL-functions in the elderly it would be possible to create an environment which was better adapted to their needs.

AIMS

The aims of these studies were:

- to delineate the functional capacity in some essential activities of daily living (ADL) in seventy-year-old men and women representative of urban Swedish populations (I)
- to present muscle strength values in seventy-year-old men and women as representative as possible for the "healthy" population of that age (II)
- to obtain informations on muscle morphology and the importance of different variables for the muscle force in men and women in the seventies,without locomotor and neurological disturbances,who were also otherwise symptomless (III)
- to investigate the effect of physical training on muscle strength and muscle fibre composition and area in men aged 69-74 (IV)

SUBJECTS

All subjects were interviewed concerning previous occupational physical activity and previous and present leisure-time physical activity according to a formular by Saltin & Grimby (58) using four levels from low to high intensities (Groups I-IV). Each subject was informed about the procedure and the risks involved in the experiments before he agreed to participate. All the participants in the study underwent medical examination. The hypothesis used in the actual study for definition of disease is that reported by Svanborg (65,66).

PAPER I. The number of participants in the different tests and the drop-outs are described in Fig. 1. A systematic sample comprising 30 percent (1 281 subjects) of the 70-year-olds living in Göteborg in 1976/77 were invited to participate in the population study of "70-year-olds in Göteborg" (57,65,66). The method of sampling as well as the design and performance of the general study have been described by Rinder et al. (57). Forty percent of the total sample were systematically selected for the muscle function study. The subjects studied were considered to be representative of the general population of 70-year-olds in Göteborg. All probands were investigated in accordance with a broad social, psychological and medical programme in a standardized manner (57). Forty men and 32 women were free from signs and symptoms presented in Fig. 2. apart from minor locomotor disorders in the hands (62). These probands were called "healthy" in all tests including the lower extremities. The 20 men and 22 women defined as healthy in the tests of manual ability were without locomotor disorders in the hands also. These healthy subjects had good vision, with or without correction glasses. Concerning leisure-time physical activity during the last ten years, the subjects of both sexes belonged predominantly to the group which practised moderate physical activity (Group II) (58). Probands who, in the opinion of the examining physician, had clinical contraindications (Fig. 1) to participation in the quadriceps muscle strength study were excluded from this test, as well as from the manual ability test and step test which, for practical reasons, took place at the same time. All but about 4 percent, who lived in institutions, lived in their own homes. About 8 percent needed walking aids.

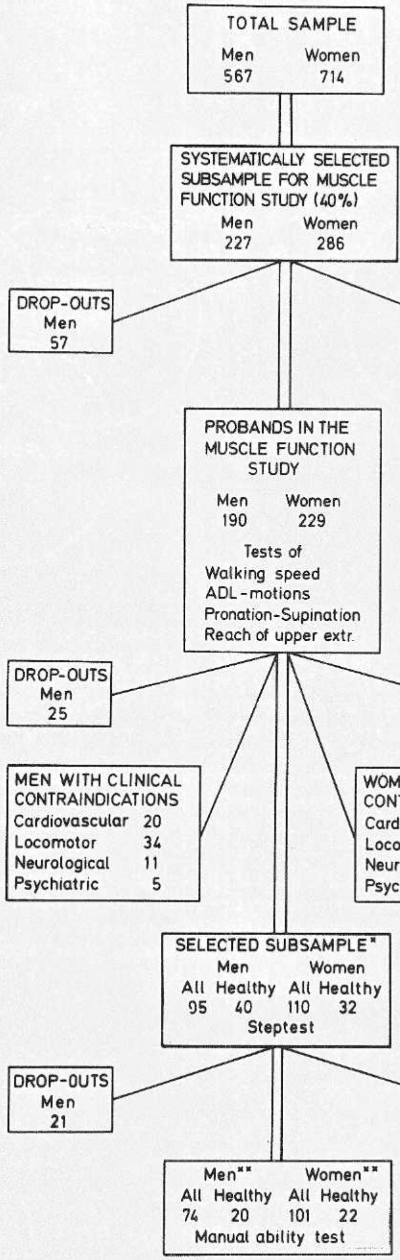

Fig. 1. Participants in the tests of muscle function

*Participated also in a test of muscle strength of M. quadriceps dx.

**Participated also in tests of muscle strength, endurance and coordination of the upper extremities

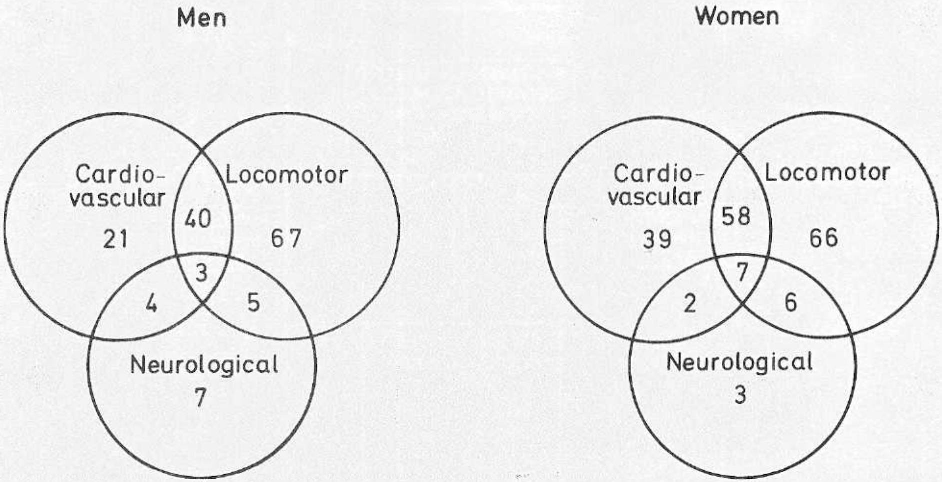

Fig. 2. Number of 70-year-old men and women in the systematically selected subsample participating in the muscle function study with cardiovascular, locomotor and/or neurological signs and symptoms. In addition, the following symptoms and signs were found: Anaemia Hb <120 g/l (men: n=7, women: n=12), bronchopulmonell disease (men: n=35, women: n=30), treated cancer (men: n=8, women: n=15), treated diabetes mellitus (men: n=17, women: n=12), partial gastric resection (men: n=20, women: n=13). In total were 190 men and 229 women investigated.
Definitions: Cardiovascular (arrhythmia, chest pain, congestive heart failure, treated hypertension, calf pains), locomotor (joint and lower back pains, amputees), neurological (central peripheral paresis, transitory ischaemic brain attack, rigidity, coarse-wave tremor, treated Mb. Parkinson).

