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ISOMETRIC MUSCLE STRENGTH AND MUSCULAR ENDURANCE IN NORMAL PERSONS AGED BETWEEN 17 AND 70 YEARS

E. Bäckman,[1] V. Johansson,[1] B. Häger,[1] P. Sjöblom[1] and K. G. Henriksson[2]

From the Departments of [1]Clinical Neurophysiology and [2]The Neuromuscular Unit, University Hospital, Linköping, Sweden

ABSTRACT. Isometric muscle strength was measured in 63 women and 65 men, randomly selected, aged 17–70 years, using Penny & Giles' hand-held dynamometer. Eight muscle groups as well as the hand grip strength were tested bilaterally. The muscular endurance was measured as time to exhaustion in the abductors of the shoulder and the flexors of the hip. Reference values for muscle strength and muscular endurance are given in the age groups 17–18, 20–29, 30–39, 40–49, 50–59 and 60–70 years of age. The mean strength of females was about 65–70% of that of the men, but when the results were related to weight, the differences almost disappeared. Both men and women seem to have the greatest muscle strength at the age of about 17–18. The strength is rather constant up to the age of about 40 years, after which a discrete decline is seen up to about 60, from where the decline is more obvious. Muscular endurance showed great variability between individuals. However, no decrease in endurance was seen in older ages. For both sexes, lower reference limits of endurance, with the methods used, for arm abductors are suggested as being 3 minutes and for hip flexors, 90 seconds.

Key words: adults, muscle strength, muscle endurance.

INTRODUCTION

Assessment of neuromuscular functions and evaluation of isometric muscle strength is part of any routine neurological examination. The 0–5 scale designed by the Medical Research Council in Great Britain (MRC-scale) (23) gives only an estimation of muscle strength. This scale is more accurate in severe weakness, but less so when normal and slightly decreased muscle strength is evaluated. There is a need for measurements of isometric muscle strength, not only for estimations. Measurements instead of estimations are, for example, to be preferred to follow the course of a neuromuscular disease and to evaluate the effect of physical therapy and other types of treatment.

Reference values for muscle strength are especially needed to determine whether a pathological muscle weakness is present or not in a person who complains of decreased muscle strength and endurance, but has no obvious weakness on manual muscle testing.

Some studies of isometric muscle strength have been reported in the literature with various kinds of myometers (3, 14, 28). Hand-held myometry, which is used in our study, has been used with different kinds of myometers mostly in children, but also in adults, and the methods have been found to be very reliable (5, 11, 26, 27). In children, the standard error of a single determination made by the same observer was found to be about 9% of the muscle strength. In children tested four times by four different investigators, the coefficients of variation of measurement error varied between 8% and 11% (5). Thus, the reproducibility of this method is acceptable for a method to be used in clinical practice.

The main purpose of this investigation was to obtain reference values for muscle strength and endurance at different ages for both men and women. Reference values for children in different ages have been published earlier (5).

Muscle strength as it is measured or estimated in routine clinical practice depends on nervous, muscular and biomechanical factors.

The nervous factors include degree of cooperation, motivation, and ability to activate all motor units, and to do so with optimal frequency. The degree of central activation can only be evaluated in routine clinical practice. With techniques like the interpolating twitch technique (8), the degree of central activation of motor units can be measured in a few muscle groups, but this test is not used in routine practice. Great variation in results of three consecutive tests is,

Table I. *Values of weight and height in different ages for women and men*
n = number of subjects. Values of age, weight and height are given as mean ± SD.

Women				Men			
n	Age (years)	Weight	Height	n	Age (years)	Weight	Height
10	17.7 ± 0.6	58 ± 10	166 ± 8	10	17.6 ± 0.6	76 ± 7	186 ± 7
10	23.4 ± 2.7	61 ± 8	170 ± 9	12	24.4 ± 3.3	71 ± 9	176 ± 7
10	34.8 ± 3.0	63 ± 6	168 ± 7	11	35.1 ± 2.6	82 ± 11	182 ± 8
13	43.1 ± 2.8	63 ± 11	166 ± 6	10	43.8 ± 3.5	74 ± 9	180 ± 6
10	54.0 ± 2.9	64 ± 8	168 ± 7	10	54.0 ± 3.3	76 ± 5	180 ± 6
10	65.4 ± 2.8	64 ± 2	163 ± 8	12	65.6 ± 3.1	75 ± 7	178 ± 4

for example, an indication of poor cooperation and, consequently, at least three tests should be performed at each examination.

