EFFECT OF STRETCH TRAINING FOR POST-INJURED SKELETAL MUSCLE ON THE MUSCULAR CONTRACTILITY AND RELAXATION

Shengnian Zhang and Aiyun Lu
Department of Sports Science, Shanghai University of Sport, Shanghai, China

The purpose of this study is to identify the effect of the post-injured skeletal muscle training on its contractive strength and relaxation. From the 46 SD rats, 10 are randomly taken as the control group; the others are acutely strained in the triceps surae muscles under the same condition and then further randomly divided into natural recovery group and stretched training group. Their isometric muscular contractive strength and stress relaxation of the gastrocnemius are respectively tested on the 2^{nd} day, 10^{th} day, 17^{th} day, 24^{th} day and 30^{th} day. For the early-stage slight and moderate muscle injuries, the great changes in their muscular contractive strength are mainly caused by inflammation. The early-stage recovery of their contractive strength is not consistent in time with the repair of muscular structure, which may be the major causes of the muscular re-injury. Stretch training, at the early stage, has a negative effect on the recovery of the muscular functions; however, it greatly helps it at the late stage.

KEY WORDS: skeletal muscle, stress, contractive strength, relaxation, strain

INTRODUCTION: Clinically, stretch training is a commonly used healing and rehabilitation means for patients suffering from soft tissue injuries. However, in the present studies, little fundamental research has been conducted on it, especially little is known about the effect of the post-injured skeletal muscle exercises on the muscular physiological and mechanical properties. This research studies the effect of stretch training for acute injured skeletal muscle on its contractility and stress relaxation properties to accomplish some preliminary work for further studies.

METHODS: 6-week-old male Sprague Dawley (S.D.) rats (n = 46) weighing 180-200 g were used for this study. Ten of them were randomly separated from the others to form a blank control group (C). The rest, under the same condition, were acutely strained in the triceps surae muscles. After that, they were further randomly divided into two groups, 20 for natural recovery group (NR) and 16 for stretch training group (ST).

The rats were injected 0.4% sodium pentobarbital in the abdominal cavity and got anesthetized. Then they were fixed in the supine position onto a special splinting board, with knee joints in hind-limbs fixed, but ankle joints free and feet tied onto a foot splinting board. Two platinum needle electrodes are inset in the two ends of the triceps surae muscles and the other ends were connected with the outputs of a electro-stimulating device. The tibialis posterior muscle group was stimulated into isometric contraction by electro-stimulating (50v, 75 Hz) with ankle joints is flexional. Meanwhile, the foot splinting boards were pulled in the opposite direction with an extending device at a rate of 0.55 m/s to cause the dorsiflexion of the ankles at the angular velocity of 25.56 rad/s and the eccentric contraction of the triceps surae muscles. At last, a moderate acute strain in the triceps surae was produced by a controlled stretch of the muscles (Zhou, Li, 1998).

NR group, kept free in cages after the injury. ST group, began to undergo stretch training in the triceps surae three days after the injury.

We recorded and tested at two time points2^{nd} day, 30^{th} day) for C group, the mean value of which was used as contrastive value of normal muscles, while, for the other groups, four rats of each group were recorded and tested at each point of the whole experimental course (after injury 10^{th} day, 17^{th} day, 24^{th} day and 30^{th} day).

After being anesthetized, the rats fixed on to the splinting board. Then we operated on the posterior-part of its right leg, measuring respectively the length and the perimeter (the point---1 cm off the nearest-end insertion site)of gastrocnemius, with the metatarsus pose being dorsiflexion 90°. The tibia and fibula were cut broken at 0.5 cm off the ankle and tested immediately when muscular properties in contractility and relaxation were tested in the state of semi-separation from the body. The sample preparation process was completed within 3min.

Calculating the contrastive cross section area of gastrocnemius muscle based on the available researches, we calculated the cross section area (CSA) of the gastrocnemius by applying the regression equation(Houman,1985): CSA = 1.060387 + (0.008371) × body weight (g) + (-0.755974) × muscular length (cm) + (0.30825) × muscular perimeter (cm).

The gastrocnemius muscle, in the state of being half away from the body, was fixed with a sensor on one end and with a slip-block of a loading device on the other. The slip-block moved at the speed of 0.5 mm/s to load the muscle, with the computer controlling the amount value of the load. Computer began to collect data from the muscle when it had been loaded 1 kg, and the muscle was made isometric contraction which lasted 12 s with a 75 hz, 50 v electrostimulating. Sampling 1000 times, at 20 ms intervals, the computer recorded the curve of muscular force --- time. The difference of maximum tension value minus the 1kg pre-load was taken as the muscle contractility, and calculate the muscular contractile stress.

When the muscle was loaded 4 kg, computer started to collect data. Sampling 3000 times in 1min, at 20 ms intervals, the computer recorded the muscular tension---time curve. The difference of the original strength value minus the minimum strength value was divided by the muscular cross section area. The result was taken as the evaluating indices for stress relaxation within 1min. The data is processed by the LSD of ANOV in SPSS.