PAPER II. The material comprised the healthy group of 40 men and 32 women (Fig. 1) who were completely free from any locomotor disorders in the lower extremities, described in and recruited from the population study "70-year-old people in Gothenburg" 1976/77 (57,65,66). The examined subjects did not differ with respect to body height, weight or physical activity during leisure-time from the rest of the randomly selected sample (I). All except one women and two-fifths of the men had had physically light work since their forties at least (Groups I-II) (58), in accordance with the rest of the randomly selected sample (I, unpublished results).

PAPER III. Fifty-two men (66-76 yrs)and 13 women (67-71 yrs), partly recruited from the selected subsample from the population study "70-year-old people in Gothenburg" 1976/77 (57,65,66) described in Paper I (Fig. 1) and partly from a pensioners´ club, volunteered to participate in the study. The intention was originally to recruit all participants from the population study but most people asked did not want to be biopsied. The participants were found to be without functional locomotor disturbances. Seven men (but no women) used antihypertensive and/or heart-regulating drugs but were symptomless. Apart from this, the participants were apparently healthy. None of the subjects participated in any systematic physical training (Groups III-IV)(58) All of them except one physically inactive woman were engaged in moderate physical activity for at least 4 hours a week (Group II) (58). There was good agreement between the subjects in this study and the apparently "healthy" participants in Paper II as to body height, weight, and leisure-time physical activity. Good agreement was also found with respect to the muscle strength results except at the highest measured velocity (180°/s), where the men in this study were significantly ($p < 0.05$) stronger than those in Paper II.

PAPER IV. Fourteen of the 69-74-year-old men studied in Paper III volunteered to participate in the training programme. Two of them did not complete the training programme, one for acute medical reasons (stomach disease) and one for family reasons. Twelve men, matched for muscle strength, from the selected subsample in Paper I (Fig. I) served as controls. The participants were all found to be without functional locomotor disturbances. Two men, one in each group, used antihypertensive and heart-regulating drugs but were symptomless. Apart from this, the participants were all apparently healthy.

Seven of the men had had light occupational physical activity since at least their forties (Group II) (58), whereas the remainder had had more physically demanding jobs (Group III) (58). All the men in the training group had had moderate leisure-time physical activity (Group II) (58) during the last year.

None of the subjects participated in any systematic physical training. No significant difference with respect to occupational and leisure-time physical activity was observed between the subjects in the training group and their controls. There were no significant differences with respect to body height, weight, muscle strength or leisure-time physical activity between the participants in this study and the apparently healthy group in Paper II.

METHODS

Anthropometric measurements. Height and weight were measured (I-IV). Body cell mass (BCM) was calculated (III-IV) from the total body potassium according to Moore et al. (49). Total body potassium was measured in a whole body counter by measurement of naturally occuring ^{40}K (60).

Walking test (I). The proband was requested to walk a distance of 30 metres in a corridor of his (her) usual walking speed. This is a usual distance for pedestrian crossings of larger urban streets. The flooring was of non-slip material. The examining physician observed the proband by walking behind him or her without interfering. The time taken was registered with a chronometer.

Step test (I). The test equipment consisted of three boxes which could be combined to form steps of 10, 20, 30, 40, and 50 cm height. Handrails were mounted on the wall. The proband was requested to climb up and down with alternating right and left leg steps starting with the highest level. If the proband could not perform the test without using the handrail he was allowed to do so. The highest possible step height which the proband was able to climb up and down with either leg with and without using the handrail was registered.

Upper extremity function test (I). Mobility in the upper extremities in hygiene and dressing activities was tested in the sitting subject with some basal tasks: (1) Grasping ear-lobe with arm in front of head (2) Grasping ear-lobe with arm behind head (3) Fitting hand between buttock and seat and (4) Putting finger tips to opposite big toe.

Pronation of the forearm was tested in a power and precision activity-pouring water from a jug to a glass. The jug contained one litre of water. Pronation and supination of the forearm were tested in a precision activity - pouring water from one glass to another and back again. The tests of pronation and supination are parts of a quantitative test of upper extremity function developed by Carroll (19).

Reach of the upper extremities was tested by having the subject lift a glass and a one-kilogram packet (6 cm x 9 cm x 19 cm) on to shelves at 180, 160 and 140 cm height. The shelves, which had a depth of 30 cm, were mounted on the wall above a cupboard of 60 cm depth and 90 cm height, simulating standard Swedish kitchen fittings.

Manual ability was tested in the subsample in some activities of importance for an independant life: (1) Pulling out and inserting key in lock (2) Pulling out and inserting plug in socket (3) Unscrewing and screwing out an electric light bulb (4) Inserting coin in slot and (5) Dialling numbers 0-9 on a telephone. The equipment was mounted on a horizontal panel, and the panel was placed at chest-height with the subject sitting. Those who needed correction glasses for carrying out the test used them. The performance time was measured.

All upper extremity function tests were performed with the subject´s dominant hand. The observer noted whether the subject could perform the activity without difficulty, with some difficulty or could not carry out the test at all.

In connection with the ADL-tests, which were performed with the subject sitting, the ability to rise from a stool was also tested. The height of the stool was 45 cm and the seat was 35 cm x 35 cm.

