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Changes in Weight of Muscles of Arthritic and Immobilized Arthritic Joints.*

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We have previously studied the synaptic mechanism in muscles of inflamed joints (Frugone, Thomsen, and Luco[1]). In view of the results reported by Thomsen and Luco,[2] we thought it would be interesting to study the changes in weight of such muscles, and the possibility of modifying the weight through immobilization in different positions.

Methods. Cats were used. Immobilization was carried out under ether or sodium pentobarbital (Nembutal Abbott) anesthesia, using bandages impregnated with plaster directly on the skin, extending from the metatarsal region to just below the knee. The arthritis was produced by injecting 0.1 cc of a 5-10% solution of silver nitrate into the articular cavity of the tibia-tarsal joint. The cast was applied immediately after the injection of the silver nitrate. We immobilized in the extreme positions of extension and flexion, that is, in positions of forced hyperextension and hyperflexion held by the cast. The soleus and tibialis anticus muscles were weighed 2.5 to 16 days later, immediately after extirpation. As some of the animals developed marked edema of the immobilized extremity, we ran

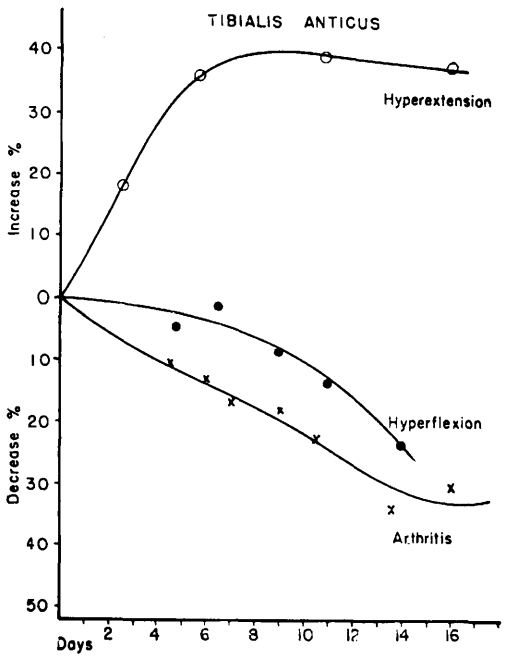

FIG. 1.
Changes of weight of the tibialis anticus in arthritis, arthritis with immobilization in hyperflexion, and arthritis with immobilization in hyperextension. The curves represent the plotted average values of Tables I, III, and V respectively.

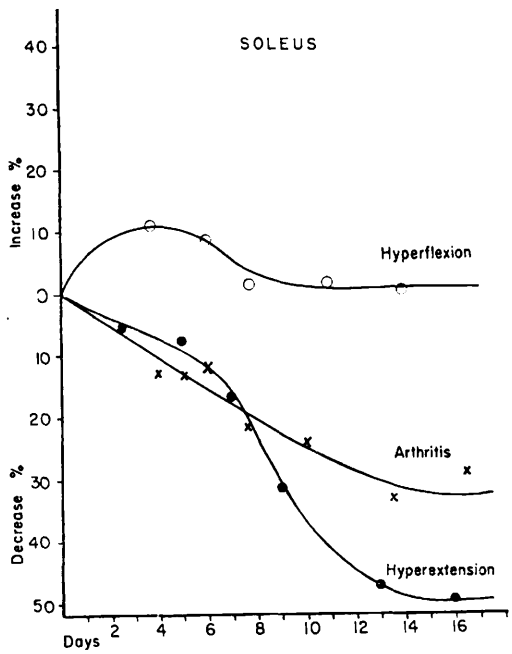

FIG. 2.
Changes of weight of the soleus in arthritis, arthritis with immobilization in hyperflexion, and arthritis with immobilization in hyperextension. The curves represent the plotted average values of Tables II, IV, and VI respectively.

* Aided by a grant from the National Foundation for Infantile Paralysis.

[1] Frugone, J. E., Thomsen, P., and Luco, J. V., in press.

[2] Thomsen, P., and Luco, J. V., *J. Neurophysiol.*, 1944, **7**, 245.

TABLE I.
Showing Loss of Weight of Tibialis Muscle in Arthritis.

Animal No.	Days of arthritis	Wt in g N	Wt in g A	% difference
1	4	4,930	4,620	— 6.5
2	4	2,600	2,300	—11.
3	4	3,200	3,120	— 2.5
4	5	750	560	—25.3
5	5	4,975	4,625	— 7.
	Avg 4.4			—10.4 ± 3.1
6	6	3,400	2,800	—17.
7	6	2,620	2,370	— 9.
	" 6			—13. ± 4.
8	7	3,470	3,170	— 8.
9	7	3,080	2,435	—19.
10	7	4,620	3,550	—23.
	" 7			—16.6 ± 4.46
11	8	4,690	3,980	—14.
12	8	2,700	2,200	—18.
13	8	2,910	2,350	—19.2
14	8	3,060	2,570	—16.
	" 8			—16.8 ± 0.37
15	9	4,320	3,600	—15.
16	9	1,380	1,130	—18.1
17	9	2,080	1,770	—14.9
	" 9			—16. ± 1.
18	10	3,750	2,520	—32.
19	10	2,970	2,570	—13.
20	10	880	810	— 8.
21	10	3,600	2,750	—23.
22	11	3,700	2,550	—31.
23	11	3,190	2,200	—31.
24	11	4,190	3,280	—21.
	" 10.4			—22.7 ± 3.58
25	13	2,220	1,330	—40.
26	13	4,310	4,070	— 5.5
27	14	3,100	1,780	—43.
28	14	4,500	2,340	—48.
	" 13.5			—34.1 ± 9.55
29	16	4,600	3,800	—17.
30	17	2,640	1,470	—44.
	" 16.5			—30.5 ± 13.52

N—Normal.
A—Arthritis.

several controls with muscles desiccated in the oven, at 105°C for 24 hours, to eliminate the excess of water.

Results. A. Weight of Muscles in Arthritis. The results of the 30 experiments in this series given in Tables I and II, show that the percentage loss of weight of the tibialis anticus and the soleus is similar and varies with the

TABLE II.
Showing Loss of Weight in Soleus Muscle in Arthritis.

Animal No.	Days of arthritis	Wt in g N	Wt in g A	% difference
1	4	2,970	1,800	—10.
2	4	1,450	1,200	—17.
3	4	1,850	1,620	—12.
	Avg 4			—13. ± 2.
4	5	670	560	—16.4
5	5	2,375	2,120	—10.
	" 5			—13.2 ± 3.
6	6	2,100	1,900	— 9.5
7	6	2,240	1,900	—15.
	" 6			—12.3 ± 2.45
8	7	1,885	1,875	— 5.5
9	7	1,970	1,520	—22.
10	7	2,480	1,820	—26.
11	8	2,550	2,200	—13.
12	8	2,000	1,800	—10.
13	8	2,680	1,520	—43.2
14	8	1,730	1,120	—35.2
	" 7.6			—21.4 ± 5.55
15	9	2,300	1,930	—16.
16	9	1,040	680	—34.6
17	9	1,510	920	—39.
18	10	1,610	1,190	—26.
19	10	2,580	2,050	—21.
20	10	700	510	—27.
21	10	1,900	1,700	—11.
22	11	1,950	1,600	—19.
23	11	2,240	1,530	—32.
24	11	2,170	1,930	—15.
	" 10			—24. + 2.91
25	13	1,350	1,050	—22.
26	13	2,720	2,010	—26.1
27	14	1,880	1,160	—38.
28	14	1,820	1,320	—27.4
	" 13.5			—33.3 ± 4.35
29	16	2,930	2,420	—17.
30	17	2,070	1,300	—37.
	" 16.5			—27. ± 10.

N—Normal.
A—Arthritis.

number of days of arthritis. This relationship is seen more clearly in Fig. 1 and 2.

B. *Weight of Muscles of Arthritic Joints Immobilized in Hyperflexion.* In this series we used 28 animals and the results are shown in Tables III and IV, and Figs. 1 and 2. In this position, the soleus after an initial increase tends to maintain its normal weight. The tibialis anticus undergoes atrophy, but not as much as in the case of pure arthritis, although the weight of desiccated muscles shows that the loss of weight is similar to that produced by the arthritis alone.

C. *Weight of Muscles of Arthritic Joints*

TABLE III.
Tibialis in Arthritis with Hyperflexion.

