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LEG MUSCLE STRENGTH IN BELOW-KNEE AMPUTEES

By

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In a series of unilateral below-knee amputees using a prosthesis, the isometric contraction power on flexion and extension of the hip joint on the amputated side, and of the hip and knee joints of the other side was studied. The aim of the investigation was to study the extent to which amputation and the use of a prosthesis affected the muscle strength. This is of interest in the question of whether physical capacity and mobility, *e.g* the distance which can be walked, is limited by reduced muscle strength.

MATERIAL

Twenty patients, eighteen men and two women, were selected at random from a follow-up series of unilateral below-knee amputees (ten right sided and ten left sided), who had used a prosthesis for at least one year. The mean age was 39.4 years (range 15–58 years). The average time since the first amputation was 12.5 years (range 1–43 years). The reason for amputation was in most cases accidental injury. No patients had been amputated because of circulatory disturbances. None of the patients had clinical signs or a history of any other disease or injury that could limit his walking capacity.

The patients were informed beforehand that the investigations were of a purely scientific nature and that the results would not be used for disability assessment.

METHODS

The muscle strength in the lower extremities was measured by four different tests. These tests comprised measurement of the maximal isometric contraction power in the flexors and extensors of the hip joints and also in the flexors and extensors of the intact knee joint, by methods described by *Asmussen, Heebøll-Nielsen & Molbech* (1959), *Bonde Petersen* (1960), and *Asmussen & Heebøll-Nielsen* (1961).

The dynamometers were based on the strain-gauge principle. An amplifier (KWS/T-5) + a coupling unit UDS/II-5: Hottinger—Messtechnik, Darmstadt, Germany) were used both to supply current to the bridges and for amplification of the output signals. The output signals were recorded with a potentiometer writer (H. pot. recorder, Control Instruments Ltd., Birkenhead, England). Each part of the test was performed by the patient three times, the criterion for an acceptable result being that the two best efforts at least, should show good mutual agreement. At each part the minimum duration of muscle contraction was 3 seconds. When assessing the results, values produced by a transient muscle jerk were excluded by eliminating the peak values. Occasionally more than three tests were required to fulfil the above criteria. Because of the technical procedure, the strength of the hip joint muscles was expressed in kp, there being no definable biological lever, while the strength of the knee flexors and knee extensors, which was measured with reference to a definable biological lever, was expressed as the moment of the force (torque) in kpcm.

Examination of the *hip muscles* was performed with the patient standing, *i.e.* placed with the body vertical and each foot on a low stool. During the measurements the stool under the test leg was removed. For testing of the extensor muscles the abdomen was supported against a padded plate, and the patient contributed to fixation of his body by the use of his hands. For testing of the flexor strength the buttocks were supported by the padded plate, but it was not always possible to obtain adequate fixation of the upper part of the body. This meant, especially when testing the intact leg (when the patient was supported only by the prosthesis), that falsely low values could be obtained due to the difficulties in fixation. With both types of test a strap was placed around the thigh 5 cm above the upper margin of the patella (see Figure 1).

For testing the *knee joint muscles* the patient was placed in a sitting position. By means of a lower leg clamp the intact leg was fixed with both the knee and the hip joint flexed at an angle of 90°. The foot rested on a plate, and straps were applied at the ankle and immediately below the knee (see Figure 2). In addition the patient contributed to fixation of the trunk by holding on to the chair with one hand and to a bar attached to the wall with the other. Because of the construction of the dynamometer the patient was thus placed eccentrically with flexion of the left knee and extension of the right knee.

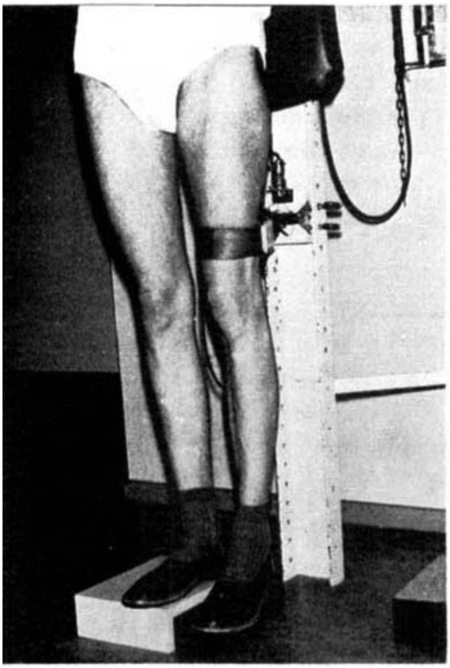
An attempt was also made to measure the strength of the knee flexors and knee extensors on the amputation side. The below-knee support which was used did not allow standardized conditions, however, and the results could not therefore be used as a basis for accurate assessment.