Bicycle ergometer test (IV). The heart rate response to two submaximal loads (50 and 100 W) was studied on a bicycle ergometer (Monark). The heart rate was recorded from a bipolar chest lead.

Quadriceps muscle force (I-IV) and velocity measurements (II-IV). Submaximal exercise (50-100 W) for 6-10 min. was performed on a bicycle ergometer (Monark) before the muscle test to give a warming-up effect.

Muscle strength of the right quadriceps was measured as the torque output during maximal static contractions and at maximal knee-extension with constant angular velocities, using an isokinetic dynamometer (Cybex II, Lumex, Inc., New York). The apparatus has been described in detail elsewhere (68). The subjects sat in a special chair with a hip angle of 90 degrees and the lower leg attached to the lever of the dynamometer. The knee-joint was aligned with the dynamometer's axis of rotation and the range of angular movement of the knee-joint was from 100 to 0 degrees, i.e. full knee-extension. Angular velocities of 30, 60, 120 and 180* degrees per second were preset. Maximum isometric torque was measured with the same equipment at knee-angles of 60 and 90 degrees. Measurement at 30 degrees knee-angle was excluded because of the large methodological error (17%). Two measurements were performed at each knee-angle and velocity and the highest value was recorded. Torque output and knee-angle were recorded on an x-y-oscilloscope (Tectronix) (Fig. 3). The methodological errors, calculated from duplicate determinations with about three months' interval, ranged from 6 to 11% for men and from 9 to 14% for women in the different velocities measured.

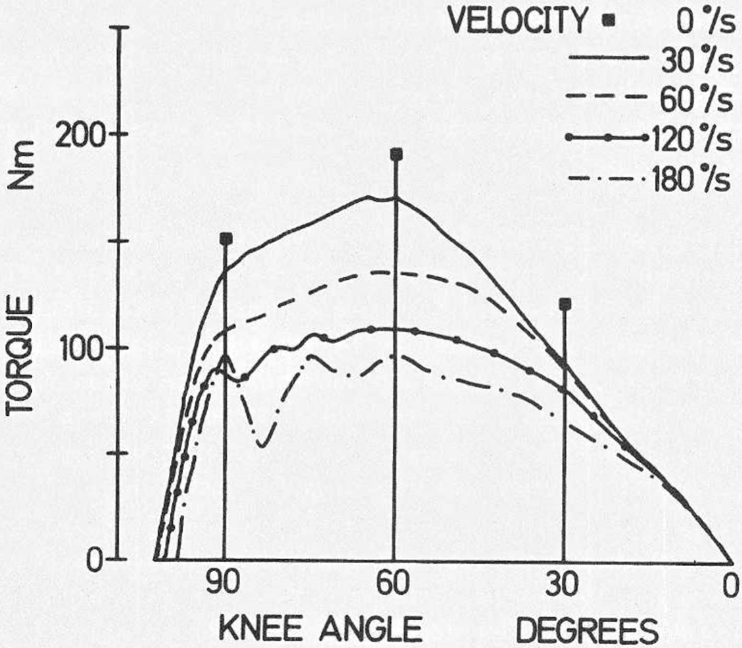

Fig. 3. An example of maximal torque for knee extension from 100 to 0 degrees during isokinetic contraction at different velocities and during isometric contraction at knee angle of 30, 60, and 90 degrees.

* π radians = 180 degrees

Maximal knee-extension velocity was measured with a special, very light lever arm. The subjects sat in the same chair as before and were instructed to extend the leg as quickly as possible starting from a knee-angle of 110 degrees. The time was measured electronically with photoelectric cells between a knee-angle of 67.5 and 22.5 degrees. The highest angular velocity from five experiments was used as the value for MEV. The methodological error was 6.6% for men and 7.1% for women. To allow them to become familiar with the apparatus, the subjects were carefully informed about the tests and were also allowed to try each of the items beforehand.

Muscle sampling (III-IV). Muscle biopsies from the middle portion of the right vastus lateralis muscle were taken according to the needle biopsy technique described by Bergström (12) just before the performance test. The muscle specimens were divided into two parts. One was frozen immediately in liquid nitrogen for enzyme activity and metabolite analyses, the other part was trimmed, mounted, and frozen in isopentan, cooled by liquid nitrogen for histochemical analysis. Both were stored at $-80^{\circ}C$ until analysis.

Histochemical methods (III-IV). Serial transverse sections (10 μm) were cut with a cryotom at $-21^{\circ}C$. The myofibrillar ATPase method (26,55) was used for muscle fibre classification. The reactions were carried out at pH 9.4 following alcaline preincubation (pH 10.3). By this procedure, fibre classification can be made into Type I (slow twitch) and Type II (fast twitch) fibres (24). The Type II fibres were subclassified into Type II A, II B, and II C using preincubations at pH 10.3, 4.6, and 4.4 (15,23).

The uniformity of the fibre sizes was classified (III) according to Jennekens, Tomlinson & Walton (36) with a 4-point-scale. Normal sections are graded 0. Sections classified as Grade I show largely normal, regular-size fibres, but among these normal fibres single, small atrophic fibres or groups of 4-5 small fibres are found. In sections classified as Grade II, single, small fibres and groups of up to 15-20 small fibres occur, and in Grade III there is a great variation in fibre size with the majority of the fibres being small and atrophic. To assess the denervation/reinnervation phenomenon (III) the classification of histopathological findings was divided into "enclosed" fibres, defined as fibres completely surrounded by fibres of their own histochemical type (37) and "fibre type grouping", defined as at least 16 fibres of a certain fibre type grouped together (10). The expected number of "enclosed" fibres of a certain fibre type was estimated as Np^7 (37), where N is the total number of fibres observed and p is the proportion of that fibre type in the sample. The standard deviation for this estimation is $\sqrt{Np^7 (1-p)^6}$.

