Effect of KAATSU training on thigh muscle size and safety for a patient with knee meniscectomy over 3 years

Tomohiro Yasuda\textsuperscript{1,2}, Seiya Oosumi\textsuperscript{3}, Shinpei Sugimoto\textsuperscript{3}, Toshihiro Morita\textsuperscript{3}, Yoshiaki Sato\textsuperscript{4}, Masanori Ishii\textsuperscript{3,5}, Toshiaki Nakajima\textsuperscript{2,6}.

\textbf{Objective} It is well known that knee meniscectomy is one of the major knee surgeries, which induces thigh muscle atrophy. However, it is unclear whether thigh muscle size after knee meniscectomy can be improved with KAATSU training. We examined effect of KAATSU training on thigh muscle size and safety for a patient with knee meniscectomy.

\textbf{Methods} The patient was a 57-year-old woman (standing height 159 cm and body weight 52 kg). The KAATSU training composed of 7 types of resistance exercise and one type of cycling exercise was provided for a total of 125 sessions over approximately 3 years. Transverse scans were carried out for mid-thigh length. Thigh muscle cross-sectional area (CSA) in affected-leg and unaffected-leg was measured by the CT scan before, 63 weeks, and 152 weeks after the training.

\textbf{Results} Thigh muscle CSA was highly increased for affected-leg, and the attained level was exactly similar for both legs after the 152 weeks training period.

\textbf{Conclusion} The long-term KAATSU exercises were a highly safe and effective training method for a patient with knee meniscectomy.

\textbf{Key words:} knee meniscectomy, muscle hypertrophy, thigh muscle, long duration, rehabilitation.

1. Case review

Patient: A 57-year-old woman (standing height 159 cm, body weight 52 kg), a physical education teacher

Diagnosis: knee meniscectomy

Chief complaint: Left knee joint pain on walking.

Family history of illness: No notable findings.

History of present illness & course of symptoms: On 15 October, 2014, she received meniscectomy implementation of the left knee under arthroscopy, and visited Okamoto-Ishii Hospital for receiving rehabilitation. At the first visit, the patient was suffering from strong leg swelling, heat sensation, and severe pain for left knee and was unable to walk without a cane. The KAATSU training started from October 30. After that, she received icing. The pain gradually decreased, and she could raise the stairs with crutches. After 1 month of KAATSU training, her pain was remark-
ably mitigated and she was able to walk without cane. On January, 2015, the pain was abolished. After 9 months, she was able to go upstairs and downstairs, and began to run a little without pain. She noticed the increase of muscle power and mass. After that, she also began to climb the stairs without problems, and could run through the hallway, and jump rope in physical education class. At present, she is doing mountain climbing at her elementary school excursions. On September 2017, she has received KAATSU training for approximately three years. Any side effects have not been occurred during the long-term training.

The principles of the World Medical Association Declaration of Helsinki and the American College of Sports Medicine Guidelines for Use of Human Subjects were adopted in this study. The study was approved by the Ethics Committee, and informed assent consent was obtained from the patient.

2. KAATSU training protocol

During the KAATSU training sessions, a patient wore a specially designed pneumatic cuff (50 mm width, KAATSU Master, KAATSU Japan Co., Ltd., Tokyo, Japan) around the most proximal portion of both thighs. KAATSU training was provided for a total of 125 sessions over approximately 3 years (from October 2014 to September 2017, 152 weeks). Basically, the cuffs were set at 40 SKU and air pressure was inflated to 200 SKU. The training protocol (7 types of resistance exercise and one type of cycling exercise) was shown as Figure 1 and 2. Eight exercises over 60 min were performed each session.

| Exercise                        | Menu                          | Intensity                   |
|---------------------------------|-------------------------------|-----------------------------|
| Unilateral knee extension       | 6 sets (30, 30, 20, 20, 10, 10 reps) | Lower leg weight + 1.5 kg weight |
| Bilateral calf raise            | 6 sets (30, 30, 20, 20, 10, 10 reps) | Body weight + 3.0 kg weight   |
| Go up and down with one step    | 6 sets (30, 30, 20, 20, 10, 10 reps) | Body weight + 1.5 kg weight   |
| Unilateral knee flexion         | 6 sets (30, 30, 20, 20, 10, 10 reps) | Lower leg weight + 1.5 kg weight |
| Hip adduction                   | 6 set (30, 30, 20, 20, 10, 10 reps) | Lower leg weight             |
| Hip extension                   | 3 sets (30, 20, 10)           | Lower body weight            |
| Hip flexion                     | 3 sets (30, 20, 10)           | Lower body weight            |
| Bicycle ergometer               | 30 min                       | 65-70 watt                   |

3. Computed tomographic (CT) finding

Subjects rested quietly in the body coil in a supine position with their legs extended and relaxed. Transverse scans were carried out for mid-thigh length (from the top edge...
of the great trochanter to the lateral condyle of femur). From the cross-sectional image, outlines of the thigh muscles were traced, and digitized by using a personal computer (MacBook, Apple, Tokyo, Japan) for analysis using image analysis software (Image J 1.5, NIH, USA), and muscle CSA was calculated. The CT scan was measured at October 9, 2014, December 24, 2015, and September 9, 2017. Thigh muscle CSA was highly increased for affected-leg, and the attained level was exactly similar for both legs at September 9, 2017 (Figure 3).