The test situation is also of great importance; distraction must be reduced to a minimum (9) and the subject must be enthused to perform maximally (16, 32).

The muscular factor is related to the amount of contractile proteins. This means that strength is correlated to the muscle fibre area or, approximatively, the muscle cross-section area. Among the biomechanical factors, the positions of the extremities, as well as of the patients, and the length of levers used are of importance, and therefore the examination should be strictly standardized.

The presence of muscular pain makes measurements uncertain, and the intensity of pain during the test should be recorded.

One way of testing muscular endurance is to measure time to exhaustion, while the muscle is subjected to a standardized static load. The static load can be a certain percentage of maximal voluntary contraction strength or the weight of an extremity. In this study we have used the second alternative as it is an easier method to use in clinical practice. Pain is elicited during an endurance test. The intensity of pain should be recorded in order to be able to establish whether the person finishes the test because of pain or because of perception of exhaustion. In clinical practice, muscle endurance is usually measured as the time to exhaustion in muscle groups that are exposed to a standardized load. The fact that both pain and perception of exertion determine the endpoint of the test sometimes makes it difficult to judge whether the result of the test is a measure of muscle endurance or a measure of pain tolerance.

This paper gives reference values for isometric muscle strength and for muscular endurance in a randomized, healthy adult population, aged 17–70 years.

MATERIAL AND METHODS

Material

The subjects were selected in two ways: One group was randomly selected from the national population register. The other group consisted of all healthy adults living in a defined, randomly chosen, geographic area of Linköping, Sweden. We randomly chose 145 persons, aged 17–70 years, and 128 of them participated in the study. Eight had some form of chronic disease and were therefore discarded, and 9 were not interested in participating. The mean values of body weight, body height and the number of subjects in different age groups are presented in Table I.

Methods

Muscle strength. Isometric muscle strength was tested with a portable electronic dynamometer (Myometer, Penny & Giles Transducers Ltd, Dorset, England). Three of the authors took active part in the testing. The operating range of the dynamometer was 0–60 kg and the accuracy was found to be ± 0.6 kg (25). The muscle groups tested, the sites of application of resistance and the way of fixation are presented in Table II. The joint angles are described according to the recommendations of the American Academy of Orthopedic Surgeons (1). Eight muscle groups were tested bilaterally, three times each, with an interval of 3–5 minutes. The maximum value of measurements was used, as was the breaking force technique. Left or right handedness was noted for all persons. The results of the non-dominant side, which was defined as the left side in the upper as well as the lower extremity if the person was right-handed, are presented. Values of strength of the non-dominant side were considered to be less dependent on motor skill than at the dominant side.

Hand grip strength was measured with a strain gauge (Rank Stanley Cox), with a graded scale of 0–100 units, one unit(y) corresponding to the developed force in Newton(x) according to the formula $y = 0.80 + 0.13 \times$ (21). The size of the grip was 62 mm. The measurements were made in a sitting position, with the elbow bent 90° and with the arm supinated. The same instrument was used in all

Table II. *Muscle groups tested, the sites of fixation and application of resistance, the position of the subject and the joint angle (1)*

Muscle group	Subject's position Joint angle	Immobilization	Applicance of resistance
Elbow flexors	Sitting 90°	Posterior aspect of upper arm just above the elbow, keeping the joint free.	Flexor surface of forearm, just above the wrist.
Knee extensors	Sitting 0°	Posterior aspect of thigh, just above the knee.	Anterior aspect of lower leg, just above the malleoli.
Ankle dorsal flexors	Sitting 0°	Posterior aspect of the leg, just above the ankle, avoiding pressure on the tibialis anterior.	Dorsal aspect of the foot proximal to the metatarsophalangeal joint.
Shoulder abductors	Sitting neutral position 90°	Over the middle third of the shoulder, keeping the joint free. Shoulder elevation is prevented.	Dorsal part of the arm, just proximal to the wrist.
Hip flexors	Supine 90°	The pelvis is held at the iliac crests	Anterior aspect of the distal third of the thigh.
Hip abductors	Supine 30°	The pelvis is held at the iliac crests.	Lateral aspect of the distal third of the thigh.
Knee flexors	Prone 90°	The pelvis is pressed against the couch.	Posterior aspect of the distal third of the leg, just above the ankle.
Wrist dorsal flexors	Supine 70°	Distal third of the ventral aspect of the forearm.	Dorsum of the hand.

measurements. Three maximal contractions were performed, and the highest value was used. The results of the non-dominant side are presented.