Measurements of the fibre areas (III-IV) were made on photos of DPNH-activity-stained transverse sections (51). An optical illumination device ("particle size analyzer", Carl Zeiss, West Germany) projecting the muscle fibres as circles of varying sizes was used and the total fibre area was approximated. When comparing this method with the planimetric area measurement method, no statistical difference was found. Linear simple regression analyses between the two area measurement methods showed a highly significant correlation ($p < 0.001$, $r = 0.992$, $n = 37$). Based on duplicate determinations, the standard error of a single determination, expressed in percent of the mean, was 1.8% (n=10)

Amylase-PAS-staining to visualize capillaries (3) were used for capillary analyses (III-IV). The capillary supply was calculated according to Andersen & Henriksson (4).

Methodological errors found in our laboratory from two different measurements of capillary density (cap x mm^{-2}) were:

a) 5.4% (n=17) for two different areas in the same section

b) 5.3% (n=10) for the same area in adjacent sections using different stains

c) 9.2% (n=10) for the same area in two sections, one 300 μm deeper than the other, and using different stains

Biochemical methods. The enzyme activity determinations (III-IV) were performed by means of fluorimetric techniques using a Farrand ratio-fluorimeter-2 (Farrand Optical Comp., New York). The reactions catalyzed by the enzymes under investigation were coupled to NAD-NADP-linked reactions according to Lowry & Passonneau (47). The enzymes analyzed were Mg^{2+}-stimulated ATP-ase (e.c.3.6.1.4.), myokinase (MK) (e.c.2.7.4.3.) and lactate dehydrogenase (LDH) (e.c.1.1.1.27.). The LDH activities were determined both for the lactate oxidation and the pyruvate reduction according to the Lowry technique (48) as modified by Karlsson (39). Muscle adenosintriphosphate (ATP) and creatinphosphate (CP) were determined (III) according to the methods described by Karlsson (39) and Karlsson et al. (40).

The methodological errors for the determination of enzyme activities (n=57) and metabolite concentrations (n=39) were: Mg^{+2}-stimulated ATPase 11.6%, MK 3.8%, LDH (lactate→pyruvate) 4.0%, LDH (pyruvate→lactate) 6.9%, ATP 5.0% and CP 7.4%.

Training regimen (IV). The subjects exercised under supervision for 45 min three times a week for twelve weeks. Each training period started with warming-up exercises, such as walking or jogging. Various static and dynamic exercises, using body weight and no special equipment as resistance, were performed with the aim to increase muscular strength and flexibility, mainly of the lower extremities. Cardiovascular conditioning exercises were employed but were not emphazised. The work load during the training sessions was estimated from heart rate counting during various activities to correspond to not more than 70% of the predicted maximal oxygen uptake and was unchanged during the training period. The only medical complication related to the training was achilles-tendinitis of short duration in one man.

Statistics. Standard statistical methods were used to calculate means, standard deviations (SD) or standard errors (SE) of the means and correlation coefficients (r). The methodological error was calculated from duplicate determinations according to the formula $\mathcal{E} = \sqrt{\frac{\Sigma (d^2)}{2n}}$ where d is the difference between duplicate determinations. Statistical comparison between two groups and correlation analysis were performed by means of Pitman´s non-parametric permutation test (13). The x^2-test was used in frequency analyses. Only two-sided tests were used.

RESULTS

I. Functional capacity in activities of daily living. In the tests of basal movements in tasks relating to hygiene and dressing a minority, at most 7%, of the subjects had problems, and then mainly in the hand-to-toe test. The tests rising from a stool, supination and pronation, and reaching to shelves caused problems to the same extent. Difficulties in the latter test were mainly correlated to the height of the subjects, positional vertigo and arthritic disorders.

The women showed poorer results than the men in the manual ability test, due to problems in handling the electric plug. There was a correlation between ability to handling the plug and strength in the key grip. The elderly men and women showed poorer results in the manual ability test than young men and women in a reference group.

The average walking speed was in men 1.2 m/s and in women 1.1 m/s, which is lower than that recommended in Sweden as the norm for pedestrians at signalized intersections (1.4 m/s).

using a handrail. Without using a handrail one-fifth of the women but only a few men had problems at this step-height, but all subjects managed the 30 cm step without difficulty. With the 50 cm step the difficulties increased, especially for the women.

Correlations were found between muscle strength, step test results and walking speed as well as between walking speed and leisure-time physical activity.

II. Isometric and isokinetic muscle strength. The muscle strength in women was on average 56% of that in the men (Fig. 4). The force-velocity relationship showed a parallel decrease in peak torque values with increasing velocity in both sexes. The decline in the torque at a knee-angle of 60 degrees between the lowest (30°/s) and highest (180°/s) measured contraction velocity was 44%.

There was no difference in maximal velocity extension between the men (11.6 rad x s^{-1}) and women (10.8 rad x s^{-1}).

No correlation between muscle strength and body height was found in the women and only a weak correlation in the men. Muscle strength was correlated to body weight in both sexes, but the correlation was stronger in the men. An inverse correlation was found between muscle strength and previous occupational physical activity in the men.

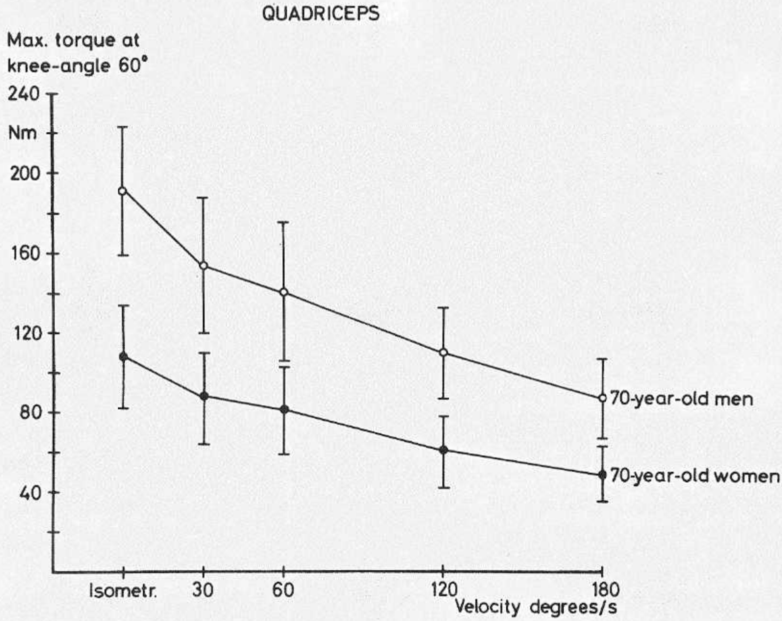

Fig. 4. Maximal torque at 60 degrees knee-angle for isometric and isokinetic knee extension in 70-year-old healthy men (n=40) and women (n=32).

