EVALUATION OF DISUSE ATROPHY OF SKELETAL MUSCLE BASED ON MUSCLE ENERGY METABOLISM - A 31P-MRS STUDY -

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Introducton

Much has been reported about disuse atrophy of skeletal muscle, however, most studies were based on *in vitro* measurements (1,2). The intramuscular energy metabolism need to be measured *in vivo,* and it is important to examine the changes in metabolism in the working muscle (3), which has been made possible using phosphorus-31 magnetic resonance spectroscopy (31P-MRS). The purpose of this study was to evaluate disuse atrophy of skeletal muscle using a hind-limb suspension model (4) with special reference to the energy metabolism using 31P-MRS.

Methods

Materials Twenty-four Sprague-Dawley rats were used and divided into four groups: control group (C), hind-limb suspended for 3 days (HS-3), for 7 days (HS-7) and for 14 days (HS-14). The gastrocnemius-plantaris-soleus (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 the muscle oxidative capacity (5). Maximum tension was measured at the muscle contraction induced by 0.25Hz; the wet weight of the whole and each muscle in the GPS muscle was also measured.

Results

Muscle weight The weight of the whole GPS muscle in C, HS-3, HS-7, and HS-14, was 2.65, 2.38, 2.32, and 2.13 (g) respectively (Fig. 1). Thus, the muscle mass significantly decreased with time ($p<0.05$). Especially, among the GPS muscle, the decrease in weight of the soleus muscle was remarkable; in the HS-14 group its weight decreased to 60% of that in the C group (Fig. 2).

Maximum tension The maximum tension in C, HS-3, HS-7, and HS-14 was 5.0, 4.4, 4.3, and 4.4 (N) respectively. This was significantly greater in the C group than that in any other groups, however there were no significant differences among the three HS group.

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 the gentlest ($p<0.05$), but this did not differ among the three HS groups (Fig. 3). During aerobic exercise the slope indicates muscle oxidative capacity (5). Therefore, the oxidative capacity in the C group was higher than in any HS group and it did not further decrease even if suspension of the limbs was prolonged beyond 3 days.

Discussion

Skeletal muscle atrophy, as evaluated by measuring the muscle wet weight, worsened with time. The decrease was greater in the soleus muscle whose fiber are mostly of the slow type. These data indicated that hindlimb suspension induced muscle atrophy, and that disuse affected mainly the muscle constituted by slow type fibers. The present results were in agreement with those of previous reports. (1, 2, 3)

As for skeletal muscle function parameters, we measured maximum tension and oxidative capacity. The tension decreased during the initial three days and remained at the same level until Day 14. The oxidative capacity of the GPS muscle group was measured *in vivo* and in real time during muscle contraction by 31P-MRS. The oxidative capacity was significantly decreased after three days of HS; however, it did not decrease any further thereafter despite prolonged suspension for 14 days. The present study showed that in disuse atrophy, muscle mass and muscle function did not change simultaneously. Thus, it is necessary to develop countermeasures to prevent muscle atrophy and muscle function deterioration independently.

References

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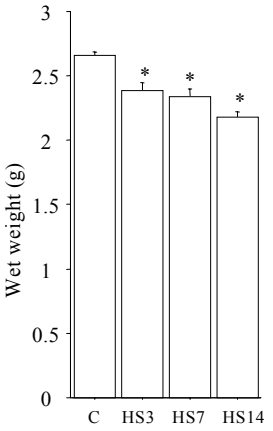

Fig. 1 Wet weight of GPS muscles.

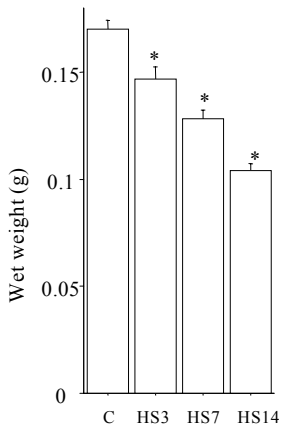

Fig. 2 Wet weight of soleus.

The bar means S.E. * Significant difference at $p<0.01$ compared to C group.

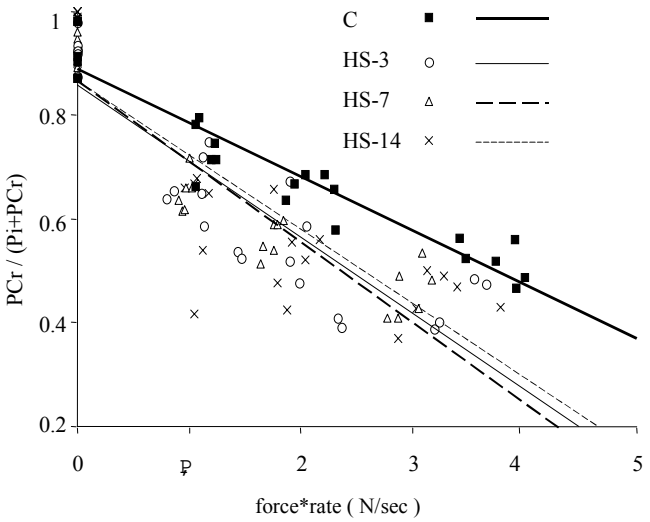

Fig. 3 Regression lines between PCr / (Pi + PCr) and force * rate.

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