Discussion

The improvement of intrinsic morphology for the thigh muscles is important in exercise training for patients with knee injury and knee surgery. To the best of our knowledge, this is the first study to investigate the effect of KAATSU training on muscle strength and function for a patient with knee meniscectomy. The primary finding of this study was that KAATSU training remarkably increased the thigh muscle CSA for affected-leg, which was comparable with the unaffected-leg after the long-term period for 152 weeks.

Our findings show that KAATSU training after 63 weeks produces a hypertrophic potential of 0.33% per session for unaffected-leg, which is similar to that observed following KAATSU training after 12 weeks using weight machines (0.33% per session, Yasuda et al. 2014). This suggests that this training protocol is enough method for improving thigh muscle size for unaffected-leg over a long period. Additionally, the increase in thigh muscle CSA is approximately 2-fold higher in for affected-leg (0.61% per session) compared to unaffected-leg after the 63 weeks training period. Taken together, KAATSU training using body weight can induce large improvement in thigh muscle size for a patient with knee meniscectomy over the long period.

In the present study, heart rate and ratings of perceived exertion during 7 types of KAATSU resistance exercises (90-129 BPM and 11-16, respectively) and KAATSU cycling exercise (~127 BPM and ~11, respectively) were not high level (data not shown). These results are similar to that reported in previous KAATSU training studies for healthy subjects (Yasuda et al., 2014; Kim et al., 2016; Yasuda et al., 2016). Thus, it appears that these KAATSU exercises were a highly safe and effective training method for a patient with knee meniscectomy.

In conclusion, KAATSU training is potentially highly useful as a new method of rehabilitation for a patient with knee meniscectomy.

Acknowledgement

This study was supported, in part, by Grant-in-aid (#15K01553) from the Japan Ministry of Education, Culture, Sports, Science, and Technology.

Yasuda T, Morita T and Nakajima T belonged to the department of Ischemic Circulatory Physiology (up to September 2014) at University of Tokyo, which was funded by KAATSU Japan Coy Ltd.

References

1) Akima H, Furukawa T (2005) Atrophy of thigh muscles after meniscal lesions and arthroscopic partial meniscectomy. Knee Surg Sports Traumatol Arthrosc. 13: 632-637.
2) American College of Sports Medicine (1998) American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc 30: 992-1008.
3) Ericsson YB, Roos BM, Dahlberg L (2006) Muscle strength, functional performance, and self reported outcomes four years after arthroscopic partial meniscectomy in middle-aged patients. Arthritis Rheum. 55: 946-952.
4) Hiraizumi Y, Nakajima T, Sato Y, Imanishi T (2016) KAATSU training as a new effective exercise therapy in a case of femoral medial condyle osteonecrosis. Int J KAATSU Training Res. 12: 1-4.
5) Kim D, Singh H, Løenneke JP, Thiebaud RS, Føhs CA, Rossow LM, Young K, Seo DI, Bemben DA, Bemben MG (2016) Comparative Effects of Vigorous-Intensity and Low-Intensity Blood Flow Restricted Cycle Training and Detraining on Muscle Mass, Strength, and Aerobic Capacity. J Strength Cond Res. 30: 1453-1461.
6) Nakajima T, Yasuda T, Fukumura K, Kurano M, Imanishi T, Morita T, Sato Y, Hiraizumi Y (2015) KAATSU training® as a new exercise therapy for femoral head avascular necrosis: A case study. Int J KAATSU Training Res. 11: 1-6.
7) Ozaki H, Yasuda T, Ogasawara R, Sakamaki-Sunaga M, Naoto H, Abe T (2013) Effects of high-intensity and blood flow-restricted low-intensity resistance training on carotid arterial compliance: role of blood pressure during training sessions. Eur J Appl Physiol. 113: 167-174.
8) Thiebaud RS, Løenneke JP, Føhs CA, Rossow LM, Kim D, Abe T, Anderson MA, Young KC, Bemben DA, Bemben MG (2013) The effects
of elastic band resistance training combined with blood flow restriction on strength, total bone-free lean body mass and muscle thickness in postmenopausal women. Clin Physiol Funct Imaging. 33: 344-352.

9) Yasuda T, Fukumura K, Fukuda T, Uchida Y, Iida H, Meguro M, Sato Y, Yamasoba T, Nakajima T (2014) Muscle size and arterial stiffness after blood flow-restricted low-intensity resistance training in older adults. Scand J Med Sci Sports. 24: 799-806.

10) Yasuda T, Fukumura K, Uchida Y, Kashi H, Iida H, Masamune K, Yamasoba T, Sato Y, Nakajima T (2015) Effects of Low-Load, Elastic Band Resistance Training Combined With Blood Flow Restriction on Muscle Size and Arterial Stiffness in Older Adults. J Gerontol A Biol Sci Med Sci. 70: 950-958.

11) Yasuda T, Fukumura K, Tomaru T, Nakajima T (2016) Thigh muscle size and vascular function after blood flow-restricted elastic band training in older women. Oncotarget. 7: 33595-225607.