Muscular endurance. The muscular endurance was measured as 1. the time the person could sit with the arms abduced 90° from the neutral position. 2. the time they could lift the leg of the dominant side 30° up from the bench while lying in the supine position.

The perception of pain during the investigation was measured by the persons on a visual analogue scale (VAS), graded 0–10 (19). They also noted their perception of exertion on the Borg-scale, graded 6–20 (6). Persons with a perception of exertion of less than 17 during the endurance test were excluded from the endurance study.

Statistics

The results are given as means ±1 standard deviation. Student's *t*-test was used for statistical analysis of significance. For tests of significant differences between the dominant and non-dominant sides, Student's paired *t*-test was used. Regression analyses were performed to analyze the relationship between strength and on strength influencing variables.

RESULTS

Dominant vs non-dominant side

Mean values were obtained for muscle strength in 8 muscle groups on the dominant and the same number on the non- dominant side in the 6 age groups. Thus, in all, 48 muscle groups were tested on the dominant side and 48 muscle groups on the non-dominant side. In the whole material, 7 men and 8 women were left-handed.

In most muscle groups, no significant differences in muscle strength were found between the two sides. However, the values for isometric muscle strength showed slight, but significant, differences between the dominant and non-dominant side in 8 of these 48 pairs of muscle groups. In 6 of them, the values were higher on the dominant side. For example, in women 40–49 and 60–70 years old, the strength of the elbow flexors of the dominant side was more pronounced than on the non-dominant side.

In men in all age groups except two and in women in all age groups except one, the hand grip strength was significantly higher on the dominant side.

Muscle strength and endurance in women

Muscle strength. The results of isometric muscle

Table III. *Muscle force in Newton (N), in the non-dominant body-half for women (w) and men (m) of different ages*

Values are given as mean ± SD.

	Age	17–18	20–30	30–40	40–50	50–60	60–70
Elbow flexors	w	202 ± 29	197 ± 27	231 ± 32	216 ± 46	210 ± 30	170 ± 42
	m	347 ± 31	365 ± 84	372 ± 56	330 ± 69	367 ± 56	328 ± 60
Knee extensors	w	367 ± 112	268 ± 75	306 ± 99	266 ± 71	241 ± 65	245 ± 67
	m	403 ± 132	436 ± 85	407 ± 122	422 ± 107	381 ± 116	354 ± 92
Ankle dorsal flexors	w	394 ± 52	370 ± 72	383 ± 89	335 ± 79	354 ± 74	343 ± 68
	m	473 ± 86	469 ± 84	491 ± 71	447 ± 71	465 ± 98	434 ± 67
Shoulder abductors	w	83 ± 18	84 ± 13	96 ± 20	80 ± 13	83 ± 22	69 ± 17
	m	128 ± 16	141 ± 33	132 ± 36	137 ± 27	135 ± 23	119 ± 27
Hip flexors	w	246 ± 44	230 ± 36	224 ± 37	219 ± 40	211 ± 41	183 ± 20
	m	351 ± 32	328 ± 51	323 ± 84	328 ± 57	308 ± 67	273 ± 60
Hip abductors	w	443 ± 107	380 ± 94	380 ± 64	349 ± 86	320 ± 60	273 ± 61
	m	513 ± 59	467 ± 97	442 ± 98	455 ± 95	454 ± 91	390 ± 97
Knee flexors	w	236 ± 57	190 ± 44	177 ± 45	152 ± 32	144 ± 46	119 ± 73
	m	287 ± 50	246 ± 47	242 ± 45	207 ± 34	211 ± 35	162 ± 40
Wrist dorsal flexors	w	187 ± 32	185 ± 56	195 ± 18	178 ± 32	192 ± 39	165 ± 36
	m	274 ± 15	238 ± 53	235 ± 59	264 ± 31	270 ± 48	209 ± 44

strength in the non-dominant side are presented in Table III. Usually, the highest values of isometric muscle strength were found in the younger age groups. In 5 of the 8 muscle groups investigated, the highest strength was found in the youngest age group. In 6, the weakest muscle strength was found in the oldest age group.

On the non-dominant side, the strength of the *elbow flexors* was significantly lower for the oldest age group than for all other age groups but the two youngest ones.

In the *ankle dorsal flexors*, no significant changes were found throughout the age groups.

In the *shoulder abductors*, significantly less strength was found in the oldest age group compared with that of the 20–29-year age group.

The *hip abductors* displayed a significant decrease of muscle strength already in the 50–59-year-olds compared with that of the younger age groups, and in comparison with the youngest, the 40–49-year-olds were also weaker.

In the *knee extensors*, the youngest age group showed significantly greater strength than the other age groups except the 30–39-year-olds.

In the *dorsal flexors of the wrist*, significantly less muscle strength was found in the oldest age group compared with that of the 30–39-year-olds. No other significant differences were found.

In the *hip flexors*, a significant decrease of the muscle strength was found in the oldest age group compared with that of the 40–49-year-olds and younger, but not in comparison with that of the 50–59-year-olds.

In the *knee flexors*, a significant decrease of muscle strength was found in the 50–59-year-olds when compared with that of the youngest age group, while the strength values for the oldest age group were significantly lower than those of the two youngest age groups. In the knee flexors, the youngest age group showed higher strength values than all but the 20–29-year-olds.

Hand grip strength on the non-dominant side remained unchanged through the ages up to the 60–70-year-olds, in whom a significant reduction was seen. The highest values were found in the age group 30–39 years. The results of the test of hand grip strength, non-dominant side, are presented in Table IV.

Table IV. *Hand grip strength in newton (B) in various ages, non-dominant side*

Age	17–18	20–30	30–40	40–50	50–60	60–70
Women	272 ± 54	293 ± 54	322 ± 50	312 ± 44	309 ± 33	245 ± 44
Men	470 ± 23	453 ± 78	494 ± 73	493 ± 59	480 ± 59	445 ± 52

Table V*a*. *Muscular endurance in seconds (s) for the arm abductors bilaterally and the hip flexors of the dominant side side in women*

Values are given as mean ± SD and median values for the endurance time of arm abductors, hip flexors, and for the estimation of pain at the end of the endurance tests according to the VAS scale (units). Only persons with an RPE-estimation of 17 or more are included.
n: number of persons included.

Women, arm abductors						
Age	17–18	20–30	30–40	40–50	50–60	60–70
Mean ± SD	491 ± 237	401 ± 106	451 ± 118	432 ± 181	515 ± 229	445 ± 167
n	10	10	9	11	8	9
Median	445	372	480	344	473	338
VAS	8.1 ± 1.9	5.5 ± 2.9	5.7 ± 3.1	3.6 ± 2.6	5.1 ± 3.2	2.4 ± 1.5
VAS median	8.6	5.2	4.7	4.5	5.6	3.0
Women, hip flexors						
Age	17–18	20–30	30–40	40–50	50–60	60–70
Mean ± SD	212 ± 70	182 ± 58	191 ± 40	204 ± 81	162 ± 99	203 ± 92
n	9	9	7	8	6	7
Median	180	185	200	198	130	192
VAS	7.7 ± 1.4	3.6 ± 2.9	4.0 ± 3.1	3.0 ± 2.1	2.8 ± 2.8	4.2 ± 2.9
VAS median	7.7	2.2	3.0	2.6	2.2	4.2

Table V*b*. *Muscular endurance in seconds (s) for the arm abductors bilaterally and the hip flexors of the dominant side in men*

Values are given as mean ± SD and median values for the endurance time of arm abductors and hip flexors and for the estimation of pain at the end of the endurance tests according to the VAS scale (units). Only persons with an RPE-estimation of 17 or more are included.
n: number of persons included.