Animal No.	Days of arthritis	Wt in g		% difference	Wt of desic. muscles		% difference
		N	AI		N	AI	
61	2.5	1,950	1,890	— 3			
62	2.5	3,440	3,460	+ 0.5	940	890	— 5.3
63	2.5	2,100	2,150	+ 2.3	560	560	0
64	2.5	2,470	2,480	+ 0.4	685	700	— 2.1
65	2.5	1,150	1,080	— 6	350	325	— 7.1
	—			—			
Avg	2.5			— 1.1 ± 1.15			
66	4	3,470	3,370	— 2.8			
67	5	3,410	3,320	— 2.6			
68	5	3,290	3,310	+ 0.6	860	850	— 1.1
69	5	4,970	4,320	—13.1			
70	5	4,460	4,000	—10.1			
71	5	3,300	3,300	0			
	—			—			
,,	4.8			— 4.6 ± 2.22			
72	6	4,820	4,930	+ 2.7			
73	6	2,270	2,080	— 8.4			
74	6	5,470	4,760	—14.8	1,150	1,120	— 2.6
75	6	4,120	4,280	+ 3.8	1,130	1,160	+ 2.6
76	6	5,550	5,570	+ 0.3	1,430	1,420	— 0.7
77	7	3,370	2,870	—15			
78	7	2,376	2,570	+11.9			
79	7	2,030	2,210	+ 8.7			
80	8	3,530	3,550	+ 0.5	1,040	940	— 9.6
	—			—			
,,	6.5			— 1.3 ± 3			
81	9	6,000	5,600	— 6.6			
82	9	1,970	1,780	—10			
	—			—			
,,	9			— 8.3 ± 1.58			
83	11	3,350	3,600	+ 6.9			
84	11	3,870	2,840	—26.8			
85	11	3,900	3,000	—23			
86	11	2,950	2,640	—10	700	610	—12.8
	—			—			
,,	11			—13.7 ± 7.61			
87	14	3,660	3,200	—12.2	990	770	—22.2
88	14	3,520	2,170	—35.3	950	586	—49.9
	—			—			
,,	14			—23.7 ± 11.6			

N—Normal.
AI—Arthritis with immobilization in hyperflexion.

Immobilized in Hyperextension. The results in the 30 animals studied are shown in Tables V and VI, and Fig. 1 and 2. The soleus undergoes more atrophy than in the case of pure arthritis. The tibialis anticus shows an increase in weight that is evident both in the fresh and desiccated muscles. The figures for desiccated muscles are lower but tend to parallel those for fresh muscles.

Discussion. The loss of weight caused in the soleus and the tibialis anticus by an arthritis of the tibio-tarsal joint is very similar to that described by Lippman and Selig.[3] The curve obtained by those authors in a series of 40 animals, by plotting the loss of weight against the duration (in days) of arthritis, practically coincides with the curve that we

[3] Lippman, R. K., and Seliz, S., *Surg. Gyn. Obst.*, 1928, **47**, 512.

TABLE IV.
Soleus in Arthritis with Hyperflexion.

Animal No.	Days of arthritis	Wt in g		% difference	Wt of desic. muscles		% difference
		N	AI		N	AI	
61	2.5	1,210	1,530	+26.2			
62	2.5	1,730	1,950	+11.2	450	480	+ 6.2
63	2.5	1,180	1,220	+ 3.4	310	330	+ 6.4
64	2.5	1,060	1,220	+15	300	345	+15
65	2.5	750	1,000	+31.8	220	280	+27.2
66	4	2,440	2,340	— 4.1			
67	5	2,370	2,460	+ 3.6			
68	5	2,430	2,360	— 2.8	540	560	+ 3.7
69	5	2,200	2,770	+25.8			
70	5	2,620	2,740	+ 4.6			
71	5	1,830	1,890	+ 3.2			
	Avg. 3.7			+10.7 ± 3.74			
72	6	2,700	3,000	+11			
73	6	1,330	1,470	+10.5			
74	6	2,250	2,580	+14.6	520	600	+15.3
75	6	3,000	2,930	— 2.3	770	770	0
76	6	2,480	2,690	+ 8.4	630	640	+ 1.6
	" 6			+ 8.4 ± 2.82			
77	7	2,030	1,450	—28.5			
78	7	1,050	1,080	+ 2.8			
79	7	1,530	2,018	+32			
80	8	2,670	2,400	—10.1	670	610	— 8.9
81	9	3,650	3,450	— 5.4			
82	9	1,370	1,620	+18.3			
	" 7.8			+ 1.45 ± 8.78			
83	11	1,850	2,220	+15.8			
84	11	2,220	2,370	+ 6.4			
85	11	2,550	2,410	— 5.5			
86	11	1,590	1,400	—11.9	380	360	- 5.2
	" 11			+ 1.7 ± 5.66			
87	14	1,870	1,850	— 1	450	450	0
88	14	2,550	2,600	+ 1.9	630	650	+ 3.1
	" 14			+ 0.4 ± 1.58			

N—Normal.
AI—Arthritis with immobilization in hyperflexion.

obtained for the tibialis in a series of 30 animals.

The muscular atrophy produced by arthritis is different from that obtained by immobilization and as observed by Thomsen and Luco; in the former case both muscles undergo atrophy, while in the latter case only the muscle that is in a state of maximum shortening undergoes atrophy.