III. Muscle morphology, enzyme activity and muscle strength.

The body cell mass was significantly ($p < 0.01$) higher in the men (29.2 kg) than in the women (22.3 kg) and was strongly correlated to muscle strength in both sexes.

The fibre distribution was similar in both sexes, with an average of 48% Type I fibres in the men and 54% Type I fibres in the women. The women had significantly ($p < 0.01$) fewer Type II B fibres (4%) than the men (18%). The average fibre area of the Type I (men 4.94 and women 4.29 $\mu m^2 \times 10^3$) did not differ between the sexes. The fibre areas of the Type II (men 4.58 and women 3.20 $\mu m^2 \times 10^3$) as well as the subgroups (Types II A and II B) and thus the mean fibre area (men 4.80 and women 3.76 $\mu m^2 \times 10^3$) were significantly ($p < 0.01$) smaller in the women than in the men. Furthermore the ratio between the mean Type II and

Type I fibre area was significantly ($p < 0.01$) smaller in the women (0.76) than in the men (0.95). Signs of denervation/re-innervation, such as type grouping and an increasing number of enclosed fibres, were observed very rarely and no great number of atrophic fibres indicating neuropathy was found. An example of a cross-section of quadriceps (vastus lateralis) muscle in an old woman is shown in Fig. 5. There was a reduction in the Type II fibre size compared with young people in both sexes. The capillarization was almost similar in men and women.

There was no difference between the enzymatic (Mg^{2+}ATP-ase, myokinase and LDH) and the phosphagen (ATP and CP) content values between the sexes and no correlation was found between these variables and muscle strength.

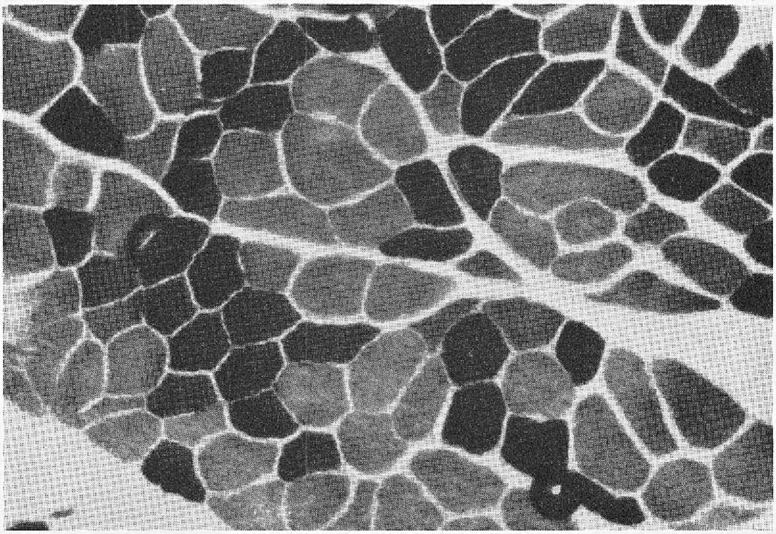

Fig. 5. Cross-section of quadriceps (vastus lateralis) muscle in a 70-year-old woman. The section is stained for myofibrillar ATPase using preincubation at pH 10.3.

Type I (slow twitch) fibres = lightly stained

Type II (fast twitch) fibres = darkly stained

IV. Effects of physical training. The maximal knee extension torque at isometric contractions increased significantly (9-22%, $p < 0.05-0.01$) at all measured angular velocities with training. There were no changes in the control group. There was an inverse correlation between the maximal torque at start and the increase in strength with training at the high angular velocity of $180^{\circ}/s$.

The proportion of Type II fibres increased significantly ($p < 0.05$) from 49% to 62% mainly due to an increase of the Type II A fibres. A significant ($p < 0.01$) increase with training of the relative area of the Type II A fibres from 32% to 47% was also found. There was a tendency ($p < 0.10$) towards a larger ratio between the mean fibre area of Type II B and Type I fibres after training from 0.77 to 1.02. Further there was a correlation between the increase in muscle strength at the high contraction velocity ($180^{\circ}/s$) and the increase in the absolute area of the Type II B fibres.

There was also enzymatic evidence of training adaptation, with a significant increment (23%, $p < 0.05$) in myokinase activity. With training there was a significantly ($p < 0.05$) decrease in heart rate of about 10% at submaximal loads.

There was no change with training in the maximal extension velocity, body cell mass, mean fibre area or capillarization.

DISCUSSION

Muscle strength. A decline in muscle strength has been reported in several studies (6,25,44,74). As reduction in physical activity with age seems to be a plausible explanation for part of the reduction in muscle strength with age, an attempt was made in this study to analyse the effect on muscle strength of leisure-time activity as evaluated by interview. However, the classification of the activity level was rough and covered a relatively long period, so that the analyses did not give much information. When previous occupational physical activity was correlated to quadriceps muscle strength, however, the men with previous relatively high activity levels in their occupations had, to our surprise, the lowest muscle strength.

