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**Original Article**

# Occlusion and KAATSU training effects on strength–endurance development in combat sport athletes: a pilot study

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**Abstract**
Problem statement In Japan, KAATSU training has been extensively utilized by athletes, ordinary people, and older adults. This pneumatic band workout, involving controlled blood flow restriction, is gaining global recognition. Its rehabilitation and hypertrophic effects have been definitively proven. Its positive role in rehabilitation is supported by research demonstrating that it reduces symptoms in patients with metabolic syndrome. Owing to its high metabolic effect and the application of 20–40% of one-repetition maximum (1RM), KAATSU training also significantly impacts muscle mass gain. Approach and purpose This study investigated the effect of high-repetition training using KAATSU on strength endurance. We implemented a training protocol encompassing exercises at 20–25 percent of 1RM. We compared the performance differences between KAATSU users and those in traditional dumbbell-based strength and endurance training. Did KAATSU training lead to enhanced one-repetition maximum performance? Moreover, we investigated whether, in addition to the low intensity and high repetition rate, functional hypertrophy occurred among subjects employing KAATSU. The study enrolled ten male combat sports athletes into two groups (5 individuals per group). Both groups performed two large bilateral exercises: bench press and back squat. Results After the 6-week program, the results showed that KAATSU use had no significant effect on 1RM, with a 6% improvement at maximum. However, at the maximum number of repetitions at 40% of 1RM, the KAATSU group exhibited a 9% increase in horizontal pressure and a 32% improvement in squats. In contrast, the traditional volume-based group showed modest enhancements of 10% and 18%, respectively. The KAATSU group experienced functional hypertrophy during the program because their upper arm circumference increased by 1.2 cm, chest circumference by 3.7 cm, and thigh circumference by 2 cm after completing the training program. Conclusions It can be concluded that the KAATSU method did not significantly affect the value of 1RM when applied at 20–25%. However, it significantly improved strength and endurance levels, particularly in the lower body muscles. The results indicate that KAATSU-based training has a more significant effect on strength and endurance than conventional weight training using 1RM at 30–50%.
**Key Words: KAATSU training, strength-endurance, functional hypertrophy, combat sports**

## Introduction

*The physiological foundations of KAATSU training*

KAATSU training is performed with a specially designed pneumatic band (Figure 1) that reduces blood flow in the muscle, thereby limiting the accumulated venous blood backflow. After proper use of KAATSU, arterial blood flow will be restricted, and deep venous outflow will not be able to flow back, causing the capillary-venous space to swell. (Figure 2).

Figure 1. KAATSU Air Bands
(Source: https://kaatsu.hu/)


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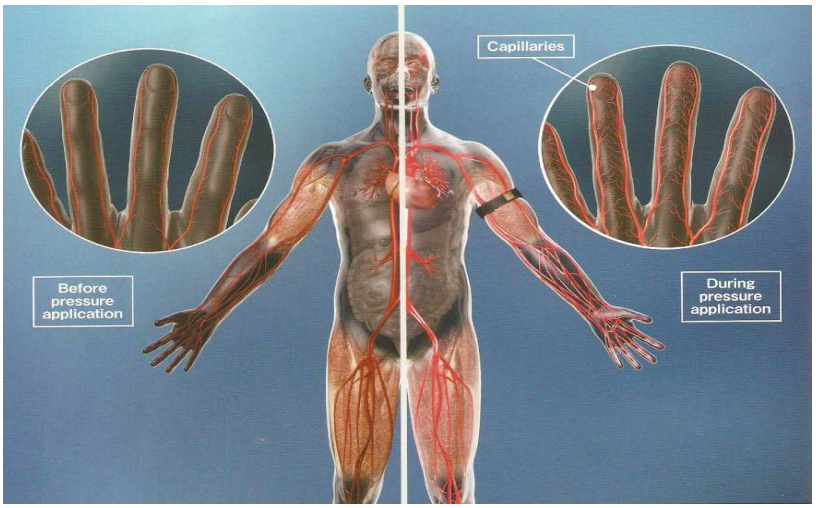


Figure 2. Capillary and venous blood flow before and after applying pressure on vessels.
(Source: 30. KAATSU Impact - Wonder Mechanism of KAATSU Training, p. 10.)

*The principles of blood flow restriction technique, occlusion training*

Occlusion training is a training load during which it occurs by impeding venous reflow of the limb performing the work. A smooth rubber clamp or a blood pressure cuff may also be applied (Radák, 2019). