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MUSCLE PERFORMANCE IN AN URBAN POPULATION SAMPLE OF 40- TO 79-YEAR-OLD MEN AND WOMEN

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An urban population sample of 40 to 79-year-old men and women was investigated to evaluate the influence of age and activity level on muscle strength and endurance and to establish a reference material. During the investigation 144 persons were tested bilaterally, except for ankle strength, when only the right side was examined. Isometric muscle strength was determined in the knee extensors and flexors. Isokinetic (at 60°/s and at 180°/s) muscle strength was determined concentrically and eccentrically in the knee extensors and flexors. The dynamic and static endurance of the extensors was measured. Isometric strength was determined in the ankle plantar and dorsiflexor muscles. Isokinetic ankle plantar flexion strength was determined concentrically at 60°/s with and without prior eccentric muscle contraction. Hand-grip strength was evaluated with a dynamometer. Walking velocity and the number of heel-rises were recorded. Physical activity level was assessed by questionnaire. Muscle biopsies were taken from the vastus lateralis muscle for histochemical and enzymatic analyses. Walking and the different muscle tests declined with age, and with a slight gender difference. Muscle biopsies showed a trend toward smaller muscle fibers with age. The results of our study can be used as reference material for clinical studies in different age groups.

Key words: muscle strength, endurance, hand grip, muscle fiber morphology, muscle enzymes.

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INTRODUCTION

In clinical practice and in the laboratory setting, it is necessary to compare patient performance with what is expected of a "normal" person. In reality, we often claim that the patient performs at a lower level than normal, but this is usually a personal judgement that is based on experience and cannot readily be quantified. To improve evaluations of our interventions, we must be able to compare performance before and after interventions. "Normal" performance therefore needs to be estimated and quantified in different settings.

Isokinetic dynamometers have been found useful for diagnostic and physical training procedures. The information gained should relate to age, body size and physical activity. It is known that, with age, there is a decline in muscle function in several muscle groups, as has been demonstrated: the quadriceps (1–4), the triceps surae muscles (5) and the hand grip (6). Frequently used clinical tests of muscle function include walking tests and performance of heel-rises, but we have little knowledge of normal performance. The normal capacity with respect to the number of heel-rises was originally set to one (7), but four to five repetitions were later considered normal (8). Most of these investigations are not based on a population sample, which possibly reduces the ability to generalize the results. Aniansson et al. (1) tested muscle strength in a population sample of 70-year-old men and women and showed that the muscle strength of the women was on average 56% that of the men. The assumption that, on average, men are stronger than women was reconfirmed by Borges (9) and Rantanen et al. (3, 10). Nordensköld & Grimby (6) evaluated hand-grip strength in a large population of men and women, but the population consisted of healthy volunteers from the hospital staff. The National Isometric Muscle Strength (NIMS) Database Consortium recently presented an article (11) in which they argued for the use of normal data for comparison in order to evaluate muscle weakness. There is a report in the literature of hand-held dynamometer reference values for different age groups (12) but, again, this was a convenience sample.

With increasing age, human skeletal muscles gradually decrease in volume. This is mainly due to a reduced number of motor units and muscle fibers and a reduction in the size of type 2 fibers (13). These findings are consistent in many studies with a type 2 (fast-twitch) fiber size reduction with increasing age, while the size of type 1 (slow-twitch) fibers remains much less affected (2, 14–18).

Our purpose was to investigate an urban population of 40–79-year-olds randomly chosen in order to evaluate the influence of age and activity level on muscle strength and endurance, with a view to establishing a good reference material that included biopsies. We also wanted to test muscle performance in functional exercises often employed by physical therapists.

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Table I. *Background information of the study group*

Age (years)	*n*	Mean	95% CI	Height (cm) *n*	Mean	95% CI	Weight (kg) *n*	Mean	95% CI	BMI *n*	Mean	95% CI
Men												
40–49	16	44.1	1.5	16	180	5.8	16	85.4	6	16	26.4	1.4
50–59	20	54.2	1.2	20	176.7	2.6	20	79.3	5	20	25.4	1.3
60–69	18	64.2	1.3	18	177.1	3.5	18	85.6	6.3	18	27.2	1.6
70–79	15	73.9	1.5	15	177.2	3.2	15	78.2	5.2	15	24.9	1.5*
Women												
40–49	19	45.1	1.3	19	167.8	3.5	19	69.4	6.4	19	24.6	2
50–59	15	55.3	1.6	15	164.4	3.7	15	65.9	4.9	15	24.5	2
60–69	27	64	1	27	164	2.3	27	68.1	4.8	27	25.2	1.6
70–79	14	73.9	1.6	14	159	3.8*	14	63.9	5.6	14	25.4	2.7

BMI = body mass index; *n* = number; CI = confidence interval.
* Statistically different from the age group above.

MATERIAL AND METHODS

Population

All residents in Sweden are registered in a database, and from this database the computer randomly selected residents of Göteborg born between 1915 and 1955. The study took place in 1994 and 1995, at which time the persons were between 40 and 79 years of age. An invitation was sent by mail to a total of 639 persons. They were asked to contact us (by phone or mail) if they wished to participate. The design was influenced by an ethical concern; we did not want to influence anyone to participate in biopsies, but wanted the decision to be their own. Therefore, we decided not to call people, and instead asked them personally if they wanted to participate. Of these, 23% (144 persons, 69 males and 75 females) were willing to participate and were, in their own opinion, in "good health" and were considered clinically healthy. Contraindications for participation were prior CNS involvement, musculoskeletal problems, cardiac disease with impaired physical performance (heart failure, angina), or the presence of an active disease requiring treatment by a physician.

The number of subjects tested in the different age groups and their background variables are presented in Table I. Ten persons (7%) were not Swedish citizens. None of the participants had blood pressure levels of over 160/95 in consecutive registrations, i.e. no persons with hypertensive blood pressure.

Set up. A physical examination was carried out on the *first* visit, performed by the physician (KSS). The subject's clinical history was recorded, and heart and lung sounds were evaluated. Height, weight and blood pressure were also recorded. Blood samples were drawn for hemoglobin, white blood cell count and sedimentation rate (SR). During the first visit, walking speed, heel-rises and hand grip were evaluated. The subject was asked to complete an activity questionnaire; if no contraindications (diabetes, treated hypertension or treatment with anti-coagulation drugs) were present, he or she was asked whether a muscle biopsy could be taken. At the *second* visit, torque and endurance were evaluated in the legs and feet. At the *third* visit, a biopsy was taken from those who volunteered. This requires approximately 3.5 to 4 hours of examination. No payment was offered to the participants, nor were they reimbursed for any eventual loss of salary.

The study was approved by the Ethics Committee of Göteborg University, Göteborg, Sweden. The participants gave informed consent, and the study was conducted according to the Helsinki declaration.

Test procedures

Vital statistics. Sex, age, height in centimeters and weight in kilograms were recorded. Body mass index (BMI: weight in kg/(height in m)^2) was calculated and blood pressure was recorded.

Questionnaire. The activity level was estimated using a questionnaire (PASE; Physical Activity Scale for the Elderly (19), translated into Swedish) completed by the subject at the first visit. PASE is an epidemiologically based questionnaire that has been developed for elderly people. The questionnaire is self-administered and comprises self-reported occupational, household and leisure activities. The questions relate to sitting activities, sports and other types of physical activities such as lawn work, caring for others, housework and gardening, and also cover the most recent seven days' work situation. Scores were calculated from weights and frequency values for the 12 types of activities. The PASE questionnaire has been shown to have good reliability (20) and validity (21, 22).

Walking test. The subjects were asked to walk 30 m at their normal walking speed, wearing their own footwear. The test was performed as described by Lundgren-Lindquist et al. (23). After a 2-minute rest, the subjects were encouraged to walk the same distance at maximum speed. The time and number of steps taken were registered and walking speed was calculated. The test is of known reliability (24).

Dynamometer hand strength. We recorded the peak maximum grip force and the mean value of the 10-second sustained grip for both hands, as measured by Grippit® (AB Detector, Göteborg, Sweden). The subject was seated on a chair without arm-rests, with the lowest rib at a level with the edge of a table. The tested forearm was placed in the arm guide and the other arm rested on the table. The palm and fingers were completely clasped around the handle, and the force exerted against the transducer in the handle was recorded using the same method and set-up as that described in Nordensköld & Grimby (6). This test has also been shown to be reliable (25).

The standing heel-rise test. Touching the wall for balance, with the fingertips at shoulder height, the subjects performed a maximal heel-rise test on a 10° tilted wedge, one rise every other second, according to Gaffney et al. (26). This means that the tested foot was in a 10° dorsiflexed starting position. The contralateral foot was held slightly above the floor. The subject was encouraged verbally to continue as long as possible. The test stopped when the heel-rise was performed in compensatory manner or when the subject said that he/she was exhausted. The maximal number of heel-rises was counted for each leg.

Muscle performance of the knee extensors and flexors

Measurements of torque were performed using a Kin-Com® (Chattanooga Group Inc., PO Box 489, Hixson, TN, USA) dynamometer with the patient seated comfortably with his/her back against a back-rest. A seatbelt was strapped around the waist, at a hip angle of 90°, and the tested leg was attached to the lever arm of the dynamometer. The axis of the actuator arm of the Kin-Com was carefully adjusted to the axis of rotation of the knee joint. Warm-up, submaximal exercise, was performed on a bicycle ergonometer for 5 minutes prior to the muscle test. A rest of approximately 2–2.5 minutes took place between each set of tests for each leg, which occurred, in the same order. The order of the right or left leg was randomized.

Peak isometric strength was measured at a 60° knee angle during extension and flexion in both legs. Maximal isokinetic strength was measured at a velocity of 60°/s and at 180°/s during the concentric and

Table II. *Grip force N*

	Right hand						Left hand					
	Peak torque			Average 10 s			Peak torque			Average 10 s		
Age	*n*	Mean	95% CI	*n*	Mean	95% CI	*N*	Mean	95% CI	*n*	Mean	95% CI
Men												
40–49	16	552	46	16	502	48	16	528	45	16	482	46
50–59	20	507	31	20	459	27*	20	467	29*	20	422	25*
60–69	18	470	35	18	416	31*	18	441	32	18	389	31
70–79	15	407	45*	15	354	42**	15	374	46***	15	332	42***
Women												
40–49	19	327	33	19	287	32	19	299	22	19	262	21
50–59	14	304	33	14	274	31	13	283	28	13	256	26
60–69	27	267	21	27	233	19*	27	249	21	27	219	19*
70–79	4	227	24*	14	199	25*	14	210	28*	14	182	27

N = Newton; s = seconds.

eccentric muscle actions of extension and flexion in both legs. Isometric endurance was measured in the right leg as the time the subject could keep 40% of his/her isometric peak torque at a 60° knee angle; a follow-up period of 5 minutes was used to evaluate the recovery process, with a maximum voluntary isometric contraction every minute. In the left leg, isokinetic endurance was evaluated as the reduction in peak torque at an angular velocity of 180°/s between the first and the last three knee extensions in a series of 50 maximal concentric muscle actions (27).

Muscle performance of the dorsal and plantar/flexors of the right foot

Isokinetic movement. The subject was placed in a prone position during all measurements, with the tested foot hanging over the edge of the bench to allow free movement of the ankle. The hip and knee joints were in straight positions. The lower part of the leg was fastened with a Velcro strap, attached to a pad at the end of the bench. The subject was also secured to the bench with a belt around the waist to minimize horizontal gliding and with two pads to support and secure the shoulders. The arms were elevated and the elbows flexed, which allowed the head to rest on the hands. The axis of the actuator arm of the Kin-Com was approximated to the axis of rotation of the ankle joint. The tests were performed at 60°/s. First, the subject made a pure concentric plantar flexion within the range of motion of approximately 80°–115° of the ankle joint. The actuator arm was passively moved back to a given starting position between each muscle action. After three to five trials at submaximal level, three trials were performed at maximal effort. Without changing the position of the subject, a second test was performed about 2 minutes later, with the same range of motion. The movement started with a maximal eccentric action, immediately followed by a concentric action at maximal effort, as described in Svantesson & Grimby (28). The tests were performed on the right foot. Footwear was standardized by using the same type of shoe in appropriate sizes.

Isometric measurement 90° foot angle. The set-up was as described above in order to minimize horizontal gliding, with the subject tested in prone and supine position with the foot outside the bench. The axis of the actuator arm of the Kin-Com was approximated to the axis of rotation of the ankle joint. The foot was tested in two different ways with respect to support of the foot, once with a pedal (prone position) and once with the forefoot resting on a special foot device (supine position). The order of the two tests was randomized with a resting period interval of 2–2.5 minutes. The second version was standardized (since the length of the feet varied), taking into consideration the distance of the pin from a zero point. The ankle was in a 90° position, which was defined as the point at which the sole of the foot was perpendicular to the axis of the leg. Peak plantar flexion torque was measured in the two above-mentioned ways. Peak dorsal flexion torque was measured with the foot strapped to the pedal.

Muscle biopsy

Muscle biopsies were taken under local anesthesia and using the conchotome technique (29) from the middle portion of the right vastus lateralis (half-way between the upper border of the patella and the anterior iliac spine). At least two samples were taken; one was frozen immediately in liquid nitrogen and used for analysis of enzymatic activities, and the other was trimmed, mounted, frozen in cooled isopentane (−160°C) and used for histochemical and histopathological analyses. Both samples were stored at −80°C until analyzed.

Histochemical and histopathological analyses. Serial transverse sections (10 μm) were cut with a cryotone at −21°C. The myofibrillar adenosinetriphosphatase method (30) was used for fiber classification. The reactions were carried out at pH 9.4 after alkaline preincubation (pH 10.2). The procedure allows classification into type I and type II fibers. By preincubation at pH 4.6 and 4.3, the type II fibers were subclassified into IIA, IIB and IIC. Measurements of the fiber areas and capillaries were taken using a semiautomatic system with a camera and specially developed software (Scan Beam, Hadsund, Denmark).

Amylase-periodic acid-Schiff staining was used to visualize capillaries (31). The number of capillaries per fiber area was calculated for the different fiber types.

Enzymatic assays. The enzyme activity was determined by means of fluoremetric techniques with a radiofluorometer-2 (Farrand Optical, Valhalla, NY). The reactions catalyzed by the enzymes under investigation were coupled to NAD-NADP-linked reactions and determined according to principles developed by Lowry & Passoneau (32). The enzymes analyzed were myokinase (MK), lactate dehydrogenase (LDH), triose phosphate dehydrogenase (TPDH), 3-hydroxyacylCoA-dehydrogenase (HAD) and citrate synthase (CS). The assays were performed at 25°C. The protein content was determined according to Lowry et al. (33).

Statistical methods

Statistics were performed using Statview. Mean, standard deviation and 95% confidence intervals are shown. The Mann-Whitney U-test was used for comparisons among groups. Pearsons's simple correlation or regression analysis was performed to establish relationships between two variables. Most of the statistical findings were highly significant ($p < 0.001$), and thus only p-values differing from this will be specifically noted in the text.

RESULTS

The female subjects' hand grips with either hand were between 56 and 58% of the male subjects' levels, regardless of whether peak or average over 10 seconds was recorded (Table II). The

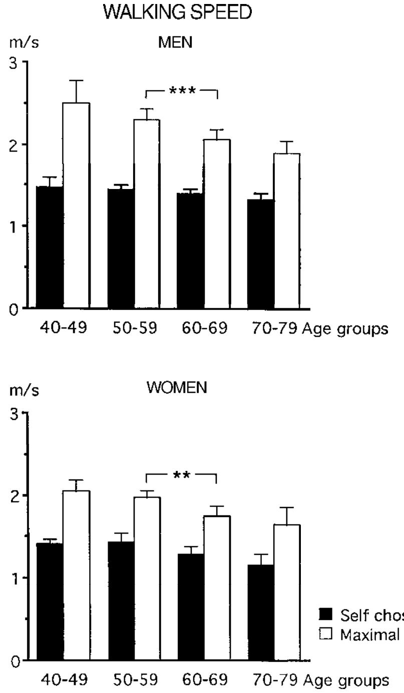

Fig. 1. Self-chosen and maximal walking speed for men and women. Self-chosen velocity seems to vary little with age, while the maximal walking velocity declines for both men and women, with women being slower. Average values and 95% CI (confidence interval) shown, $p < 0.05$.

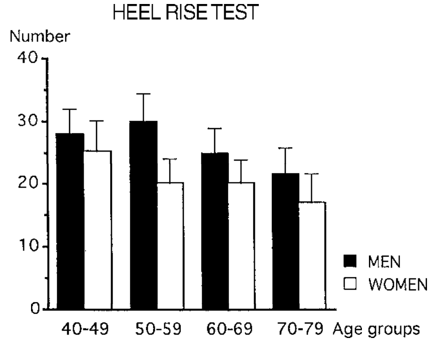

Fig. 2. The heel-rise test shows a declining trend with age. Women were less able to perform heel-rises. Average values and 95% CI shown, $p < 0.05$.

right hand was usually highly significantly the stronger, both for peak torque (6.4% lower on the left side for men, 7.3% for women) and for sustained grip (5.8% lower on the left side for men, 7.1% for women). Regression analysis showed a highly significant relationship between age and peak maximum hand grip in both men (right hand r: 0.585 and left hand r: 0.59) and women (right hand r: 0.597 and left hand r: 0.616). The same was true for sustained hand grip in both sexes. The results are basically the same for the left side as well. The hand grip, in either hand (both peak maximum and sustained over 10 seconds), correlated significantly ($p < 0.05$) with the activity index (PASE) for both genders (r for the men was 0.29 for both hands and for the women r was 0.41 right hand maximum grip, 0.44 sustained grip, left side maximum 0.33 and sustained 0.35).

