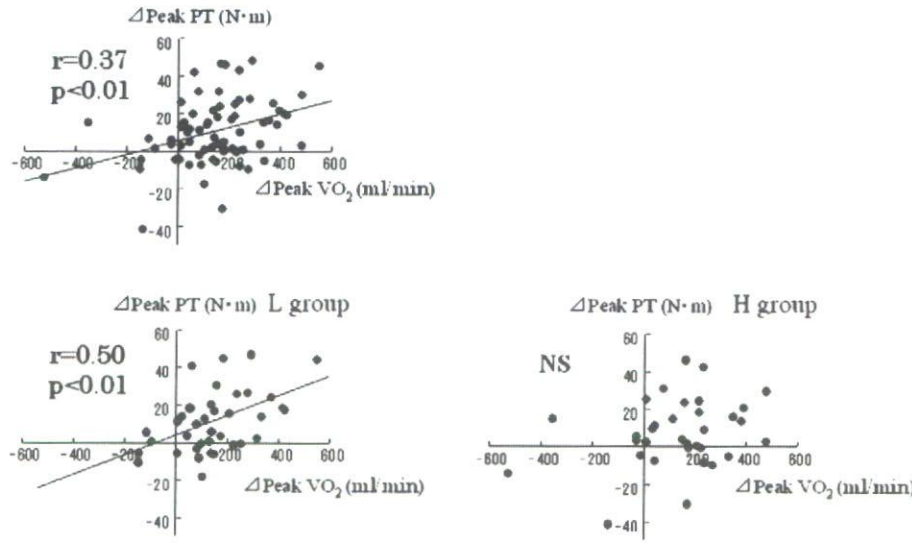

Fig. 1. Correlations between delta muscle strength and delta exercise capacity. Positive correlations were observed between delta PT and delta peak VO_2. Delta PT was significantly and positively correlated with delta peak VO_2 in L group, but not in H group. PT = peak torque, VO_2 = oxygen uptake.

strength in the L and H groups. No significant changes were observed in the total muscle volume and the upper or lower limb muscle volume in the 2 groups. A significant increase of PT in both groups was observed: group L, 113.4±34.5 to 126.0±37.5 Nm ($p<0.0001$); and group H, 137.9±33.3 to 146.1±39.7 Nm ($p<0.05$).

3.3. The relationship between the delta skeletal muscle strength and delta exercise capacity

The delta PT positively correlated with the delta AT ($r=0.26$, $p<0.05$) and the delta peak VO_2 ($r=0.37$, $p<0.01$). A positive and significant correlation was observed between the delta PT, the delta AT ($r=0.46$, $p<0.01$) and the delta peak VO_2 ($r=0.50$, $p<0.01$) not in the H group but in the L group (Fig. 1).

3.4. The relationship between the delta lower limb muscle volume and delta exercise capacity

The delta AT had no correlation with the lower limb muscle volume including the thigh and crus. Moreover, the delta AT had no significant correlation with the delta lower limb muscle volume in the L and H groups.

The delta peak VO_2 revealed no correlation with the lower limb muscle volume including the thigh and crus. The delta peak VO_2 observed no significant correlation with the delta lower limb muscle volume in the 2 groups (Fig. 2).

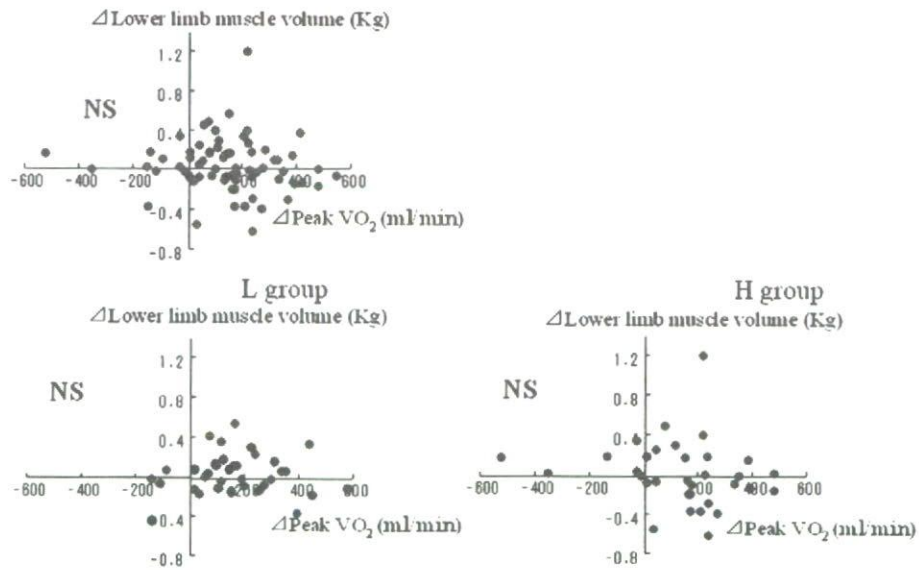

Fig. 2. Correlations between delta lower limb muscle volume and delta exercise capacity. There was no correlation between delta lower limb muscle volume and delta peak VO_2. A correlation was not significant in both H and L groups. VO_2 = oxygen uptake.

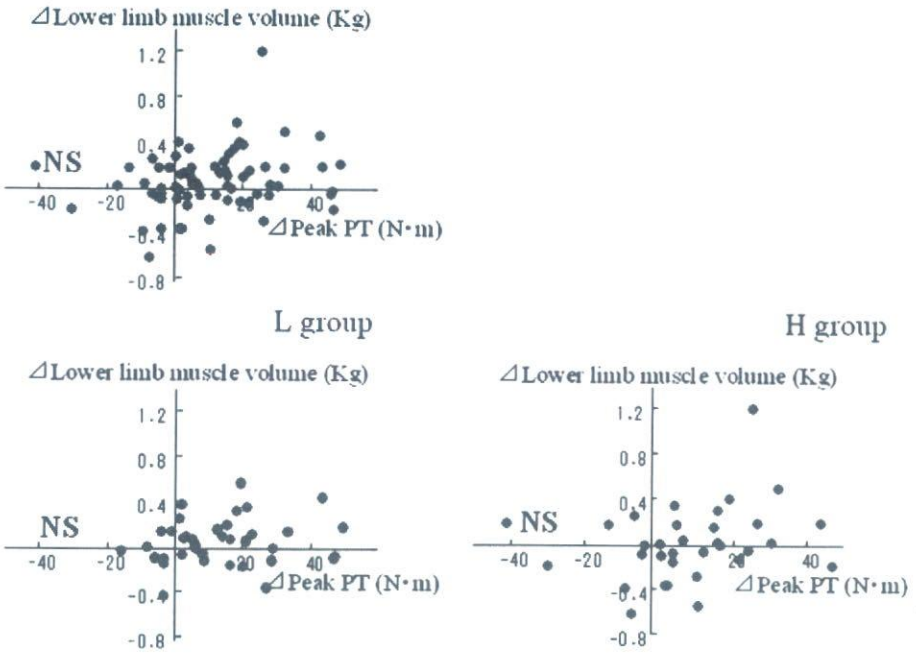

Fig. 3. Correlations between delta muscle strength and delta lower limb muscle volume. No correlation revealed between delta PT and delta lower limb muscle volume. A correlation was not significant in both H and L groups. PT = peak torque.

3.5. The relationship between the delta skeletal muscle strength and the delta lower limb muscle volume

The delta PT revealed no significant correlation with the delta skeletal muscle volume of the whole body or upper limb or lower limb including muscles of thigh and crus. No significant correlation was observed between the PT and the lower limb muscle volume in L and H groups (Fig. 3).

4. Discussion

In the present study, we measured the lower limb muscle strength and volume at 1 and 3 months after 12-week recover-phase CR program and analyzed the improvement.

And we evaluated the influence of the skeletal muscle volume on exercise capacity in a relatively large population of patients with MI using bioelectricity impedance, a new method for measuring the skeletal muscle volume.

4.1. Exercise capacity after 12 week recover-phase CR program

Resistance exercise training was performed at 50% intensity of 1 repetition maximum combined with aerobic training. AT and peak VO_2 were significantly improved, which was the similar results as previous reports without cardiac or orthopedic complications [5,8]. Many study reports have suggested the necessity of exercise training which improves exercise capacity in patients with cardiac disease [4–8,14,15]. In addition, exercise capacity was significantly improved both in the L and H groups. CR improved exercise capacity regardless of the degree of skeletal muscle volume in patients with MI.

4.2. The skeletal muscle volume and strength after 12 week recover-phase CR program

Murabayashi et al. [4] reported significantly increased muscle volume after 3-month exercise training in patients with MI; however, no significant increase was observed in this study. The training effect on skeletal muscle volume and strength in our study was similar to that demonstrated by Beniamini et al. [7]. In the present study, there was a tendency that the L group increased more muscle volume than the H group. This trend suggested that exercise therapy along with exercise training would be more effective to the patients with low muscle volume.

A significant improvement of the skeletal muscle strength was observed in this study, which was similar to the results of previous studies [6,7]. Fragnoli-Munn et al. [8] reported that middle-intensity strength training was effective to improve exercise capacity and muscle strength but not body composition. Beniamini et al. [7] demonstrated that high-intensity strength training (80% of one repetition maximum) during 12-week recover-phase CR program improved exercise capacity and to changed body composition.

4.3. The relationship between the delta lower limb muscle strength and delta exercise capacity

In the present study, we analyzed the improvement of exercise capacity based on the lower limb muscle strength as an index of acceptable muscle quality. This is the first study

report to indicate a correlation between the delta lower limb muscle strength and delta exercise capacity in the overall investigation. The delta lower limb muscle strength correlated with delta exercise capacity not in the H group but in the L group. The skeletal muscle volume in the L group was somewhat smaller than the H group, which would not have been found if our patients had been cachectic. Cachectic patients with CHF are characterized not only by small muscle volume, but also by endocrine, catabolic, or cytokine abnormalities that apparently cause qualitative changes of skeletal muscle such as increased Type II b fiber, decreased Type I fiber, and the decreased mitochondria volume [16,17] in skeletal muscle biopsy. We believe that these changes were responsible for the discrepancy of the results in MI patients. Accordingly, it is necessary for patients in the L group to increase lower limb muscle strength by muscle training which improves exercise capacity.

4.4. The relationship between the delta lower limb muscle volume and delta exercise capacity

The amount of muscle volume was also analyzed in this study. The lower limb muscle volume was used as indexes of acceptable muscle quantity and the improvement of exercise capacity. No correlations were observed between the delta lower limb muscle volume and delta exercise capacity neither in the overall investigation nor a comparison between the 2 groups. Murabayashi et al. [4] found a significant correlation between the delta skeletal muscle volume and delta exercise capacity in patients with MI.

Exercise capacity was improved by increased muscle strength without any change of muscle volume. Previous studies reported no significant changes of skeletal muscle volume [7,8]. A certain period of bed rest during hospitalization, which causes deconditioning, might affect the result. Patient's muscle remains unchanged in the acute phrase of MI; however, it takes a time to increase muscle volume.

4.5. The relationship between the delta lower limb muscle strength and the delta lower limb muscle volume

No correlation was observed between the delta lower limb muscle strength and volume neither in the time-change and overall investigations nor a comparison between the L and H groups. No study has described the relationship between the delta lower limb muscle strength and volume. We presumed that muscle and/or nerve fibers and a psychological factor, such as patient's willingness to move after the MI onset, possibly affected an increase of muscle strength before muscle volume increased.

5. Study limitations

The data obtained in the present study was insufficient to evaluate the following 2 points; since muscle biopsies of the lower extremities were not performed, we were unable to adequately observe muscle tissue change. The evaluations of the distal skeletal muscle blood flow at rest and during exercise were not evaluated. Future studies would be necessary to address these points. Our evaluations of skeletal muscle strength were also lacking, as we based them on peak torque alone rather than peak torque and muscle endurance in combination. We measured only skeletal muscle strength of the thigh. Future studies should also evaluate muscle endurance to improve the reliability of data on skeletal muscle strength and measure skeletal muscle strength of the calf. This is attributed to the fact that it was too small to analyze the muscle volume changes in MI patients during 3 months after the onset using a bioelectrical impedance method (mean 0.05±0.27 kg).

6. Conclusions

CR program combined with resistance and aerobic training improved exercise capacity and increased not the skeletal muscle volume but the skeletal muscle strength in patients with AMI in their recovery phase. The improvement of exercise capacity is thought to depend on the skeletal muscle strength. It is vital for MI patients with low muscle volume to increase their lower limb muscle strength by muscle training which improves exercise capacity.

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