Sperling (62), who studied most of the subjects included in this study, could not demonstrate any significant correlation between hand and arm muscle strength and previous occupational activity. Ufland (74), who studied upper arm and back muscles, found the opposite results. This may be explained by the fact that the subjects in that study were still in gainful employment and also by the industrial mechanization that has occured since the early thirties.

The muscle strength in the men and women in this investigation was in line with that in the 55-year-old subjects in a study by Asmussen & Heebøll-Nielsen (6). A possible explanation for this might be that our material was more representative of the population and/or that better living conditions, including better food, have improved the population´s muscle strength during the more than fifteen years that have elapsed between the studies. Differences in body height were taken into consideration in these comparisons. The decline in muscle strength in the legs in the subjects in the study by Asmussen & Heebøll-Nielsen (6) starts between the thirties and forties. It seems to be faster in the women, and in both sexes occur earlier in the lower extremities than in the upper. A more pronounced decline in quadriceps muscle strength in the women than in the men was also observed in this study. This comparison was possible as most subjects also participated in a muscle strength study of the upper extremities (62). According to Larsson et al. (44), a more pronounced decline in quadriceps muscle strength in a cross-sectional study in 16-65-year-old moderately active men was not seen until the fifties. Studies of the literature (6,44 and Quetelet & Reijs cited in 44) since the middle of the nineteenth century show that there has been a gradual shift of the decline of muscle strength towards higher ages (44). The elderly men, who participated in the physical training in this investigation increased their isometric and isokinetic quadriceps muscle strength at all measured velocities by an average of 9-22 percent and then attained muscle strength values corresponding to those of the 50-59-year-old men in the study by Larsson et al. (44). The percentage increase is in line with those seen in training studies in young men (20,68). The initially weakest subjects increased most at the highest velocity measured (180^{o}/s) that is in a muscle function they were presumed not to have normally used in their daily physical activities.

Morphological changes. A usually regular manifestation of aging parallel with a decline in muscle strength is the occurence of muscle atrophy, manifested in a reduction in muscle mass as measured by creatine excretion (73), lean body mass (2) and body cell mass (64). In the elderly men and women in this study there was a correlation between muscle strenght and body cell mass. The body cell mass-values in this study were compared with those of 54-year-old and 70-year-old men and women representative for their ages (64). The men in this study had similar values to the 70-year-old men, but lower values than the 54-year-old men. The women in this study, however, had somewhat higher values than the 54- and 70-year-old women, which two groups had similar values.

The comparatively high body cell mass-values in the elderly women may partly be explained by their having a similar level of muscular work to younger women. The body cell mass did not increase with training in the elderly men in this study. The initial correlation between muscle strength and body cell mass remained, however, intact. From studies by several authors (e.g. 22,33) it appears that neural factors account for the main initial strength increment produced by strength training and that both neural factors and hypertrophy are involved in the subsequent increase. Moritani & de Vries (50) have even attributed a larger relative importance to neural factors than to hypertrophy for the increase in muscle strength with training in elderly compared with young men.

The senile muscle atrophy is according to Gutmann & Hanzlikova (29) the result of a complex mechanism involving the decline of the trophic function of the nerve cell, resulting in a very slow progressing disturbance of neuromuscular contact ("functional denervation"). Disuse due to reduction of nerve impulse activity, hormone deficiency and actual nerve atrophy might also contribute (29).

The atrophy especially affects Type II fibres (70). In line with this, Rexed (56) described atrophy and degeneration with advancing age of the largest and fastest conducting nerve fibres, innervating Type II fibres (17). In support of these findings, Campbell (18) demonstrated electrophysiologically a decreased number of functioning motor units in old age and also reported that the remaining motor units tended to have relatively slow twitches. "Neuropathic" as well as "myopathic" fibre changes have been described in senile muscle atrophy by Tomonaga (70). Signs of denervation/reinnervation, such as type grouping (10) and an increasing number of enclosed fibres (37), occurring in the aging muscle (59,69,70) were hardly seen more often than expected from the randomly distribution in this study. Single or small groups of atrophic fibres were found in a minority of the subjects but there was no higher degree of atrophic fibres. The lack of evidence of more pronounced neuropathic muscle changes in this investigation speaks against a denervation process being a major cause of muscle atrophy and reduced muscle strength in 70-year-old subjects. It thus seems that it is at ages above seventy that more marked morphological changes appear (27,36,70).

This study did not show a clear change in the proportion of Type I and Type II fibres in men and women around the seventies compared with younger age-groups (e.g. 5,32) in contrast to a cross-sectional study of sedentary men of different ages (45). In agreement with the studies referred to above (27,45,70), however, this study showed a reduction in size of Type II fibres compared with younger age-groups (e.g. 5,32).

The decrease in Type II fibre size was not pronounced enough to result in a clear reduction in mean fibre area in the elderly men and women compared with the younger groups (5,32). Thus the reduction in body cell mass with age cannot be explained by a reduced fibre area as presented in the results of vastus lateralis biopsies. One cause of the reduction in body cell mass may, however, be variations in muscle atrophy between different muscle groups (27,36). Behind the decline in body cell mass with age may also be a reduction of the number of muscle fibres with age in each motor unit and/or a reduction in the total number of motor units and then probably of both the Type I and Type II fibres to the same extent.

The reduced Type II fibre size in both sexes, combined with the lack of correlation between muscle strength and Type II fibre areas in the men in contrast to in younger men (44), may indicate a relative loss of the functional importance of Type II fibres in these elderly subjects. Disuse of the Type II fibres might be a common feature in elderly people since in their daily activities they probably use less intensive muscle contractions and also less rapid movements, during which the fast twitch fibres are assumed to be selectively activated (28).

In most training studies fibre composition is not changed (20,68). However, this study showed an increase in the relative number of Type II A fibres as well as an increase in the relative area of the Type II A fibres. Corresponding changes have also been observed in isokinetically strength-trained young and middle-aged women (43). The relative number of Type II fibres was also reported to increase in four young male "anaerobically" trained long-distance runners (35). The mechanisms behind the change in fibre composition is unclear. The present observations of such a change after a relatively short period of training should be interpreted cautiously. The problems concerning the representativeness of a muscle biopsy and the variability in fibre composition in elderly persons (Nygaard & Sanches, pers. comm.) must be taken into account here.

