Combination of KAATSU training® and BCAA intake for a patient after aortic valve replacement surgery: A case study

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Abstract

We report a case in which a favorable course was obtained by using KAATSU training® and BCAA intake early after aortic valve replacement surgery. The patient was a 43-year-old male with low cardiac function who underwent aortic valve replacement surgery. Heart failure and hypotension persisted while waiting for surgery. He tended to lie on a bed all day, so that disuse muscular atrophy advanced. Therefore, in addition to the postoperative rehabilitation program, KAATSU training and BCAA intake were performed postoperatively and continued in outpatient rehabilitation. The KAATSU training was performed using knee extension twice or three times a week. For BCAA intake (2.5 g), one pack of jelly containing BCAA (Reha-Time Jelly, Clinico Co., Ltd.) was taken within 30 minutes after the training. About 3 months later, the thigh circumference (+7.3 cm), the maximum voluntary isometric contraction of knee extension (+20 kgf), the quadriceps muscle thickness (+1 cm) evaluated by a B-mode ultrasound, the muscle mass of the lower limb (+1 kg), and a marked increase in thigh muscle cross-sectional area as measured by CT scan were observed. No deterioration of circulatory hemodynamics and side effects were observed during the course. In conclusion, the combined use of KAATSU training and BCAA intake early after cardiac operation seems to be a safe and effective way to obtain muscle hypertrophy and muscle strengthening, but further studies are needed to clarify it.

Key word: KAATSU training, cardiac surgery, muscle hypertrophy, muscle strength, BCAA

Introduction

Rehabilitation for patients with heart disease is based on aerobic exercise to improve cardiopulmonary function and resistance training for increasing muscle strength and mass. However, excessive exercise load may increase the risk of arrhythmia and heart failure exacerbation. Therefore, aerobic exercise based on prescription under anaerobic threshold (AT) is usually performed. For a kind of aerobic exercise, an ergometer or a treadmill is used, and its strength is determined by cardiopulmonary exercise testing (CPX). On the other hand, resistance exercise more than 67% of 1 repetition maximum (1 RM) is required for improving muscle strength and mass. But, it is recommended to start from a load of 50-60% in the lower limbs, taking safety into consideration. For that reason, the improvement of muscle strength and an increase in muscle mass are not observed in several cases.

KAATSU training is a method that inventor Dr. Yoshia-ki Sato repeatedly have conducted research for over 47 years. It is a novel exercise under the conditions with the restricted muscle blood flow, by binding the proximal portion of lower or upper extremities with a specially-designed belt. This training has been reported to induce muscle hypertrophy and strengthen muscle in athletes and healthy subjects, by using a short-term low-intensity exercise. Until now, several clinical studies using KAATSU training have been also reported to promote muscle hypertrophy in patients with cardiovascular diseases including ischemic heart disease. In addition to resistance training, the effect of ingesting

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a beverage containing branched-chain amino acid (BCAA) has been attracted attention. BCAA is considered to induce an increase of the muscle mass by enhancing the synthesis of muscle protein\(^9\) and preventing the degradation of muscle protein\(^10\).

Here, we report a case with low cardiac function in which a marked improvement of muscle strength and mass were obtained by using KAATSU training\(^8\) and BCAA intake early after aortic valve replacement surgery.

**Materials and method**

1. **Subjects**

   The patient was a 43-year-old male (173.0 cm, 66.3 kg, BMI 22.2 kg / m\(^2\)). He was urgently introduced to our hospital with suspected heart failure from a nearby doctor. He had no medical history, and coronary risk factors including dyslipidemia, hyperuricemia, and hypertension. At the time of admission, plasma brain natriuretic peptide (BNP) level was 2566 pg / ml. The cardiac ultrasound examination showed thinner heart wall, and prominent left ventricular enlargement (left ventricular (LV) end-diastolic diameter (LVDd) 72.1 mm, left ventricular end-systolic diameter (LVDs) 57.8 mm, left ventricular end-diastolic interventricular septum (IVS) thickness (IVST) 7.5 mm, left ventricular end-diastolic posterior wall thickness (LVPWT) 9.2 mm, left atrial diameter (LAD) 47 mm). The left ventricular ejection fraction (LVEF) was 34%. He received medication treatment. Cardiac rehabilitation started from the 7th disease day. However, the circulatory hemodynamics was unstable, and the exacerbation of heart failure was observed on the 16th disease day. Symptoms of hypotension also persisted and he became lying bed, so systemic marked waste muscle atrophy was recognized. Postoperative rehabilitation was resumed on the 42th day (Postoperative day 4: POD 4) after aortic valve replacement by thoracotomy on the 38th disease day. Since he was young, muscle recovery was desired for social reintegration. For that reason, KAATSU training and BCAA intake were introduced from the 49th disease day (POD 11), and outpatient rehabilitation continued even after discharge.

   This study has been approved by the ethics committee of Dokkyo Medical University Hospital.

2. **Method**

   In the preoperative evaluation, only body composition analysis (see below) was carried out in consideration of hypotension and risk. On the 44th disease day (POD 6), the thigh circumference was measured in the supine position using a body composition analyzer (Inbody S10) as shown previously\(^12\). The muscle mass of left and right leg was obtained by 280 I.U. (20 µg) vitamin D / 120 g. The BCAA composition (per 120 g of a bag) was isoleucine 0.63 nmol / ml (0.6 g / 120 g), leucine 1.44 nmol / ml (1.4 g / 120 g), and valine 0.47 nmol / ml (0.5 g / 120 g).

3. **Clinical Evaluation**

   The thigh circumference was measured at the midpoint of the thigh length at the supine position. Hand Held Dynamometer (ANIMA Corporation, µTas F-1) was used for measuring MVC of knee extension. In measurements, limb position was a sitting posture with the trunk in the vertical position. The hip and the knee joint were bent 90 degrees and the upper limbs were assembled with the front chest. The position of the sensor was the distal part of the lower leg, and the fixing belt was attached so as to be perpendicular to the direction in which the force was applied. The measurement was performed twice on each side and the maximum value was adopted as MVC of knee extension.

   The quadriceps muscle thickness was measured at the midpoint of the thigh length using an ultrasonic tomography apparatus (GE Healthcare Japan, Ltd., LOGIQ e Premium) as previously described\(^12\). It was measured at supine position, and the measurement was performed twice at each side of the thigh, and the average value was adopted.

   Body composition analysis was measured in the supine position using a body composition analyzer (Inbody Japan, Body Composition Analyzer Inbody S10) as shown previously\(^12\). The muscle mass of left and right leg was evaluated.

   The femoral muscle cross-sectional area was obtained by...
reconstructing the range from the upper edge of the greater trochanter to the upper edge of the patella with a slit of 1.5 mm with a 320-row CT apparatus (Canon Inc., Aquilion ONE). It was measured using ZioStation software. The image data was opened by 3D analysis. The cine was created by re-saving the cine and enlarging the right thigh with the midpoint from the upper edge of the greater trochanter to the upper edge of the patella as the measurement point of the axial image. The rescued right femoral region image was opened with the protocol of body fat measurement. The CT value of the subcutaneous fat of thigh part was 50 ~150 Hounsfield Unit (HU), and the CT value of the visceral fat of 0 ~ 80 HU was changed to muscle CT value and measured. Bones were excluded, and the outer periphery of the thigh muscles was finely adjusted to measure the cross sectional area of the thigh muscle.

For nutritional evaluation, CONUT (controlling nutritional status) modified method\(^\text{13}\) using three items, serum albumin (Alb), peripheral total lymphocyte count (TLC) and hemoglobin (Hb), was used. In the measurement of serum BCAA concentration, blood was collected in control without taking breakfast (control) and 60 and 120 minutes after one bottle of jelly containing BCAA (2.5 g, Reha -ime Jelly, Clinico Co. Ltd., Japan).

4. Result

After the KAATSU training plus BCAA intake, the thigh circumference, the MVC of knee extension, quadriceps muscle thickness, and lower limb muscle mass gradually increased (Table 1). At 80 days after starting the training, the thigh circumference was + 7.3 cm, and the MVC of knee extension was about + 20 kgf for both left and right, compared with the control level before the training. The quadriceps muscle thickness increased about + 1 cm, and the lower limb muscle mass increased about + 1 kg in both left and right (Table 1). Also, in the femoral CT image after 100 days of the training, there was a marked increase in femoral muscle cross-sectional area of 56.9 cm\(^2\) on the right and 55.9 cm\(^2\) on the left, compared with the control level (Table 1, Figure 1).

Table 1. Changes of each evaluation before and after KAATSU training combined with BCAA intake

| Days after KAATSU training | Before | 7 days later | 17 days later | 29 days later | 52 days later | 80 days later | 100 days later |
|----------------------------|--------|-------------|--------------|--------------|--------------|--------------|--------------|
|                            | 44th   | 56th        | 66th         | 78th         | 101th        | 129th        | 149th        |
| Femoral circumference (cm) | 38.2   | 39.0        | 39.5         | 39.8         | 44.3         | 45.5         |              |
| Right knee extension muscle force (kgf) | 40.4   | 38.5        | 38.9         | 39.8         | 53.7         | 64.0         |              |
| Left knee extension muscle force (kgf) | 31.7   | 34.0        | 37.7         | 44.5         | 53.8         |              |              |
| Quadriceps muscle thickness (cm) | 2.1    | 2.4         | 2.4          | 2.6          | 2.8          | 3.1          |              |
| Muscles mass of right lower limb (kg) | 6.7    | 7.2         | 7.4          | 7.7          | 7.8          | 7.9          |              |
| Muscles mass of left lower limb (kg) | 6.7    | 7.1         | 7.3          | 7.7          | 7.7          | 7.9          |              |
| Femoral muscle cross-sectional area (left) (cm\(^2\)) | 61.6   | 117.5       |              |              |              |              |              |
| Femoral muscle cross-sectional area (right) (cm\(^2\)) | 62.2   |              | 119.1        |              |              |              |              |

Figure 1. Comparison of femoral CT scan images before (A) and 100 days after KAATSU training (B) combined with BCAA intake
BCAA intake. The modified CONUT score showed 3 points at the start of the training, and decreased to 0 point after 29 days of the training. Eighty days after the training, he recovered to almost the weight before the operation (Table 2).

Table 3 shows the changes of serum BCAA concentration before and after BCAA intake. The serum concentration of BCAA showed a remarkable increase in numerical value at 60 minutes after BCAA intake, and maintained a high level at 120 minutes, compared to the control level (Table 3).

5. Discussion

This case was a patient with low cardiac function and prominent left ventricular enlargement. However, there was no appearance of any arrhythmia and side effects during the training even early after the cardiac operation. Furthermore, by performing the combined KAATSU training and BCAA administration immediately after the training, the marked muscle strength improvement and muscle hypertrophy could be obtained.

Rehabilitation intervenes during the perioperative period. Resistance training is frequently necessary to improve the reduction of muscular strength and muscle mass due to surgical invasion and waste syndrome due to decreased activity. However, lower limb resistance training for patients after cardiac surgery begins with low load exercise at the level of daily living behavior in the early postoperative period. Subsequently, the resistance exercise with load is recommended to start 5 weeks after surgery. For that reason, the improvement of muscle strength and an increase in muscle mass are not recognized in several cases. In addition, in this case, the preoperative bedtime period due to exacerbation of heart failure and hypotension was long, and the severe muscle weakness and atrophy developed. However, the KAATSU training can be conducted from a low load. The ordinary resistance training mobilizes from small slow muscle fibers of the movement unit according to the principle of size. As the exercise intensity rises, large fast muscle fibers of the exercise units can be mobilized. Therefore, at a low intensity of 20-30% of 1 RM, fast muscle fibers are hardly mobilized and it is difficult to recognize muscle hypertrophy and muscle strength improvement. On the other hand, in KAATSU training, hypoxia caused by restricted muscle blood flow promotes recruitment of fast muscle fibers as well as muscle activity of slow muscle fibers. Therefore, it can expect muscle hypertrophy and muscle strengthening similar to normal high-intensity training, even by using low-intensity load. In fact, we have already reported that KAATSU training was a useful method for improving muscle strengthening and muscle mass in patients with ischemic heart disease. In this study, we performed the KAATSU training in a young cardiac surgery patient with low cardiac function early after aortic valve replacement surgery. Since a low load at an intensity of 20-30% of 1 RM can be used during the KAATSU training, we started the training early after the operation. In addition, in terms of nutrition, resistance training under malnutrition is predominant in protein degradation, making it difficult to increase muscle mass. Before the KAATSU training, nutritional status was bad in this case with blood albumin of 3.3 g / dl and CONUT score 3 points. Therefore, BCAA administration was concomitantly used for the training. As a result, the marked increase in muscle strengthening and muscle hypertrophy could be observed after the intervention. During the training, the nutritional state also improved, and the CONUT score decreased to 0 point after 29 days of the training. From these observations, in addition to the effects of KAATSU training, it is most likely

Table 2. Changes in body weight and nutrition before and after KAATSU training combined with BCAA intake

| Days after KAATSU training | Before | 7 days later | 17 days later | 29 days later | 52 days later | 80 days later |
|----------------------------|--------|-------------|--------------|--------------|--------------|--------------|
| 44th disease day           | 58.7   | 59.0        | 59.4         | 61.0         | 63.5         | 65.9         |
| Modified CONUT score (point)| 3      | 4           | 1            | 0            |              |              |
| Alb (g/dl)                 | 3.3    | 3.1         | 3.5          | 3.9          | 4.3          |              |
| TLC (µL)                   | 2101.6 | 1387.5      | 1929.6       | 1795.5       | 2037.6       |              |
| Hb (mg/dl)                 | 10.9   | 10.4        | 11.6         | 13.7         | 13.9         | 14.8         |

Alb: Serum albumin, TLC: Peripheral total lymphocyte count, Hb: Hemoglobin

Table 3. Changes in blood BCAA concentration before and after BCAA (2.5 g) intake

| Amino acids | Reference value (nmol/ml) | Before | 60 minutes | 120 minutes |
|-------------|---------------------------|--------|------------|-------------|
| Valine      | 147.8 ~ 307.0             | 236.9  | 333.7      | 296.3       |
| Isoleucine  | 43.0 ~ 112.8              | 86.5   | 187.8      | 116.6       |
| Leucine     | 76.6 ~ 171.3              | 146.9  | 329.8      | 231.4       |
| Total BCAA  | 265.8 ~ 579.1             | 470.3  | 851.3      | 644.5       |

BCAA: Branched Chain Amino Acids
that protein synthesis has become dominant by ingesting BCAA immediately after exercise. Protein synthesis is considered to increase rapidly after 1 to 2 hours after exercise. Looking at the trend of BCAA in this case, serum BCAA concentration was about twice higher than the control level before taking BCAA. Therefore, it is likely that considering the resistance training and intake time of BCAA was effective for efficient muscle strengthening and muscle hypertrophy in this patient.

In this study, the KAATSU training was conducted under a medical doctor who was qualified as a KAATSU instructor. And, according to the rehabilitation guidelines for cardiovascular disease, blood pressure measurement, electrocardiogram monitoring, and subjective strength measurements (Borg scale) were carried out. No side effects as previously described were observed during the training. The most common side effects in KAATSU training are petechia as described previously. This patient received warfarin therapy, but no petechia had occurred during the training.

6. Conclusion

By using KAATSU training together with BCAA intake, a marked improvement in muscle strength and muscle hypertrophy was obtained in a patient with low cardiac function early after aortic valve replacement surgery. The combined use of KAATSU training and BCAA intake early after cardiac operation seems to be a safe and effective way to obtain muscle hypertrophy and muscle strength increase, but further studies are needed to clarify it.

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