As a rule the tests caused no noteworthy discomfort to the patients. In no case were adequate measurements made impossible by the occurrence of pain due to effort.

RESULTS

Table 1 shows the means and ranges for the whole series of patients on flexion and extension of the hip. The values for muscle strength are given in absolute figures, and the percentage figures denote the relationship to predicted normal values according to *Asmussen & Heebøll-*

Figure 1. Measurement of strength of hip flexors. Healthy subject.



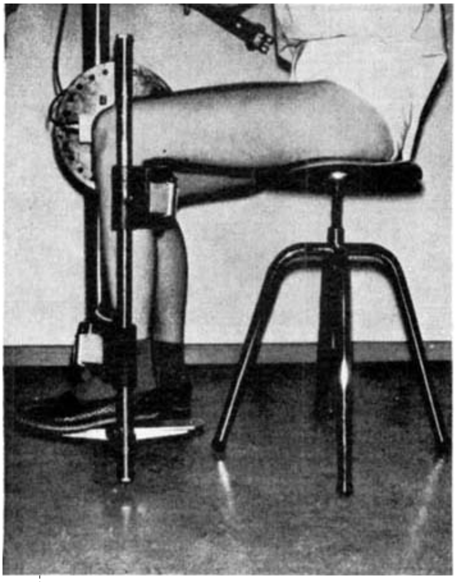


Figure 2. Measurement of strength of knee extensors, left leg. Healthy subject.

Nielsen (1961)[1]. For each patient the individual sex and the values for body height and age were taken into consideration. It can be seen in the table that the mean differences between the intact and amputated side for flexion and extension were 2 per cent and 6 per cent, respectively, although some individual patients exhibited larger differences. For the whole series, however, the mean value for hip flexion is distinctly lower than that reported by *Asmussen & Heebøll-Nielsen*.

Table 1.

	Hip flexion				Hip extension			
	Intact leg		Amp. leg		Intact leg		Amp. leg	
	kp	%	kp	%	kp	%	kp	%
M	45	77	44	75	48	104	45	98
n	20	20	20	20	20	20	20	20
Range	20–74	38–113	21–60	36–92	21–72	51–156	22–70	50–149
S.D.		17.2		17.2		20.1		20.1

Table 2a. Able to Walk 1 Km.

	Hip flexion				Hip extension			
	Intact leg		Amp. leg		Intact leg		Amp. leg	
	kp	%	kp	%	kp	%	kp	%
M	46	79	44	76	49	107	48	105
n	16	16	16	16	16	16	16	16
Range	20–74	38–113	22–60	36–92	21–72	51–156	31–70	71–149

Table 2b. Unable to Walk 1 Km.

	Hip flexion				Hip extension			
	Intact leg		Amp. leg		Intact leg		Amp. leg	
	kp	%	kp	%	kp	%	kp	%
M	43	77	40	72	43	95	33	73
n	4	4	4	4	4	4	4	4
Range	32–49	57–85	21–47	36–81	38–48	85–109	22–40	50–91

[1] The tables give the standard deviations found by *Asmussen & Heebøll-Nielsen*. 5 patients out of the whole group showed values which were reduced by more than 2 S. D. with hip flexion on the intact and/or amputated side. Of these, 1 patient was not able to walk more than 1 km. With hip extension, one intact and one amputated leg (2 different patients) showed values reduced by more than 2 S. D.

Table 3. Muscular Strength in Knee Flexors and Knee Extensors, Intact Leg.