Both self-chosen walking speed (ranging from 1.16 m/s to 1.47 m/s) and maximum walking speed (varying between 1.64 m/s and 2.51 m/s) decreased with age (Fig. 1), women being the slower walkers. Regression analysis showed a highly significant association between body height and self-chosen walking speed (r: 0.34) and maximum walking speed (r: 0.38). The step length was also highly significantly dependent on height, both at normal gait (r: 0.51) and at maximum walking speed (r: 0.54).

The number of heel-rises varied between age groups (Fig. 2). Men between the ages of 50 and 59 years performed the greatest number of heel-rises, 30 (SD 9) on the right leg and 28 (SD 9) on the left. Among the women, the youngest group (40–49 years) performed the greatest number, 25 (SD 10) on the right and 24 (SD 11) on the left side. On average, the men performed 5.3% more heel-rises on the right side ($p < 0.01$) than on the left. There were no significant side differences for the women.

Age has an impact on torque; i.e. there is a general decline in strength with age. This was shown by regression analysis between age and torque at isometric extension at a 60° knee angle. There was a highly significant relation for the right leg (r: 0.532 for the men and r: 0.591 for the women) but not for the left leg ($p < 0.0002$, r: 0.436 for the men and r: 0.543 for the women). The performance of the left leg was 8.3% lower among the men and 4.9% lower in the women, compared with that of the right leg, which was highly significantly different. Isometric flexion at a 60° knee angle showed the same tendency, with the younger men reaching a higher torque than the older men. Regression analysis showed a highly significant correlation with age for both legs (right r: 0.477 and left r: 0.417). The performances of the left leg were highly significantly lower (5.2%) than for the right leg among the men. In the women, regression analysis showed a highly significant correlation with age for both legs (right r: 0.579 and left r: 0.516). There were no significant side differences. On average, the women showed 56–65% of the performance of men of the same age.

The isokinetic knee extension strength at 60°/s was higher for the younger subjects (Table III). Regression analysis showed a relation with age for both legs, which was highly significant for both men (right r: 0.537 and left r: 0.542) and women (right r: 0.637 and left r: 0.627). Isokinetic extension at 60°/s showed a side difference of 4.1% lower on the left side (highly significant) among the men and 1.9% among the women ($p < 0.05$). On average, the women showed 61–69% of the men's performance at a corresponding age. The pattern was the same at 180°/s, with the younger subjects reaching the highest torque values. Regression analysis showed a highly significant correlation with age for both legs, in men (right r: 0.595 and left r: 0.603) and women (right r: 0.665 and left r: 0.676). There were no significant side differences. The women showed 58–68% of the men's performance.

Knee flexion strength at both 60°/s and 180°/s declined highly

Table III. *Knee extension, concentric muscle action (Nm)*

	Right leg						Left leg					
	60°/s			180°/s			60°/s			180°/s		
Age	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI
Men												
40–49	15	198	19	15	144	22	15	187	20	15	141	14
50–59	19	163	11**	19	113	10**	19	157	14*	19	111	10**
60–69	18	157	18	18	112	12	18	155	18	18	109	11
70–79	14	136	17	14	90	13**	14	126	17*	14	88	12*
Women												
40–49	19	128	12	19	87	6	18	122	10	18	87	7
50–59	15	113	10	15	76	7*	15	108	9*	15	76	7*
60–69	27	101	8	27	70	6	27	100	7	27	70	5
70–79	13	83	11*	13	52	9**	13	81	9**	13	53	7**

Table IV. *Peak torque of knee flexion, concentric muscle action (Nm)*

	Right leg						Left leg					
	60°/s			180°/s			60°/s			180°/s		
Age	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI
Men												
40–49	15	100	15	15	77	11	15	89	12	15	67	10
50–59	19	82	9*	20	60	6**	20	72	7*	20	54	6**
60–69	18	71	13*	18	55	8	18	69	10	18	50	7
70–79	14	66	9	14	49	7	14	62	8	14	45	8
Women												
40–49	19	62	7	19	45	5	18	55	5	18	39	5
50–59	15	50	5**	15	37	4*	15	48	5	15	34	5
60–69	27	47	4	27	33	3	27	43	4	27	31	4
70–79	13	34	6**	12	25	6*	13	34	7*	12	24	5

