Acta orthop. scand. *50*, 693–697, 1979

STRENGTH OF PLANTAR FLEXION AND FUNCTION AFTER RESECTION OF VARIOUS PARTS OF THE TRICEPS SURAE MUSCLE

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Nine patients who had undergone resection of various well defined parts of the triceps surae muscle because of tumour were examined. The function was estimated from the patient's history and the muscle strength was measured statically and dynamically using a Cybex II dynamometer. Two patients reported slight symptoms. The loss of strength was less than one might expect from theoretical calculations. The strength of the operated limb showed a particular pattern depending on the part resected. From this pattern it was concluded that the soleus is more active when the foot is dorsiflexed and the gastrocnemius more active when the foot is in plantar flexion, and that the gastrocnemius is most important in quick movements of the foot.

Key words: ankle joint; biomechanics; Cybex II; muscle contraction; muscle resection; plantar flexion; soft tissue tumour; surgical treatment

Accepted 22.iv.79

Malignant and locally aggressive tumours of the soft tissues are generally treated surgically. To secure an adequate margin of healthy tissue the surgeon must choose between amputation and wide *en bloc* resection, which often requires excision of an entire muscle or group of muscles. The preoperative planning must aim at as radical a surgical intervention as possible with a minimal loss of function. This requires knowledge of the effect of loss of certain muscles on the function of the limb. This paper reports the function of the ankle in nine patients in whom various parts of the triceps surae muscle had been removed along with a tumour and demonstrates the strength of plantar flexion.

MATERIAL AND METHODS

Between 1965 and 1976, 13 patients were operated on and various parts of the triceps surae muscle resected. The operations were performed at the Department of Orthopaedic Surgery, Sahlgren Hospital, Gothenburg. Nine of the patients were reviewed 2 – 13 years after the operation. Of the remaining four, two had died in the meantime from intercurrent disease, one had poor function of the muscle already before the operation as a consequence of repeated lengthening of the Achilles tendon, and one refused to take part in the follow-up. The age and sex distribution of the patients as well as the diagnosis and the muscles extirpated are given in Table 1.

When the patients' history was assessed inquiry was made into their ability to manage their work and into the way they spent their spare time. Notes were also made of any complaints of pain, unsteadiness of gait and limp. The patients were asked for walking distance, walking aids, ability to run, and whether they had any difficulty in walking up and down steps. Their ability to walk on tiptoes was examined. The range of motion of the ankle joint was measured.

The strength of plantar flexion was measured on both sides statically and dynamically with a Cybex II dynamometer. In this test the patient was supine with straightened knee. The ankle was

0001–6470/79/060693–05$02.50/0

Table 1. Descriptive data of the nine patients subjected to resection of different parts of the triceps surae

No.	Age	Follow-up time (years)	Sex	Diagnosis	Extirpated muscle
1	23	4	M	Haemangioma	Soleus (s)
2	76	13	F	Myxoma	Soleus (s)
3	17	2	F	Haemangioma	Medial soleus (ms)
4	21	3	F	Haemangioma	Lateral soleus (ls)
5	55	7	M	Liposarcoma	Medial gastrocnemius (mg)
6	64	3	M	Intramuscular lipoma	Lateral gastrocnemius (lg)
7	65	2	F	Myositis necroticans	Lateral gastrocnemius + lateral soleus (lg + ls)
8	32	7	M	Myxofibromatous soft tissue tumour	Medial gastrocnemius + medial soleus (mg + ms)
9	20	5	F	Unclassified soft tissue sarcoma	Soleus + medial gastrocnemius (s + mg)

fixed with straps over the front and the back of the tarsus so that the heel could not be raised more than half a centimetre. The plantar flexion torque of the ankle was recorded by an x-y-writer. Before the test the patients were allowed to practice the various movements and at the same time read the results on an oscilloscope. Static muscle strength was measured with the ankle dorsiflexed 15°, in neutral position and plantarflexed 15° and 30°. The dynamic strength of plantar flexion was measured during slow movement of the joint (30°/s), moderately fast movement (90°/s), and during fast movement (180°/s). The peak torque and its position in relation to the neutral position of the ankle was measured. The best of three maximal performances in each position and angular speed was used. The patients were allowed to rest for 1 minute between consecutive tests. In one patient (No. 2) only static strength was measured.