Men, arm abductors						
Age	17–18	20–30	30–40	40–50	50–60	60–70
Mean ± SD	362 ± 129	605 ± 270	531 ± 304	590 ± 315	470 ± 156	711 ± 725
n	10	12	10	9	10	11
Median	312	496	383	495	452	394
VAS	9.2 ± 0.7	6.0 ± 3.5	7.0 ± 2.4	7.2 ± 2.6	5.6 ± 2.9	6.3 ± 2.2
VAS median	9.3	6.7	7.6	8.2	5.0	5.8
Men, hip flexors						
Age	17–18	20–30	30–40	40–50	50–60	60–70
Mean ± SD	203 ± 95	401 ± 151	245 ± 110	302 ± 92	269 ± 163	306 ± 153
n	10	10	9	9	7	6
Median	312	387	201	309	193	254
VAS	8.9 ± 1.0	5.7 ± 3.5	7.1 ± 2.5	7.2 ± 2.2	5.7 ± 2.1	6.2 ± 3.5
VAS median	9.0	6.8	8.3	7.7	4.8	6.6

The correlations bertween weight and muscle strength in different muscle groups were generally low. They varied in the non-dominant side for women between −0.052 and 0.339. Multiple regression analyses including the variables age, height, and weight, also revealed that the age of the tested person is the factor that most influences the results.

Muscular endurance

Muscular endurance, measured as the time the person could keep the arms abduced 90° from neutral position or keep the dominant leg lifted 30° from the bench, showed no significant change with age. The perception of pain at the end of the endurance tests was significantly higher in the youngest age group than in any of the other age groups both with regard to arm abduction and hip flexion, and significantly lowest for the oldest age group in the arm abduction test (Table V*a*).

The range for arm abduction was 215–970 seconds, while the range for hip flexion was 37–370 seconds (2 women had shorter hip flexion time than 90 seconds). Seventy-five percent of the women reaching an RPE of 17 or more could keep the arms abducted at least 330 seconds and keep the leg lifted 30° from the couch for at least 134 seconds.

The results of the endurance tests, including perception levels of pain at the end of the tests, are presented in Table V*a*.

Muscle strength and endurance in men

Muscle strength. The results of isometric muscle strength on the non-dominant side are presented in Table III. Usually, the highest values of isometric muscle strength were found in the younger age groups, and in 4 of the 8 muscle groups investigated the highest strength was found in the youngest age group (Table III).

In all the muscle groups the weakest muscle strength, although it did not always reach significance, was found in the oldest age group.

No significant changes of strength throughout the age groups were found in the *elbow flexors, ankle dorsal flexors*, or *shoulder abductors*. In the *hip abductors*, the only significant difference was found between the youngest and the oldest age groups.

In the *knee extensors*, values of the oldest age group were significantly lower than those of the 20–29 year-olds.

In the *dorsal flexors of the wrist*, the values for the oldest group were significantly lower than the values for the 40–49 and 50–59-year-olds as well as for the youngest age group.

In the *hip flexors*, the values for the oldest group were significantly lower than those of the 17–18, 20–29 and 40–49 year-olds.

In the *knee flexors*, the values for the oldest age group were significantly lower than for all the other age groups, while the values for the youngest age group were higher than for all other age groups.

The values of *hand grip strength* showed no significant differences between the different age groups. The highest values were found in the age group 30–39 years old. The results of the test of hand grip strength, non-dominant side, are presented in Table IV.

The correlations between weight and muscle strength in the different muscle groups were generally low. They varied, in the non-dominant side in men, between 0.027 and 0.238. Multiple regression analyses including the variables age, height, and weight, also revealed that the age of the tested person is the factor that at most influences the results.

Muscular endurance. The men in the youngest age group showed a significantly shorter time than men 20–29 and 40–49 years of age in the endurance test, which was measured as the time the person could keep the arms abducted 90° and the hip flexed 30°. In the hip flexion test, the 20–29-year-old men also showed significantly higher endurance than the 30–39-year-olds. No other significant differences in the endurance between the age groups were found.

The range for arm abduction was 212–2701 seconds and for hip flexion 122–729 seconds. Seventy-five percent of the men reaching an RPE of 17 or more could keep the arms abducted for at least 328 seconds and keep the leg lifted 30° from the couch for at least 160 seconds.

The perception of pain at the end of the shoulder abduction test showed higher values in the youngest age groups than in the other age groups. From the age of 30–39 years, no changes in perception of pain concerning arm abduction were found in the different age groups. This was also true of hip flexion from age 20–29 years. The perception of pain in the hip flexor endurance trial was significantly highest in the youngest age group.

The results of the endurance tests, including perception levels of pain at the end of the tests, are presented in Table V*b*.