There was no significant increase in the fibre area after training except for the increase in the relative Type II A area. However, the correlation between the increase in muscle strength at high velocity (180°/s) and the increase in the area of the Type II B fibres indicates that with training these fibres may regain their importance for muscle strength at high velocities.

Although the morphological effects of the training were diffuse, it may be speculated whether the recruitment pattern had been changed i.e. whether there had been an increased engagement of the Type II fibres.

Enzymatic activities. Larsson et al. (45) concluded from an investigation in the vastus lateralis muscle in 22-65-year-old moderately active men that the ATPase and myokinase activity of importance for contractibility did not change with age. The activity of these enzymes in the oldest men in the study by Larsson et al. were in agreement with the corresponding values in the elderly men in this investigation. From an investigation in basically the same subjects of five enzymes representing the main metabolic pathways and of mitochondria, Örlander et al (52) concluded that the muscle cells up to about the seventies are still capable of maintaining as great a metabolic flow as that of young men. This finding is consistent with a proposal by Asmussen (pers. comm.) that the fall with age in maximal oxygen uptake can be explained by a decrease in muscle mass. The preserved capillary density with age (5) also indicates favourable diffusion conditions in the muscles. It seems from the above that the decline in muscle strength with age is probably not due to qualitative changes in the muscle metabolism up to the seventies.

The myokinase activity, important for the contractile process, increased with training in agreement with the results in strength-trained young men (20,68). The LDH activity increased, though not significantly, in the training group in this study. In a substudy in five men, however, (53) LDH, investigated with another method, increased significantly with training, indicating an increased anaerobic capacity. This accords with the findings in other physically trained elderly men (46,67) but conflicts with the results in the vast majority of studies in physically trained young men, in which LDH was unchanged or decreased slightly after training (e.g. 38,41). In the same substudy mentioned above (53) an increase of cytochromoxidase with training was also observed indicating an increased aerobic capacity parallel to a reduction in heart rate at submaximal loads.

Functional capacity in activities of daily living. That there is a decline in locomotor performance with age is generally accepted. This contributes to a decline in ADL-capacities, which tends to make the elderly dependent on other people´s help. This problem is not only an economic problem for society, it is also unpleasant for aged people who want to look after themselves and live an active life. The locomotor dysfunction may be due to such factors as lack of motivation for movements and disturbances of the nervous and neuromuscular system, causing a decline in balance (e.g. 31,54), coordinating (e.g. 30,62), posture (30), joint motion sensation and perception (e.g. 42) and muscle strength (e.g. 6,44). Further, there is an increased unflexibility in the joint with age. A decline in aerobic capacity with age (7) will also have influence on ADL-activities such as walking and climbing stairs. The increased prevalence of locomotor, neurological, cardiovascular and visual disorders with age may also have an effect on the ADL-capacity.

of mobility, due predominantly to joint stiffness, in the hip-joints, was seen in the hand-to-toe test. Reduced function in this movement causes difficulties in dressing and attending to pedicure. The need for technical aids for these activities in old age has previously been stated (34,61). Most probands had no difficulty rising from a chair without the support of their arms, a test regarded as a functional test of quadriceps strength. As the strength in elbow extension seems to be well maintained in the elderly (62) this may possibly compensate for a reduced quadriceps strength.

Locomotor and neurological disorders, positional vertigo and shortness of stature caused problems in the test of reach to shelves of various heights. The reduced reach in the higher age groups must above all be considered in connection with kitchen planning. There is a risk that the elderly person who cannot reach things on shelves will use a stool or chair leading to accidents. This study has shown that women especially have problems climbing up and down heights of 40-50 cm.

Both sexes showed a decline in manual dexterity in comparison with young subjects (62) in the same test but the decline was less marked in the elderly women than in the elderly men.

This is in accordance with the results from an upper extremity coordination test in the same subjects (62). When considering the relatively good results in the elderly in the manual ability test it must be kept in mind that subjects with severe arthritic conditions and neurological disorders were not tested.

Only a limited number of the probands reached, with their comfortable walking speed, the maximum walking speed at 1.4 m/s stipulated in Swedish speed limit recommendations for pedestrians at signalized intersections (72). Elderly pedestrians in a study by Dahlstedt (21) considered the walking speed 1.3 m/s to correspond to "catching a bus" and a speed of 0.9 m/s to "a normal walking speed". Most elderly people seem to have to walk over part of the road on the red signal or wait for the next green signal on a refuge. A changed gait pattern, with reduced walking speed, in the elderly has been reported in several studies (e.g. 8,9). The increased speed, noise and density of traffic might make the elderly bewildered and course them to take wrong decisions in their confusion. Postural sway is also more often observed in elderly people under conditions of stress and is associated with falls, especially in women (31). It is therefore not surprising that as many as 63% of the pedestrians killed or severely injuried, in Gothenburg 1978 were seventy years old or more (71).

There are at present no compulsary norms for step-heights on public transport vehicles in Sweden. The usual step-height from the ground to the first step in buses is 35 cm (14; The Swedish Public Transport Association, pers. comm.) and in trams 37.5 cm (Gothenburg Tram Co, pers. comm.). On the Swedish railways the maximum step-height is 30 cm (pers. comm.). In this all but one subject could climb up and down a 40 cm step using a handrail. Without using a handrail one-fifth of the women but only a few of the men had problems at this step-height but all managed the 30 cm step without difficulty. In a study of subjects aged above 70-years (16) even non-disabled elderly persons had greater difficulty climbing various step-heights than the subjects in this study. It must, however, be born in mind when considering the results that the step-tested subjects were a selected group and that they had a relatively good muscle function in both their lower and upper extremities.