RESULTS AND DISCUSSION: NR group: on 2D after the muscle was strained , its muscular force showed a significant drop to 53.37% that of normal muscles ($p < .01$), but a gradual increase on 10 D to 90.27 % that of normal muscles and up to the normal level on 17 D. There was a significant difference between the muscular force on 2 D from those on 10 D---30 D ($p < .01$). (see Table 1). The changes in muscular structure make the changes in muscular function. During the early post-injury period the inflammatory reaction reflected the most violently, the switching-on action of the inflammatory medium and the infiltration of inflammatory cells took responsibility for clearing up tissue fragments and repairing fibers, that is the main factors of the muscular contractility reducing (Nikolaou, 1987;Hasselman, 1995; Garrett, 1988). After 48 H, the muscular performance showed quick recovery due to the decline in inflammatory reaction. According to our experiment, even if the post-injured muscular contractility could recover almost to the normal level on 10 D, it didn't enter the steady period until 17 D. The results of NR express: although the clinic symptoms start to appear less and less apparent or even completely disappear two weeks later after the injury, and the muscular contractility seems to have recovered, the structural repairing work was still in the process, during which the injured muscle was very easy to get reinjured.

Table 1 Changes in muscular contractility in Group NR. (** $p < .01$, * $p < .05$).

Time	Sample	Contractility (kg/cm^2)	%C	C	C	2 D	10 D	17 D	24 D
(C)	10	0.6633 ± 9.586E-02							
2D	4	0.3540 ± 8.175E-02	53.37	**					
10D	4	0.5988 ± 5.262E-02	90.27	-	**				
17D	4	0.6818 ± 2.907E-02	102.78	-	**	-			
24D	4	0.6625 ± 3.909E-02	99.88	-	**	-	-		
30D	4	0.6905 ± 1.652E-02	104.10	-	**	-	-	-	

ST group: Compared with normal muscle, the muscle contractility showed no significant difference on 10 D, 17 D, and 24 D, but had a significant increase on 30 D ($P < 0.05$). On 2 D after the injury, the muscular contractility had significant difference from all the other time points within ST group ($p < .01$) (see Table 2). ST Group showed different dynamic properties in the recovery of the injured muscular contractility from NR. The early-stage stretch exercises intensified the inflammatory reaction and tissue fluid bleeding and facilitated the tissue degradation and autolysis. So ST group showed lower than that of NR group in muscular contractility. However, during the late recovery period stretch training had a favorable effect and caused remarkable growth in muscular contractility after 30 D. Based on this fact, we could conclude that too much stretch exercise during the early period had an unfavorable effect on the recovery of post-injured muscular contractility, during the late period, stretch training not only helped repair the injured muscular structure, but also increased reflectively the injured muscular contractility (Taylor, 1990).

Table 2 Changes in muscular contractile in Group SE. (** $p < .01$, * $p < .05$)

Time	Sample	Contractile stress (kg/cm^2)	%C	C	2D	10D	17D	24D
(C)	10	0.66 ± 9.586E-02						
2D	4	0.35 ± 8.18E-02	53.37	**				
10D	4	0.58 ± 7.15E-02	87.60	-	**			
17D	4	0.63 ± 1.32E-02	94.87	-	**	-		
24D	4	0.63 ± 4.60E-02	93.88	-	**	-	-	
30D	4	0.77 ± 6.91E-03	115.80	-	**	-	-	-

NR group: On 2 D after the injury, the stress relaxation showed significant difference from17 D, 30 D ($p < .05$), while there was no statistical difference between the different recovering periods. (see Table 3). ST Group: On 17 D, the muscle stress dropped to 137.22% with a significant difference from 24 D, 30 D and that of normal muscle. On 24 D, it recovered to normal level and tended to become even higher(see Table 4). The stress relaxation of the muscle when preloaded 4 KG was the temporal reaction of the interior muscular linking components to the exterior loading stretch, which reflected more directly the recovering progress and fibrosis degree of the strained muscle, and therefore it is an important index for function evaluation in the research of experimental muscular injuries. By 17 D after the injury, the stress reduction in Group NR became relatively steady, which was in agreement with the structural recovery and basically reflects the progress of the muscular fibrosis in the course of natural recovery. The stretch training had an active effect on the ordering and flexibility of the muscular structure and help the late-period injured muscle repair.

Table 3 Stress reduction with preload 4 KG for 1 min in Group NR. (* $p < .05$)

Group	Sample	Stress relaxation (kg/cm^2)	% C	C	2 D	10 D	17 D	24D
C	10	0.57						
NR2D	3	0.75	131.72	*				
NR10D	3	0.61	108.00	--	--			
NR17D	3	0.55	97.47	--	*	--		
NR24D	4	0.59	103.41	--	--	--	--	
NR30D	3	0.55	96.71	--	*	--	--	--

Table 4 Stress reduction with preload 4KG for 1min in Group SE. (* $p < .05$)

Group	Sample	Stress relaxation (kg/cm^2)	% C	C	2D	10D	17D	24D
C	10	0.57 ± 7.82E-02						
SE2D	3	0.75 ± 6.72E-02	131.72	*				
SE10D	3	0.67 ± 0.21	117.97	--	--			
SE17D	3	0.78 ± 0.20	137.22	*	--	--		
SE24D	3	0.52 ± 2.08E-02	91.18	--	*	--	*	
SE30D	3	0.51 ± 7.58E-02	90.41	--	*	--	*	--

CONCLUSION: For the early-stage muscular contractility changes, inflammatory reaction was one of the key factors. For the early-stage post-injured muscle, too much stretch exercises may cause negative effect on the recovery of muscular function. Stretch training in the middle and late recovery period of the muscular injury have active effect on the recovery of muscular contractility and relaxation.

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