EFFECT OF CONTINUOUS MUSCLE STRETCHING ON DISUSE-ATROPHIED MUSCLE WITH SPECIAL REFERENCE TO ENERGY METABOLISM ASSESSED BY 31P-MRS

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Introduction

Various countermeasures to prevent disuse atrophy of skeletal muscle have been established and well studied; among them muscle stretching has been reported to be effective (1,2). However, most of the research has been based on in vitro measurement. Intramuscular energy metabolism in working muscle is one of the important indicators of skeletal muscle function, and it can be monitored in vivo and in real time using phosphorus-31 magnetic resonance spectroscopy (31P-MRS). The purpose of this study was to evaluate the effects of continuous muscle stretching as a countermeasure to prevent disuse atrophy of skeletal muscle using a hind-limb suspension model (3) with reference to energy metabolism in the working muscle assessed by 31P-MRS.

Methods

Materials  Thirty Sprague-Dawley rats were used and divided into five groups: control group (C), hind-limb suspended for 3 days (HS-3), for 7 days (HS-7), HS plus muscle stretch for 3 days (ST-3), and HS plus stretch for 7 days (ST-7). Continuous muscle stretching of the gastrocnemius-plantaris-soleus (GPS) muscle group was attained by immobilizing the ankle joint at 60° in the dorsal flexion position. The GPS muscle in each group was subjected to the following measurements, and the data were compared among the groups.

Measurement After a 2-min rest, contraction of the GPS muscle group was induced by electrical stimulation of the sciatic nerve at 0.25Hz for 10 min, then the frequency was increased to 0.5 and 1.0Hz every 10 min. During the stimulation, twitch forces were recorded by a strain gauge, and simultaneously 31P-MRS was measured. On each spectrum, the peaks of phosphocreatine (PCr), and inorganic phosphate (Pi) were observed. The ratio of the area of both peaks (PCr/(Pi+PCr)) and intracellular pH, determined by the chemical shift between both peaks, were calculated as indicators of energy metabolism. The PCr/(Pi+PCr) and force were measured at a steady-state in each frequency, and the relationship between the PCr/(Pi+PCr) and peak twitch force times rate (force*rate) was examined to evaluate oxidative capacity in working muscle(5). Maximum tension was measured at the muscle contraction induced by 0.25Hz; the wet weight of the whole GPS muscle was also measured.

Results

Muscle weight The weight of the whole GPS muscle decreased significantly (p<0.05) with time in HS groups (2.65, 2.38, and 2.22 (g) in C, HS-3, and HS-7 respectively). On the other hand, in the ST-3 this was 2.78 (g) and did not differ from that in the C group. However, in the ST-7 it was 2.18(g); i.e., it was significantly (p<0.05) smaller than that in the C group (Fig. 1).

Tension The maximum tension was 5.0, 4.4, 4.4, 5.3, 4.2 (N) for C, HS-3, HS-7, ST-3, and ST-7, respectively. In HS-3, HS-7 and ST-7, it was significantly smaller than that in C (p<0.05), while in ST-3 it was not different from that in C.

MRS Measurements Intracellular pH did not decrease below 7.0 during muscle contractions, indicating the muscle exercise was aerobic. Significant (p<0.05) linear relationships between PCr/(Pi+PCr) and force*rate were found in all groups during muscle contraction. The slope in C group was gentler than that in HS-3, HS-7 and ST-7 (p<0.05), but no difference was observed between C and ST-3 (Fig. 2). During aerobic exercise the slope indicates muscle oxidative capacity (4). Therefore, the oxidative capacity of muscles was shown to be maintained for three days when continuous stretching was applied to the suspended limb.

Discussion

Skeletal muscle atrophy, as evaluated by measuring the muscle wet weight, worsened with time as the suspension period was extended, suggesting that the HS could induce muscle atrophy to the gastrocnemius-plantaris-soleus muscle. The whole muscle weight in ST-3 was almost equal to that of C group, indicating that continuous muscle stretching could prevent muscle disuse atrophy. However, the b muscle weight in ST-7 was lower than that in C group. Therefore, stretching may be effective only during the first couple of days. Based on the results of maximal tension, we found that muscle stretching also prevented muscle weakness during the first three days.

The muscle oxidative capacity was evaluated in the working muscle in vivo using 31P-MRS. Although the oxidative capacity decreased during hind-limb suspension, it could be maintained at control levels by applying continuous stretching on the disused muscles during the first three days. The capacity in ST-7 decreased to a level similar to that in HS-7, thus, the stretching effect may not persist after three days.

These data indicated that continuous muscle stretching prevented atrophy, weakness and deterioration of the muscle oxidative capacity induced by disuse only during the first three days. Therefore, other countermeasures, such as electrical stimulation, should be established to prevent deterioration of muscles in case of prolonged disuse.

References