	Knee flexion				Knee extension			
	Right		Left		Right		Left	
	Torque Kpcm	%	Torque Kpcm	%	Torque Kpcm	%	Torque Kpcm	%
M	1229	98	1108	88	1852	102	2006	110
n	10	10	10	10	10	10	10	10
Range	960–1650	62–121	650–1400	56–110	1120–2600	79–135	1750–2600	64–162
S.D.		15		15		18		18

Table 2 shows the percentage deviations from the normal values for the hip muscles when the series is divided into (a) a group of patients who stated that they could walk more than 1 km on flat ground, and (b) a group of patients who stated they were unable to walk as far as 1 km. In group (b) lateral differences are seen, with lower values for the amputation side.

Table 3 shows the mean percentage deviation from the normal values for the whole series, on flexion and extension of the knee[2]. Here also, the patients were divided into two groups in the same way as above (Table 4).

Table 4a. Able to Walk 1 Km.

	Knee flexion		Knee extension	
	Right (%)	Left (%)	Right (%)	Left (%)
M	97	92	104	105
n	9	7	9	7
Range	62–121	62–107	79–135	64–162

Table 4b. Unable to Walk 1 Km.

	Knee flexion		Knee extension	
	Right (%)	Left (%)	Right (%)	Left (%)
M	104	89	85	120
n	1	3	1	3
Range	104	56–110	85	108–133

Seven of the 18 male patients were also tested with bicycle ergometry for measurement of the "circulatory type" of the physical work capacity (*Sjöstrand* 1960). In 5 cases, with values for muscular strength within the normal range, normal circulatory conditions were found (mean value for W_{150} = 700 kpm/min). One of these patients could not walk more than 1 km.

In the other 2 cases a decreased physical work capacity was found (W_{150} = 400 resp. 450 kpm/min); one of them had a normal and the other a somewhat lowered muscular strength.

[2] On knee flexion, values reduced by more than 2 S. D. were recorded for 2 patients. The distance which one of the patients could walk was < 1 km. On knee extension no values were reduced below the limit of 2 S. D.

DISCUSSION

A large number of factors may affect the walking capacity in below-knee amputees wearing a prosthesis. One parameter is the leg muscle strength, both in the intact leg and on the amputation side. This investigation has shown that as a rule there is no marked reduction of the isometric contraction power, either in the intact or the amputation leg. Although the values in some individual patients fall into the lowest part of the normal range reported by *Asmussen & Heebøll-Nielsen* (1961), with the method used here the group as a whole shows normal values. The general reduction observed on hip flexion may, as mentioned above, possibly to some extent be related to the fact that in this test the possibilities of fixation for the patients were poor, and therefore falsely low values may have been obtained. Normal subjects may also have fixation difficulties in this test, as has been found in another study on healthy males, for whom in fact almost equally low values were noted (*Bäcklund & Nordgren* 1966).

Another explanation may be that the reduction in flexion power is a true one, and due to the fact that the flexors in these patients are exercised less than the extensors. The training of the hip extensors is obviously adequate, partly because of their function as antigravitational muscles, and partly because of the special gait developed by persons using an artificial leg; on the other hand, their inability to run or to walk quickly would be expected to result in inadequate training of the hip flexors.

The lateral differences recorded for hip flexion (Table 1) are not abnormal. In the normal series mentioned above, differences of about 2 per cent were noted both for the hip and knee joint. Differences of the same order of size have also been reported previously (*Heebøll-Nielsen* 1964). On hip extension the group as a whole showed a difference with 6 per cent lower values for the amputation side. This difference was on the average, negligible (2 per cent) in the patients who were able to walk 1 km, but considerable (22 per cent) in the other patients. This large lateral difference may, however, be due to chance, in consideration of the fact that the number of patients who, according to case history, were unable to walk as far as 1 km was only 4, and that some individuals in both the other group and in the normal series showed lateral differences of the same order of size. The classification of the patients into those who were able and those who were unable to walk as far as 1 km, may seem arbitrary. The borderline for a normal walking capacity varies considerably, *e.g.* with age, but a maximal walking distance of less than 1 km is so low that it can be considered to indicate pathologically limiting factors.

Difficulties in fixation also seem to have played some role in the knee flexion and knee extension tests. Because of the test conditions the patient was placed in an eccentric position for left-sided knee flexion and for right-sided knee extension, which probably affected the fixation of the trunk, and thus may have given systematically lower values for these tests. No similar results were obtained for the normal series, but this difference can probably be explained by the difficulty of the amputation patients in gaining a purchase with the artificial leg.

