THE COMPARATIVE ATROPHY OF THE SKELETAL MUSCLE AFTER CUTTING THE NERVE AND AFTER CUTTING THE TENDON. BY PROFESSOR ALEXANDER LIPSCHÜTZ AND ALEXANDER AUDOVA, ASSISTANT.

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QUANTITATIVE knowledge on the course of atrophy of muscle under different conditions, is still imperfect, though some observations in conditions other than those of simple nerve section have lately been made by Langley and his co-workers(1).

We have made a step towards filling in the data by comparing the course of atrophy after cutting the nerve and after cutting the tendon of skeletal muscles. On rabbits the sciatic nerve of one side in its course between the muscles of the thigh was cut and a piece of about 1 cm. was excised. At different intervals after the operation the m. gastrocnemius, soleus and plantaris of the normal and the operated side were excised, weighed and dried. In other experiments the tendon of the same muscles (tendo Achillis) was cut and a piece of 1 cm. was excised; the fresh and the dry weights of the muscles of the normal and of the operated side were compared at different intervals after the operation. The error in these experiments does not exceed about 6 or 7 p.c. In nine experiments performed on normal animals the average difference between the right and the left muscles was – 0·5 p.c. for the fresh and – 0·9 for the dry weight, the maximal difference being – 6·3 and – 4·2 p.c.

The results of the two series of experiments are given in the following tables.

It will be seen that in these experiments up to 40 p.c. of the dry weight of the muscles was lost in about two weeks, more than 50 p.c. in four weeks, and that only about 10 p.c. more was lost in a further 60 days. It will also be seen that the course of atrophy was the same after cutting the nerve and after cutting the tendon. This is especially clear if we form "curves of atrophy" with the percentage loss of dry weight as ordinates and the intervals after the operation as abscissæ (Fig. 1). We obtain similar curves if we use the original minimal and maximal instead of the average figures. Similar curves are obtained also on using the figures for the percentage loss of fresh weight.

TABLE I. ANIMALS WITH NERVE SECTION.

Number of Exps.	6	10	5	4	3	3
Duration in days	6	14	28	56	84	123
Average fresh weight of the muscles, grm.:						
(a) normal side	11·17	8·93	10·27	9·86	8·41	7·71
(b) operated side	10·43	6·81	6·35	4·68	3·56	2·70
Average percentage difference	−6·6	−23·7	−38·2	−52·5	−57·7	−65·0
Average dry weight of the muscles, grm.:						
(a) normal side	2·61	2·09	2·40	2·18	1·95	1·67
(b) operated side	2·36	1·42	1·29	0·93	0·86	0·55
Average percentage difference	−9·8	31·9	−46·1	−57·7	−55·9	−67·1
Minimal and maximal percentage differences:						
(a) for the fresh weight, min.	− 3·8	− 8·7	−16·2	−34·7	−33·1	−62·4
,, ,, max.	−10·9	−35·4	−52·1	−61·0	−63·9	−68·5
(b) for the dry weight, min.	− 8·0	−16·8	−30·2	−45·1	−29·3	−57·2
,, ,, max.	−11·5	−40·8	−55·9	−65·2	−67·1	−75·3

TABLE II. ANIMALS WITH TENDON SECTION.

Number of Exps.	6	16	5	4	5	3
Duration in days	6	12–16	28	56	84	123
Average fresh weight of the muscles, grm.:						
(a) normal side	11·06	8·34	9·61	9·73	12·11	8·69
(b) operated side	11·09	6·69	5·73	4·90	5·32	3·77
Average percentage difference	+ 0·4	−19·9	−40·5	−49·6	−56·1	−56·6
Average dry weight of the muscles, grm.:						
(a) normal side	2·63	1·94	2·21	2·24	2·76	2·00
(b) operated side	2·45	1·37	1·19	1·08	1·28	0·88
Average percentage difference	− 7·0	−29·0	−46·1	−51·9	−53·7	−55·9
Minimal and maximal percentage differences:						
(a) for the fresh weight min.	+ 6·1*	− 0·1*	−28·9	−46·3	−41·5	−52·7
,, ,, max.	− 7·1	−41·8	−45·6	−52·5	−65·6	−62·1
(b) for the dry weight min.	− 0·6	−12·8	−36·3	−48·3	−42·1	−50·5
,, ,, max.	−17·7	−41·6	−51·2	−54·7	−68·9	−63·1

The average p.c. difference is calculated from the weights to three places of decimals, in the Table the fresh and dry weights are only given to two places.

* These minimal figures are caused, as it will be seen further, by the greater water content of the atrophying muscle.

In experiments of this nature there is a possible error, *i.e.* that the loss of weight of the muscles on the operated side is caused to a certain degree by an increase of weight of the muscles on the normal side. But this possible error could not have been of any importance in our experiments, since the weight of the animals after operation varied very little. As a further test, Audova tried the effect of loss of body weight by keeping for one to two weeks without food, rabbits in which the tendo Achillis had been cut on one side. He found that, whilst the muscles in the later period were about 50 p.c. less than normal in weight, the difference in weight on the two sides was the same as in the earlier experiments.