Table V. *Peak torque of eccentric muscle action for the knee-extensors (Nm)*

	Right leg						Left leg					
	60°/s			180°/s			60°/s			180°/s		
Age	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI
Men												
40–49	9	230	41	8	242	47	7	206	38	6	208	54
50–59	15	193	26	16	186	24*	15	195	30	13	177	29
60–69	13	182	47	13	173	45	13	191	33	11	176	30
70–79	10	175	33	8	181	34	9	176	40	9	170	34
Women												
40–49	17	150	21	14	151	20	16	139	18	14	151	17
50–59	10	138	15	9	138	22	11	141	19	10	141	19
60–69	15	125	15	14	122	11	15	125	13	14	129	15
70–79	6	117	25	6	107	29	5	125	24	5	109	26

significantly with age for both men and women, and the right side was highly significantly stronger (Table IV).

In eccentric knee movement at 60°/s and 180°/s, the younger men reached the highest values (Table V). There were no statistically significant differences between the two sides. The peak torque correlated with body height for men ($p < 0.005$, right at 60°/s r: 0.43 and at 180°/s r: 0.45, left at 60°/s r: 024 and at 180°/s r: 0.39,) and highly significantly for women at 180°/s (right r: 0.43, and left r: 0.39) but not for eccentric torque at 60°/s.

Table VI. *Endurance test of the knee extensors*

	Isometric (s)			Isokinetic 180°/s % decrease					
	40% of max			Peak torque			45° knee angle		
Age	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI
Men									
40–49	15	88	14	14	36	7	12	39	6
50–59	20	90	13	14	38	7	14	37	8
60–69	17	91	16	12	42	6	12	42	6
70–79	12	107	25	10	36	5	10	38	6
Women									
40–49	19	99	14	16	35	6	16	37	7
50–59	15	82	11	15	42	6	15	41	7
60–69	27	97	20	25	42	4	25	44	5
70–79	13	82	29	8	42	5	8	43	5

Table VII. *Peak torque of dorsal and plantar/flexors. All tests performed at 60°/s*

Peak torque Nm									
	Concentric			Concentric after eccentric			Eccentric		
Age	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI
Men									
40–49	14	101	12	13	169	18	13	194	21
50–59	20	90	10	20	152	23	20	180	24
60–69	18	79	11	18	133	23	16	167	28
70–79	13	63	12*	12	120	22	12	143	26
Women									
40–49	17	72	7	17	116	12	16	138	15
50–59	15	69	7	14	112	14	14	135	15
60–69	25	56	6**	25	99	13	23	123	16
70–79	11	48	8	11	83	15	11	102	19

Table VIII. *Histochemical analyses*

	Men					Women				
	I	II	IIA	IIB	IIC	I	II	IIA	IIB	IIC
Fiber type distribution, %										
n	40	40	40	40	40	29	29	29	29	29
Mean	36.9	63.1	37.0	25.5	0.7	37.5	62.5	34.1	28.0	0.31
95% CI	4.45	4 45	3.1	3.68	0.35	5.12	5.12	3.671	4.88	0.37
Fiber area, μm^2										
n	40	40	40	40		29	29	29	29	
Mean	6103	5777	6146	5224		4765	3193	3756	2562	
95% CI	459	529	561	496		389	337	399	342	
No. of capillaries per fiber										
n	40	40	40	40		29	29	29	29	
Mean	3.63	2.95	3.17	2.62		3.07	2.20	2.48	1.89	
95% CI	0.22	0.20	0.20	0.21		0.19	0.15	0.190.16		
Fiber area/capillary, μm^2										
n	40	40	40	40		29	29	29	29	
Mean	1709	2005	1975	2062		1590	1484	1545	1392	
95% CI	125	183	175	217		156	175	166	199	

Isometric endurance at 40% of isometric peak torque at a 60° knee angle was measured in seconds. The older men (70–79 years) showed the greatest endurance but, on the other hand, the younger (40–49 years) women showed greater endurance than the older women (70–79 years) (Table VI). All age groups had recovered, i.e. could perform more than 95% of peak torque, after 5 minutes. Isokinetic endurance, measured as percentage decline in peak torque after 50 maximal extensions at 180°/s,