The correlations in both men and women between maximum step-height and walking speed show that the same persons have difficulties performing two important practical functions of the lower extremities. The importance of muscle strength for these functions is illustrated by the correlations between quadriceps muscle strength and maximum step-height and walking speed respectively.

Concluding comments. The decrease in muscle strength with age might be caused by either quantitative and/or qualitative neuromuscular changes. The correlation between muscle strength and the reduced body cell mass values points to a reduced muscle mass as an explanation. It does not seem probable, however, that the finding of a modest reduction in Type II fibre size in people in the seventies, compared with younger individuals, can explain the whole reduction in body cell mass with age. There might also be a reduction of the total number of both Type I and Type II fibres as no change in fibre composition was observed in the 70-year-olds compared to younger age-groups. It proved difficult to find a clearcut relationship between function and fibre characteristics in this investigation. The lack of correlation between muscle strength and Type II fibres in the elderly men in contrast to younger men together with the reduction in Type II fibre size, which is still more pronounced in 80-year-old persons, points to some loss of functional importance of Type II (fast twitch) fibres in elderly people. It has been discussed in what extent the muscle atrophy is caused by inactivity, "functional denervation" and/or a true nerve fibre atrophy. As the muscle fibre atrophy was partly reversible with training, inactivity, at least in the seventies, seems to be one cause. The lack of the more pronounced neuropathic muscle changes described in older subjects speaks against a denervation process being a major cause of loss of muscle strength in the seventies. There was a lack of correlation between muscle strength, phosphagen content and activities of enzymes of importance for the contractile and anaerobic processes in the muscles. Further, the capillarization seemed to be preserved with age. These findings, combined with the findings of Örlander et al. (52) that the muscle cells up to about the seventies are still capable of maintaining as great a metabolic flow as in young age and the proposal by Asmussen (pers. comm.)

that the reduction of maximal oxygen uptake with age is parallel to a reduced muscle mass, speak against qualitative changes in the metabolism as the cause of the decline in muscle performance in the seventies.

The performance in the different ADL-functions in the 70-year-old subjects was relatively well preserved in the movements of importance for hygiene and dressing activities and practical basal functions in the home. Regarding important ADL-functions outside the home, such as crossing the street at a comfortable walking speed at signalized intersections or using public transport, it appeared that even 70-year-olds had considerable problems. It seems important that further methodological studies be carried out for evaluation of the ADL-function in still older but non-institutionalized people. Such studies should lead to a better understanding of old people´s problems in practical functions of importance in their daily life. It would then be possible to adapt the environment, both inside and outside the home, to the needs of the elderly to a greater extent than is the case today. This would mean a more independent, active and hence richer life for the older part of the population. The positive influence of training, not only on muscle strength but also on the aerobic capacity, warrants an active attitude towards rehabilitation and also indicates the possibilities of physical prevention against disability, for example in the form of organized physical training for old-age pensioners.

SUMMARY

I. Various activities of daily living of importance for an independent active life were studied in 70-year-old men and women recruited from a population study.

A minority of the subjects had problems carrying out the tests involving basal movements in tasks relating to hygiene and dressing, ability to rise from a stool, function in the kitchen (e.g. reaching shelves and tasks including pronation and supination of the forearm).

In a manual ability test both sexes showed poorer results than young men and women in a reference group and the elderly women had poorer results than the elderly men, correlated to a weaker muscle strength in the key grip. Even these 70-year-old subjects might have considerable problems in ADL-functions outside the home. The comfortable mean walking speed was in both sexes lower than that recommended as the norm for pedestrians at signalized intersections.

One-fifth of the women but only a few of the men had problems climbing up and down a 40 cm step without using a handrail. Subjects with severe locomotor disorders were excluded from this step test, however. Correlations were observed between the latter test and the walking speed test and quadriceps muscle strength.

II. Isometric and isokinetic muscle strength and maximal extension velocity were measured during right knee extension in "healthy" 70-year-old men and women. The muscle strength in women was on average 56 percent of that in men. The force-velocity relationship showed a parallel decrease in peak torque values with increasing velocity for both sexes. There was no difference in maximal extension velocity between the sexes.

Equations for calculation of normal values from the individuals´ body height and weight are given. An inverse correlation was found between muscle strength and physical activity in their previous occupations in the men.

III. Isometric and isokinetic quadriceps muscle strength were

studied in relation to muscle morphology and some enzymes and metabolites of importance for the contractile processes.

The body cell mass was highly correlated to muscle strength. The Type I and Type II fibre composition was similar in the men and women. The Type II fibre size, including both the subgroups (II A and II B), but not the Type I fibre size, was smaller in the women than in the men, resulting in a smaller ratio between the Type II and Type I fibre area and a smaller mean fibre area in the women. The lack of correlation between muscle strength and Type II fibre area in 70-year-old men, in contrast to young men, together with the reduction in Type II fibre size, point to some loss of the functional importance of Type II (fast twitch) fibres in the elderly. The lack of more pronounced neuropathic changes speaks against a denervation process as a major cause of muscle strength decline with age. The capillarization was fairly similar between the sexes and compared with younger groups.

There was no difference between the enzymatic (Mg^{2+} ATPase, myokinase and LDH) and the phosphagen (ATP and CP) content values between the sexes and no correlations were found between these variables and muscle strength.

IV. Physical training, including strength training of the lower extremities, was performed for 45 min. three times a week for 12 weeks by twelve untrained men without cardiovascular or locomotor symptoms.

Isometric and isokinetic quadriceps muscle strength increased significantly, as did the Type II A fibre proportion and relative Type II A fibre area and the myokinase activity. Heart rate decreased at submaximal loads, indicating an improvement of the cardiovascular function. There was no change in body cell mass or capillarization.

The results indicate that the human muscle remains trainable at least into the seventies. The decline in muscle strength might, at least up to that age, be due to a combined effect of inactivity and aging.

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