If we combine these two conditions that cause changes of weight, *i.e.*, arthritis and immobilization in an extreme position, we observe that in some cases we obtain a summation while in others we do not. In Table VII, we show the average percentage of change in weight in the group of animals studied after 10-11 days of treatment, together with the results obtained by Thomsen and Luco[2] for the same period.

Table VII shows that the loss of weight of the soleus in arthritis is slightly over one-half the loss of weight in immobilization in hyperextension, and that the loss of weight in arthritis with hyperextension is practically

TABLE V.
Tibialis in Arthritis with Hyperextension.

Animal No.	Days of arthritis	Wt in g		% difference	Wt of desic. muscles		% difference
		N	AI		N	AI	
31	2.5	3,600	4,220	+17.2	1,080	1,170	+ 8.3
32	2.5	2,630	3,600	+36.8	780	870	+11.5
33	2.5	3,280	3,440	+ 4.8	920	980	+ 6.5
34	2.5	3,300	3,920	+18.8	820	1,020	+24.3
35	2.5	1,710	2,040	+13.4			
	—			—			
	Avg 2.5			+18.2 ± 5.2			
36	5	5,750	6,500	+13			
37	5	3,020	3,990	+32.1			
38	5	2,900	3,960	+40			
39	5	3,170	4,640	+46.3	770	1,100	+42.8
40	5	4,480	7,270	+62.2	1,130	1,410	+24.7
41	5	3,560	5,000	+40.4	870	1,050	+17.1
42	7	4,500	6,220	+28			
43	7	3,280	4,320	+24			
44	7	3,180	4,380	+37.7	830	1,050	+26.5
	—			—			
	" 5.7			+35.9 ± 4.68			
45	9	5,200	6,250	+17			
46	9	4,280	5,560	+22.8	1,110	1,220	+ 9.9
47	9	3,250	3,820	+17.5	830	960	+13.5
48	9	3,420	4,610	+25.8	840	1,120	+33.3
49	9	2,250	3,130	+39.1			
50	10	3,940	5,300	+26			
51	12	3,780	5,460	+17.9	1,020	1,220	+19.6
52	13	2,360	4,420	+87.2	590	970	+64.4
53	13	4,200	4,040	— 3.8			
54	13	1,330	2,610	+96.2	380	640	+68.4
55	14	1,510	2,760	+82.8	440	700	+59
	—			—			
	" 10.8			+38.9 ± 10			
56	16	3,900	5,600	+43.6	1,050	1,390	+32.3
57	16	2,830	3,920	+38.5	790	1,060	+34.1
58	16	2,720	3,170	+15.2			
59	16	3,640	5,980	+64.5	1,000	1,190	+19
60	16	4,610	6,430	+25.3	1,280	1,620	+26.7
	—			—			
	" 16			+37.2 ± 8.6			

N—Normal.
AI—Arthritis with immobilization in hyperextension.

the same as that with hyperextension alone.

Hyperflexion results in a slight increase in weight of the soleus, and arthritis plus hyperflexion results in no change of weight, the hyperflexion preventing the loss of weight that usually accompanies arthritis.

In the case of the tibialis anticus, in which arthritis causes a loss of and hyperextension an increase of weight, the simultaneous action of these two factors results in an increase of weight greater than by immobilization alone. No doubt edema plays a role in these results. Also, the standard error of the increase in weight is ±10, indicating that the mean value may be subject to great variation.

Hyperflexion causes a loss of weight of the tibialis, but when combined with arthritis it fails to alter the loss of weight due to the latter.

Summarizing: the loss of weight produced by immobilization and shortening of a muscle is not modified by arthritis in a period of 10 or 11 days. On the other hand, the atrophy due to arthritis does not develop, or is changed into hypertrophy when the joint is immobilized in a position which by itself causes an increase in weight.

As we said before, the increase in weight of the tibialis by immobilization and arthritis