Table IX. *Enzymatic assays, μmol/min × g protein*

	HAD	CS	TPDH	LDH	MK	Protein
Men						
n	40	40	40	40	40	40
Mean	36.29	36.13	1490.5	882.6	989.3	192.4
95% CI	2.40	2.67	81.12	102.7	54.3	2.27
Women						
n	28	28	28	28	28	28
Mean	33.67	30.89	1175.8	586.3	863.2	186.8
95% CI	2.27	2.51	105.8	96.47	79.58	3.37

showed little difference between age groups (Table VI). We did not find any relationship between activity level as evaluated with PASE and muscle endurance.

Performance in plantar/flexors was enhanced by approximately 60% by a preceding eccentric movement before the concentric movement, compared to a pure concentric action (Table VII).

Isometric plantar flexion gave somewhat different results depending on the foot device, but with no consistency. Regression analysis showed a relation between age and plantar flexion, men ($p < 0.05$) and women ($p < 0.01$), and a highly significant relation between age and dorsal flexion.

The results of the biopsies showed no significant changes with age in fiber type distribution, fiber area and capillarization, except in a few of the variables (Table VIII). There were no significant differences in fiber type distribution between men and women, except for type IIC ($p < 0.0292$). The fiber areas were significantly larger for men in type I fibers ($p < 0.0002$) and highly significantly larger for type II fibers, including IIA and IIB. The capillary count was significantly higher for men in type I fibers ($p < 0.0004$) and highly significant for type II fibers including IIA and IIB. The difference between men and women regarding fiber area per capillary count was non-significant for type I fibers, but significant for type II ($p < 0.0003$) and type IIA ($p < 0.0015$) and highly significant for type IIB fibers. The difference between men and women was non-significant for HAD (Table IX). For the other enzymes, there were significant differences; CS ($p < 0.05$), MK ($p < 0.01$) and highly significant changes for both TPDH and LDH. As can be seen in Fig. 3, there seems to be a decline with age in peak torque during fast motion, area of type II fibers and activity level of TPDH. This was not the case for endurance, fiber area of type I, or regarding endurance, fiber area of type I or HAD.

DISCUSSION

The aim of this study was to investigate an urban population of 40–79-year-olds randomly chosen to evaluate the influence of age and activity level on muscle strength and endurance, in order to establish a good reference material that included biopsies. We also wanted to test muscle performance in functional exercises often employed by physical therapists.

Of the 639 persons contacted, 23% were willing to participate. The final number of participants was chosen on the basis of our aim to have at least six biopsies in each decade. A participation rate of 23% may be too low to be representative. To evaluate whether the sample was representative, we compared our population with the population-based WHO MONICA study (34) in Göteborg. The populations were similar in terms of background data (age, height, BMI).

Walking speed had previously been determined in two groups of 70-year-olds (35, 36) in a population study, and their walking speed was found to be somewhat slower than that in the oldest group in our study. This is probably partly due to the lower average age in our study compared with the two previous

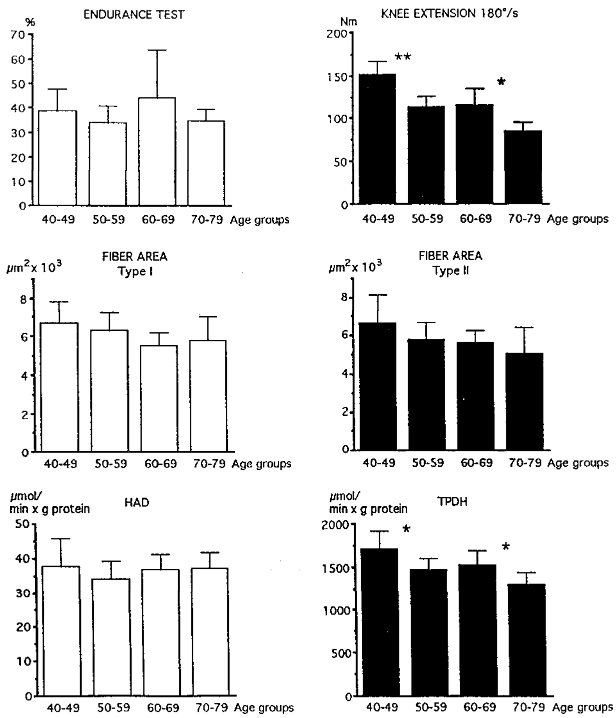

Fig. 3. Neither isokinetic endurance, type I fiber area nor the enzymatic activity of 3-hydroxy-acyl CoA-dehydrogenase seems to change a great deal with age. The decline in rapid movement with age, as shown for 180°/s, corresponds to a decline in type II fiber area and the enzymatic activity of triosephosphate dehydrogenase. All data shown are for men, but the trends are similar for women. Average values and 95% CI shown, $p < 0.05$.

studies; different test set-ups may also account for some of the variations.