RESULTS

Only two patients (Nos. 7 and 9) reported slight symptoms, viz. unsteadiness of gait when walking on uneven ground. The distance the patients could walk unhindered and their ability to run and walk up and down steps had not been affected in any of them. All the patients had returned to their previous work. Neither were their spare time activities affected, not even for those four who had regularly taken part in sports more than twice a week. All patients could stand and walk on tiptoes. In six patients the range of motion was slightly reduced, but only one was aware of it and the impairment never exceeded 10° in either direction as compared with the normal side. All patients were able to dorsiflex a minimum of 15°.

The muscle strength recordings are given in Table 2. The ankle torque of the operated side is given relative to that on the other side. Substantial differences in strength between different positions of the ankle and between static and dynamic recordings were found, but in only one patient (No. 9) was the mean of all seven measurements below 80 per cent. The differences in strength between the various positions varied with the part of the triceps surae that had been removed. Thus, the mean static recordings of the strength when the soleus or part of it had been removed (Nos. 1–4) was 79 per cent of that on the non-operated side when the ankle was in 15° dorsiflexion and 112 per cent when it was in 30° plantar flexion. This difference was statistically significant ($0.01 < P < 0.02$). When only part of the gastrocnemius had been removed (Nos. 5 and 6) the opposite relation existed so that in the dorsiflexed position the mean strength was 112 per cent and in the

Table 2. Strength of the ankle on the operated side relative (%) to that on the other side (pf=plantar flexion, df=dorsiflexion). The shift of peak values relative to that on the unoperated side is expressed in degrees (+=plantarly, −=dorsally).

Case no.		1	2	3	4	5	6	7	8	9
Resected muscle		s	s	ms	ls	mg	lg	lg+ls	mg+ms	mg+s
Side		l	r	l	r	l	l	l	l	l
Static torque	15 df	70	85	63	99	129	95	104	80	72
	0	89	97	71	99	99	88	94	89	75
	15 pf	109	116	100	98	72	86	71	93	87
	30 pf	97	117	120	113	76	84	46	89	75
Dynamic torque	30°/s	91		97	110	91	92	90	86	100
	90°/s	100		118	94	88	94	74	88	61
	180°/s	113		103	114	69	76	119	73	143
Peak difference	30°/s	+9		0	−6	−5	−1	+7	−6	−7
	90°/s	+9		+3	−3	−4	−3	+9	−6	−1
	180°/s	+11		+9	−1	−1	−8	+10	−5	−20

plantarflexed position 80 per cent, but this difference was not statistically significant. These two groups differed in strength in 30° plantar flexion $0.01 < P < 0.02$) but not in dorsiflexion. As for the dynamic strength, a comparison between the group in which only the soleus or part of it had been resected (Nos. 1, 3 and 4) and the group in which only part of the gastrocnemius had been resected (Nos. 5 and 6) showed a statistically significant difference at an angular velocity of 180°/s ($0.002 < P < 0.01$). At this angular velocity the mean strength for the group in which the soleus had been resected was 110 per cent of the non-operated side compared with 73 per cent for the group in which the gastrocnemius had been resected.* In two of the patients in whom only the soleus had been resected the peak shifted plantarly, whereas in the two in whom only the gastrocnemius had been resected the peak shifted dorsally. In the remaining three patients (Nos. 7, 8 and 9), in whom the soleus or part of it had been resected along with one of the gastrocnemii, the picture varied and no particular pattern could be discerned.

*These differences are not changed if the results are corrected for side differences suggested by Dambolt & Termansen (1978) – right leg stronger than left – and Fugl-Meyer & Pedersen (personal communication) – left leg stronger than right.

DISCUSSION

Adequate treatment of malignant or locally aggressive tumours of the soft tissues requires extensive resection and usually excision of an entire muscle with a bordering layer of fascia (Bowden & Booher 1958). Function after such an operation is rarely reported. We could trace only one case in the literature in which the strength of plantar flexion had been measured after removal of the entire triceps surae (Murray et al. 1976). This patient lost 62 per cent of the plantar flexion torque. When theoretical calculations make the triceps surae responsible for 80 per cent of the plantar flexion torque (Fick 1911, Haxston 1944) the difference was explained by compensatory hypertrophy. In a later report on the same patient (Murray et al. 1978) the gait was analysed. The patient was unable to run and had a limited walking speed. In our series of nine patients, where up to about 75 per cent of the tissue mass of the triceps surae had been removed, the loss of strength never exceeded 30 per cent when