TABLE VI.
Soleus in Arthritis with Hyperextension

Animal No.	Days of arthritis	Wt in g		% difference	Wt of desic. muscles		% difference
		N	AI		N	AI	
31	2.5	2,080	1,850	—11.1	540	510	— 5.5
32	2.5	1,730	1,740	+ 0.5	450	450	0
33	2.5	1,250	1,360	+ 8.8	360	380	+ 5.5
34	2.5	2,330	2,070	—11.1	630	560	—11.1
35	2.5	1,370	1,200	—14.2			
	Avg 2.5			— 5.4 ± 4.32			
36	5	2,850	2,800	— 2			
37	5	1,740	1,630	— 6.3			
38	5	1,950	1,710	—14			
39	5	1,800	1,230	—31.6	420	320	—23.8
40	5	1,740	1,680	— 3.4	440	390	—11.3
41	5	1,480	1,640	—10.6	420	430	+ 2.3
	" 5			— 7.7 ± 5.63			
42	7	3,100	3,000	— 3			
43	7	1,600	1,400	—12			
44	7	2,300	1,490	—35.2	520	370	—28.8
	" 7			—16.7 ± 9.5			
45	9	2,550	1,830	—28			
46	9	2,080	1,350	—35.5	450	330	—26.6
47	9	1,700	890	—47.6	470	290	—38.3
48	9	1,950	1,340	—31.2	470	310	—34
49	9	1,320	1,040	—21.2			
50	10	1,970	1,430	—27			
	" 9.1			—31.6 ± 3.16			
51	12	1,690	1,130	—33.1	460	280	—39.1
52	13	1,740	900	—48.2	440	220	—50
53	13	1,820	940	—48.4			
54	13	1,060	440	—58.5	275	110	—60
55	13	1,160	606	—48.3	310	170	—45.1
	" 12.8			—47.3 ± 4.15			
56	16	2,640	1,330	—45.4	670	330	—50.7
57	16	1,730	660	—62	430	190	—55.8
58	16	1,960	610	—69			
59	16	2,090	1,510	—27	550	290	—47.2
60	16	2,270	1,290	—43.7	620	360	—41.8
	" 16			—49.4 ± 7.36			

N—Normal.
AI—Arthritis with immobilization in hyperextension.

is less marked in desiccated muscles. This applies to both positions. On the other hand, the results obtained with desiccated soleus muscle are similar to those obtained with the fresh muscle.

With reference to periarthritis, Lippman and Selig discarded all animals that developed this complication and, nevertheless, obtained a curve that almost coincides with the one we obtained without discarding such animals.

The results obtained in this work do not agree with those of Huddleston,[4] who found that immobilization of the tibialis in a position

[4] Huddleston, O. L., *South, M. J.*, 1944, **37**, 72.

TABLE VII.

	% diff. in soleus	% diff. in tibialis
Arthritis	—24.0	—22.7
Arthritis and hyperextension	—38.8	+38.9
Hyperextension	—38.0	+28.0
Arthritis and hyperflexion	+ 2.9	—11.6
Hyperflexion	+11.0	—13.0

of maximum extension (hyperextension) caused a greater loss of weight than immobilization in maximum shortening, and that the change in the soleus was the same in either position. The experimental conditions were different in the two cases, and we believe that the different results are due to the fact that we studied the first 16 days of immobilization while Huddleston's experiments extended from 95 to 290 days. It may be that our results would change with time and come to resemble those of Huddleston. Besides, the results listed in our tables show that there are wide variations from animal to animal and, therefore, the averages must be taken from a large number of animals.

Our results cannot be compared either with those of Hines[5] who studied in rats the effect of immobilization on the recovery from paralysis caused by crushing the nerve. In our experiments the nerve was kept intact.

[5] Hines, H. M., *J. A. M. A.*, 1942, **120**, 515.

Summary. 1. Arthritis of the tibio-tarsal joint produced in cats by injecting silver nitrate, causes an atrophy of the soleus and tibialis anticus muscles. Tables I and II, Fig. 1 and 2.

2. Immobilization of the inflamed tibio-tarsal joint in hyperflexion results in a loss of weight of the tibialis that is similar or slightly less marked than that caused by arthritis alone. Table III, Fig. 1. In these conditions the soleus keeps its normal weight. Table IV, Fig. 2.

3. Immobilization of the inflamed joint in hyperextension results in an increase of weight of the tibialis. Table V, Fig. 1. The soleus, on the other hand, shows a greater loss of weight than by arthritis alone. Table VI, Fig. 2.

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Respiratory Mask and Valves for Dogs.

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The units to be described were developed in this laboratory for the purpose of collecting expired air of unanesthetized, trained dogs. The avoidance of leaks, minimization of resistance to breathing and of dead space were prime factors considered in designing the apparatus. No new fundamental principles are involved; rather, the apparatus embodies good features of older designs, eliminates some of the bad and utilizes new devices, to our knowledge never previously described.

Mask. The mask consists of a copper wire frame, on the order of carefully shaped commercial wire muzzle, made to fit loosely the snout of a 15 kg mongrel hound. The nasal end is projected about 1″ beyond the nose and fitted with a No. 9 stopper with a single 3/8″ bore. The open end is bent to fit the snout near the lip corners with about 1/4″

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