How can one explain the loss of weight the muscle undergoes after its tendon was cut? From the experiments of Heidenhain(2) and of Fick(3) we know, that the heat production of the muscle decreases when the load is smaller. When the tendon is cut we have a similar condition of the muscle. The work done is decreased. Thus the loss of weight after

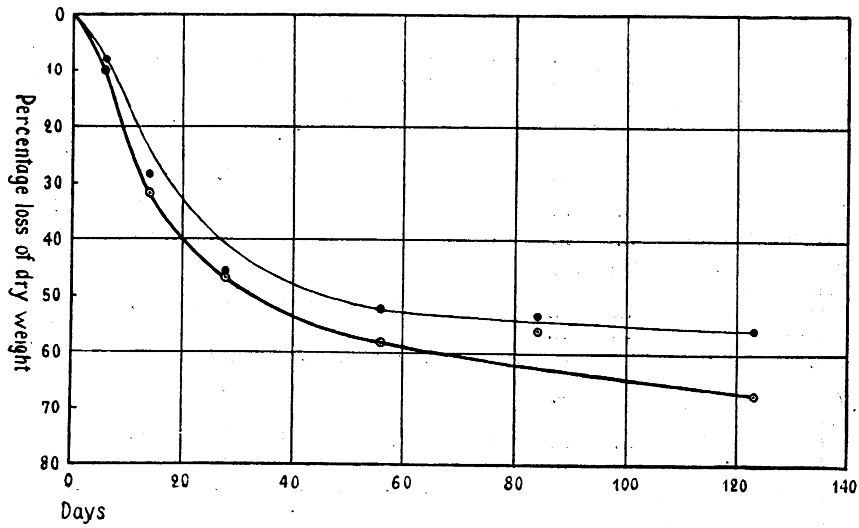

Fig. 1. ▬▬ nerve section; —— tendon section.

cutting the tendon would seem to be a pure case of atrophy by decreased activity. There are two possible objections against this point of view:

It might be said that the loss of weight after cutting the tendon is caused, not by decreased activity but by the operation itself setting up some pathological condition. This question was examined by a series of experiments in which the tendon was exposed, but instead of excising a piece a longitudinal incision was made in it. These experiments showed that in the first 14 days after the operation there may be some loss of weight; but this loss of weight was found only in three out of ten experiments, whereas in all experiments in which a piece of the tendon was excised there was, 14 days after the operation, a very noticeable loss of dry weight, cf. Table II. Further, four experiments on tendon incision showed, 53 days after the operation, no loss of weight. We see that if the longitudinal incision of the tendon can cause a loss of weight, this must be the result of some pathological condition acting in the beginning. But this condition evidently ceases afterwards and cannot be detected in the longer experiments.

Another objection which might be made is that a transverse incision, or an excision of a piece, of the tendon severs afferent nerve fibres and thus suppresses some centripetal impulses which normally influence the work and the condition of the skeletal muscle. As there is no experimental evidence on this question it cannot be said whether this objection is justified or not.

If we put aside the latter objection we can say that there is an identity in the course of atrophy caused by cutting the nerve and by decreasing the activity of the muscle by cutting the tendon. It seems that inactivity plays a great rôle in the atrophy after injury of the nerve. It is true that the course of atrophy after cutting the nerve is quicker than after cutting the tendon; but this can be explained by the assumption that in the first case there is an absolute inactivity, whereas in the second case there is only a decreased activity, the muscle still receiving impulses from the central nervous system and contracting without load.

When the muscle undergoes atrophy there is not only a loss of fresh or dry weight, but also a change in the chemical composition. As already stated Audova found that the relative amount of water in the muscle after cutting the nerve and after cutting the tendon is distinctly greater than in the normal; Audova and Takson stated further that the relative amount of water soluble substances is also increased if atrophy takes place. An augmentation of the relative amount of water in the organs has been found also by different authors in case of inanition (4) and in inanition Lipschütz (5) found an increase of the relative amount of water soluble substances. It seems that these water soluble substances are products of decomposition of the organic constituents of the living cell, and that the increase of their relative amount and the increase of the relative amount of water take place in all cases when there is an increased decomposition of living matter.

Our assumption that inactivity plays a great rôle in the mechanism of the atrophy of the skeletal muscle after the nerve was cut is in contradiction to the view put forward by Langley (1).

Langley has contested the theory that the atrophy of muscle is due to absence of contraction, since he found that making the muscles contract by electrical stimulation after their nerves had been cut did not delay the atrophy. An absence of effect of stimulation has also been found by Hartmann and Blatz(6). However this may be, the experiments recorded in this paper show that a decrease in the work performed causes atrophy, and we think that this can only be explained on the theory that atrophy is due to inactivity.

Langley does not come to any definite conclusion as to the cause of atrophy, but he suggests that it may be due to over-use caused by the continuous fibrillation. It is known that fibrillation may continue for a long time, we have seen it four months after nerve section. Langley and Hashimoto (*op. cit.* p. 64) state that there is a broad correspondence between the degree of fibrillation and degree of atrophy, but that there is insufficient evidence to decide whether the fibrillation is the cause of the atrophy or merely an accompanying phenomenon. It does not seem to us probable that even continuous fibrillation represents a sufficient expenditure of energy to cause a loss of weight. The increase in oxygen consumption in atrophying muscle found by Langley and Itagaki, which they think favours the theory of over-use, can be explained as due to the oxidation of waste products formed in the decomposition of inactive atrophying muscle.

SUMMARY.

Section of the tendo Achillis in rabbits causes atrophy of muscle which is nearly as great as that caused by nerve section. The atrophy is caused by the great decrease of work performed, *i.e.* by inactivity.

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