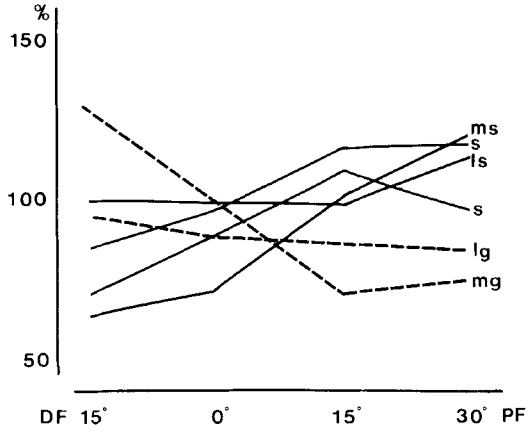

Figure 1. Plantar flexion torque (peak torque) in four positions of the foot expressed relative to corresponding values on the unoperated side (PF = plantar flexion, DF = dorsiflexion). Letters denote muscle resected (ms = medial soleus, ls = lateral soleus, s = soleus, mg = medial gastrocnemius, lg = lateral gastrocnemius).

statically measured with the foot in neutral position. This is also less than one would expect from theoretical calculations. The two patients with slight discomfort (Nos. 7 and 9) had a reduction of strength that did not differ substantially from that in the others.

Dambolt et al. (1978) recently measured the plantar flexion torque in neutral position during isometric contraction in 30 healthy persons. These authors stated that the difference between symmetrical muscle groups should exceed 15 per cent to be pathological. Only two of our patients had lost more than 15 per cent when statistically measured in neutral position. The absolute strength of the operated limb did not fall outside the range of a corresponding normal material (Fugl-Meyer & Pedersen, personal communication).

All nine patients had been subjected to resection of well defined muscles. The pattern of the loss of strength varied with the muscle resected. Static strength varied with the position of the ankle and dynamic strength with the speed of angular motion of the joints (Figures 1 and 2).

Herman & Bragin (1967), who studied the function of the gastrocnemius and soleus electromyographically, showed that the soleus is more active when the foot is dorsiflexed and that the gastrocnemius is more active when the foot is in plantar flexion and during rapid contraction. These findings were confirmed by the present investigation in which it was observed that in patients in whom the soleus had been resected the loss of strength was greatest when the foot was dorsiflexed (Figure 1), whereas in the two patients in whom parts of the gastrocnemius had been removed the loss of strength was greatest when the foot was in plantar flexion (Figure 1). Compensatory hypertrophy of the residual muscles results in less reduction of strength than expected in that part of the range of motion where the resected muscle is most important. The hypertrophy of the remaining muscles results in an overcompensation in that range of motion where these muscles develop their greatest strength.

On fast angular motion of the ankle the loss of strength was greatest in the two patients in whom part of the gastrocnemius had been removed (Figure 2), an observation that lends support to the view that this muscle is of greatest importance for rapid development of power.

CONCLUSIONS

1. Extensive resection, if not total, of the triceps surae causes only relatively in-

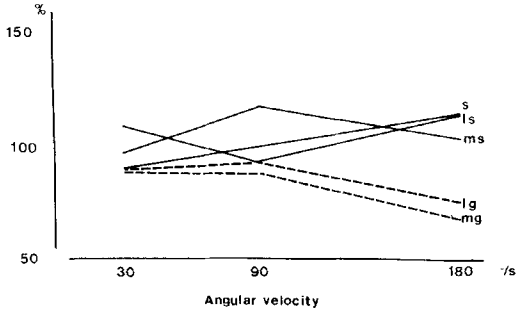

Figure 2. Peak torque of plantar flexion at three speeds of angular motion expressed relative to that on the unoperated side.

significant symptoms and does not affect the patient's ability to walk and run.

2. The loss of plantar flexion strength is small and smaller than might be expected from theoretical calculations, probably because of compensatory hypertrophy.
3. The soleus contributes most to the strength of plantar flexion when the foot is dorsiflexed, whereas the gastrocnemius develops its greatest power when the foot is in plantar flexion.
4. The gastrocnemius is of greatest importance for quick movements of the foot.

ACKNOWLEDGEMENT

This study was supported by grants from the University of Göteborg, Greta och Einar Askers stiftelse and the Norbacka Foundation.

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