Lunsford & Perry recently (37) argued for 25 repetitions of heel-rises as a normal reference value, based on a material including 122 males (average age 34.7) and 81 females (average age 29.3), where 25 was the lower 99% confidence interval. In this study the heel-rise test gave somewhat different results. There are differences in study set-ups, however, where Lunsford & Perry's study (37) is probably a convenient sample, and the mean age was below 40 for both sexes. The range in their study is also very large (6–70 for men and 7–51 for women). In the present study, we had less variation. We started with the foot in a dorsiflexed position on a 10°-tilted wedge, whereas Lunsford & Perry (37) started with a foot angle of 90°. Referring to their test results, they propose that 25 heel-rises be performed if a "normal" plantar flexion is present. From the results of our study, we can propose 22 heel-rises as a "normal" lower limit for men and 17 heel-rises as a "normal" lower limit for women, using the test set-up in the present study.

The results of the hand-grip test, both peak maximum grip force and sustained force over 10 seconds, were higher than has been previously reported with the same instrument (6). This is probably because of the different test procedures used. In this study, the subjects were encouraged verbally to do their best, while in the former study (6) the subject was given no indication of his/her performance. The original article in which PASE (19) was presented indicated a correlation between hand grip and activity level. We confirmed this in our study.

A reduction in muscle strength with age has been described in several studies (9, 38, 39). Borges (9) found a statistical decline in strength with age for isokinetic knee extension in men from 20 to 30 years of age, in women from 40 to 50 years of age and from 60 to 70 years of age in both sexes. Isometric strength decreased in that study only between 60 and 70 years of age. We found a significant decrease only at 60°/s for men in the 40–49 and 50–59-years age groups; the results were similar for the women (although not significant). We found a significant decrease in isometric strength in the left leg among men from 40 to 49 to 50 to 59 years and in women from 60 to 69 to 70 to 79 years. There are some differences between our study and that of Borges (9), which can partly be explained by, for example, different angular velocities, a different population selection and different isokinetic devices (40). Bohannon (12) also reports a decline in strength with age, but the correlation is not very strong, which he finds surprising. However, this is in accordance with the present study. As reported earlier (9), a correlation was found between body height and peak torque, which was not seen as convincingly in a study by Aniansson et al. (1). We did not find any correlation between isokinetic peak torque and activity level, as previously reported in the elderly when PASE was introduced (19). However, our population was younger and we used different equipment.

The peak torque for concentric plantar flexion was enhanced when an eccentric muscle action preceded the concentric flexion. This is consistent with the results of Svantesson & Grimby (28) among a selection of young and old men and women concerning percentage increase in concentric torque preceded by an eccentric muscle action, as in a stretch shortening cycle. As in their study, no change was noted in the effect of a preceding muscle action with age.

The wide individual variations in fiber type distribution, area and capillarization (13, 17) indicate the need for a control material of good size when comparing biopsies after different pathologies. The subgroup is nevertheless representative for the whole group (Fig. 3). Our material is too small to show any convincing significant differences with age, although the trend is toward smaller fiber size. Larsson et al. (2) showed an increase of type I fibers and a corresponding decrease in type II fibers with age for men. Lexell & Taylor (41) studied cross-sections of whole vastus lateralis muscle from 20 men, 19–84 years of age, where the cross-sectional areas of type I and type II fibers were measured in five different regions. They showed a reduction with age in fiber size for types I and II, significantly so for type II fibers. They also observed a variation within the regions, where there was a larger variation in type II fibers in the older muscles than in the younger muscles. There is always a question of the representativeness of a single biopsy (41, 42), but it was not considered feasible to conduct multiple biopsies in a population-based material.

As far as we know, this is the first major study of a sample population in which persons of different ages have been examined with respect to diverse muscle functions, including biopsies. The results ought to be of relevance as reference material to both research and clinical work in rehabilitation medicine and in physical therapy.

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