Comparison of men and women

In comparing men and women, we found that the average isometric muscle strength for women was about 70% (range 52–91%) of that of the men in all age groups. For hand grip strength, the results for women were about 65% of that of the men in all age groups but the youngest and the oldest, where the women had only 58 and 55%, respectively, of the strength of the men.

In both endurance tests, the endurance values were significantly higher for men in the age group 20–29 years old than for women of that age group. In the hip flexor endurance test the values were significantly higher for 40–49-year-old men, than for women. Ageing *per se* did not show any consistent tendency to decrease the endurance. Generally, the perceived pain was higher in men than in women although the values reached significance only for the difference between men and women in the age groups 40–49 years and 60–70 years concerning arm abduction, and in the age groups 30–39 years and 40–49 years concerning the hip flexor trial. In the test of hip flexor endurance, 25–50% of the older men and women interrupted the examination before they had come to the level of exhaustion, defined as an RPE-value of 17 or more.

DISCUSSION

Investigations in children have shown that measurements of muscle strength with the Penny & Giles dynamometer give reproducible results (5, 11). The reproducibility is acceptable for a method to be used in clinical practice. The standard error of a single determination made by the same observer is roughly 9% of the strength (5). Standardization of the position of the body as well of fixation points and dynamometer positions are of the greatest importance for obtaining reproducible results. This is also true of the hand grip strength measurement. Nordenskiöld measured hand grip strength in healthy women, mean age 40 years, age range 23–65 years, with the elbow flexed 100° and the arm in a half-pronated posture, and received strength results for 'medium grip, left hand' of 307.1 ± 61.8 N. (24). In women 20–60 years of age (mean age 39.6 years), the hand grip strength at the non-dominant side in our investigation was 305.4 ± 44.5 N. Although there are small differences in the position of the hand and arm, and there also might be some small difference in the size of the hand grip of the instrument in our investigation compared with hers, there seems to be a good correlation between our values.

In the earlier investigations of muscle strength in children, we measured the circumferences of upper and lower arm, as well as the circumferences of the thigh and the calf. We also measured the lever lengths for all examined muscle groups in order to achieve better standardization and better prediction power of the reference values. However, when the results were statistically analysed, we found that the factors age and weight were those that contributed the most to the strength values, and that adding the factors 'height' or other anthropometric variables did not significantly improve prediction (4). In this study, we have discussed the strength values mainly in relation to weight differences due to sex.

The present study shows that it is difficult to predict strength on the basis of weight or height. It was also shown that one should be hesitant to draw conclusions from strength in one muscle group to strength in another muscle group in the same person. However, there was a good correlation between strength in one muscle group on the dominant side and strength of the corresponding muscle group on the non-dominant side.

Muscle strength can be measured either as a 'make-test' where the maximal voluntary strength is recorded, or as a 'break-test', where also eccentric strength is included. The rationale for the 'break-test' has been discussed by Ploeg & Oosterhuis (27). The advantage of the 'break-test' according to these authors is that it is easier to produce a real maximal contraction in an eccentric movement. Besides, the subjects co-operate better in a 'break-test' than in a 'make-test'.

In young women a muscle strength of about 65% of that of men has earlier been shown, but the difference disappears, at least partly, when the values of muscle strength are correlated to the body weight of men and women (2, 12, 17). Our findings are in line with these results as in our material the women have a body weight of 76–86% of the men, while their muscle strength is 52–86% of that of the men. The variations of strength between persons in the same age group, cannot only be explained by differences in weight.

It should be noted that in some muscle groups there was no decline in strength due to ageing, while in other muscle groups a decline was recorded. This difference may merely reflect the fact that the bio-mechanical factors in the test situation differed between different muscle groups. A small decline of strength may be detectable only if the length of the used lever is long enough.

The differences of mean strength in any muscle group in the different age groups are not pronounced. In fact, the highest value in the total material minus 1 SD in 13 of the 16 muscle groups was less than the lowest value plus 1 SD. The lowest strength values were found in the highest age group in 6 of 8 muscle groups in women and in all 8 muscle groups in men. The highest mean values were all recorded in the 3 youngest age groups (17–39 years).

Our data indicate that the highest muscle strength during life-time is found at the age of about 17–18 years. For women in this age group, we found a very strong significance with a p-value < 0.001 in 3 of the 8 muscle groups (hip flexors, hip abductors and knee flexors) compared with the oldest age group, and in knee flexors compared with the 50–59-year-olds and the 40–49-year-olds. In men, we found a p-value < 0.001 in knee flexors and dorsal flexors of the wrist when comparing the youngest with the oldest age group. In no other comparison between different muscle groups in different ages did we find such high *p*-values.