In spite of the shortcoming of the method, which in some tests may have caused some systematic reduction of values, in general no remarkable reduction of the leg muscle strength was shown in these unilateral below-knee amputees. This finding contradicts the result of *Hettinger* (1959), who observed that in such patients there was a bilateral reduction of muscle strength in the hip, both in the flexors and extensors. In addition he noted a lateral difference for the hip flexors, with lower values on the amputation side. According to our overall assessment of the patients in this series in whom the strength reductions were accompanied by a limited walking capacity, these reductions should be regarded as a *result* of this limitation, due to other factors, rather than its *cause*. Several of the patients with low values for muscular strength were able to walk further than 1 km, and it follows, therefore, that decreased power in the muscle groups tested need not necessarily result in such pronounced limitation of the walking capacity.

One factor which is possibly of great importance for the walking capacity in these amputation patients is the occurrence of pain. Although pain of such extent as to limit the achievements of the patients did not occur in any of these tests, all four patients who were unable to walk for more than 1 km complained of pain in the amputation stump on walking. On the other hand, such pain only occurred in 2 of 16 patients who could walk for more than 1 km. It seems probable, therefore, that other factors, especially pain on effort, are of greater importance as regards the walking capacity of a patient with a below-knee prosthesis, than the muscular power of the legs. To judge from our findings physical training would have little influence on the walking capacity in such cases. However, active exercises are of great clinical importance for other reasons by counteracting contractures and improving the patient's coordination and control of his prosthesis after leg amputation.

SUMMARY

The maximal isometric muscle strength for flexion and extension in both hips and in the normal knee was assessed in twenty unilateral below-knee amputees wearing a prosthesis for more than one year. At hip flexion tests the bilateral values tended to be low. However, the group as a whole showed values within normal limits.

In some individual patients a normal walking distance was found in spite of low muscle strength. Pain in the amputation stump on walking seemed to be of grater importance as a limiting factor.

RESUME

La force maximum isométrique du muscle pour flexion et extension dans les hanches et les genoux normaux a été établie dans 20 cas d'amputation unilatérale au-dessous du genou chez des malades ayant porté une prothèse pendant plus d'un an. Au test de flexion de la hanche, les valeurs bilatérales avaient tendance à être basses. Quoi qu'il en soit, pour l'ensemble du groupe, on trouva que les données constatées restaient dans le cadre des limites normales.

ZUSAMMENFASSUNG

Die maximale isometrische Muskelkraft bei Beugung und Streckung in beiden Hüften und im normalen Knie wurde bei zwanzig Personen mit einseitiger Amputation unterhalb des Kniees, die eine Prothese länger als ein Jahr getragen hatten, geschätzt. Bei den Prüfungen der Hüftbeugung hatten die beiderseitigen Werte die Neigung neidrig zu sein. Die Gruppe als ganzes jedoch zeigte Werte innerhalb normaler Grenzen.

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REFERENCES

Asmussen, E., Heebøll-Nielsen, K. & Molbech, Sv. (1959) Methods for evaluation of muscle strength. Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis, Hellerup, Denmark, Nr. 5 and nr. 5 Suppl.

Asmussen, E. & Heebøll-Nielsen, K. (1961) Isometric muscle strength of adult men and women. Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis, Hellerup, Denmark. Nr. 11.

Bonde Petersen, F. (1960) Muscle training by static, concentric and eccentric contractions. *Acta physiol. scand.* **46**, 406–416.

Bäcklund, L. & Nordgren, L. (1966) Ny metodik för prövning av isometrisk muskelstyrka under standardiserade betingelser. Föredrag vid Medicinska Riksstämman, Stockholm.

Heebøll-Nielsen, K. (1964) Muscular asymmetry in normal young men. Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis, Hellerup, Denmark. Nr. 18.

Hettinger, Th (1959) Die maximalen Drehmomente im Hüftgelenk bei Oberschenkel- und Unterschenkel-Amputierten im Vergleich zu Normalbeinigen. *Zeitschrift für Orthopädie und ihre Grenzgebiete* **91**, 131–140.

Sjöstrand, T. (1960) Functional capacity and exercise tolerance in patients with impaired cardiovascular function. In B. Gordon (Ed.): Clinical cardiopulmonary physiology. Ed. II. Grune & Stratton. New York.