When comparing the values for 17–18-year-olds with the reference values of strength for 13.5–15-year-old teenagers (5), all strength values except those for the hip flexors in women were higher in the 17–18-year-old age group, when the same technique was used.

In a study by Larsson et al. (20) it was shown that isometric strength in the quadriceps muscle in men increased up to the third decade, remained almost constant up to the fifth decade and then decreased with increasing age. Borges et al. (7) found conflicting results while examining especially men 20–70 years of age, in whom they found a great decrease in the strength of knee extensors and flexors between 20 and 30 years. The strength remained at about the same level between 30 and 60 years, whereafter there was a decline with age.

In another study, Asmussen & Heeböll Nielsen (2) showed that isometric strength is rather constant in the age group 20–39 years, and then begins to decline. However, the decrease in strength is rather discrete up to the age of about 60 years, after which it declines more obviously. The strength in a muscle group depends partly on the muscle transverse area, and it has been shown that ageing atrophy at least in the vastus lateralis muscle begins at about the age of 25 years, and accelerates rapidly after the age of about 50. Measurements of the size of muscle fibres in the lateral vastus muscle showed a reduction of the area of 10% from 25 years of age up to 50 years of age. At the age of 80, about half of the muscle volume had disappeared (22).

Another study has shown that only minor changes in muscle volume take place up to the age of 70 (31). The degree of age-related atrophy may differ from one muscle to another. Some studies show a greater volume loss in men than in women at higher age (31), and other studies show more pronounced muscle hypotrophy in women after menopause than in men (15). Other physiological mechanisms have been discussed as causing the decrease of muscle strength. Changes in the 'neuromuscular system' (13), changes in protein metabolism and the contractile system (10, 13) as well as the 'male climacterium' (18, 30) have been discussed.

One can never be sure that the point of exhaustion in a test that is based on voluntary static contraction really represents the maximal endurance capacity of the muscle group tested. The results gave some practical guide lines, however. All subjects in all age groups reaching an RPE of 17 or more could keep the arms abducted for at least 212 seconds. All the men could keep the leg lifted 30° from the couch for at least 122 seconds, and all women but 2, for at least 109 seconds. Seventy-five percent of the men and women reaching an RPE of 17 or more could keep the arms abducted for at least 328 and 330 seconds, respectively. Seventy-five percent of the men reaching an RPE of 17 or more could keep the leg lifted 30° from the couch for at least 160 seconds, while the level for the women was 134 seconds.

The endurance investigation shows that younger persons do not have higher endurance than older ones. The age group with least endurance was actually the 17–18-year-old men. The reason for that is unclear.

In fact, the man with the best endurance capacity was a man of 69 years. He could sit with the arms abducted for 45 minutes and 1 second (RPE 19) and lie with the hip flexed for 13 minutes and 23 seconds (RPE 15)!

Young men in the age group 20–29 years showed higher endurance than women in both the endurance tests. Men in the age group 40–49 years showed higher endurance in the arm abduction endurance test than women of the same age. The motivation of the persons influences the results of the muscle strength tests as well as those of the muscular endurance tests. Pain during the test can also influence both the motivation and the ability to fully activate all motor units. In the youngest age group both women and men perceived higher pain than in the other age groups. However, only the men showed lower endurance time values compared to the other age groups.

As a lower reference limit for muscular endurance, we suggest 3 minutes for arm abduction and 90 seconds for hip flexion for women as well as for men. In our material, no men had endurance values below these limits. Two women, from the 50–59 and 60–69 years groups, respectively, had values below the reference values of the hip flexors.

Women 40–49 years of age perceived significantly lower pain in both types of endurance test than men. Further, women 30–39 years perceived less pain in the hip flexor endurance test and 60–69-year-old women perceived less pain in the arm abductor endurance test. The grading of pain perception on the VAS scale is a comparison between the actual pain and earlier pain experience. The experience of pain may be different between men and women, young and old, which at least partly could explain differences between the sexes in grading pain perception.

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Address for offprints:

E. Bäckman
Dept. of Clinical Neurophysiology
University Hospital
S-581 85 Linköping
Sweden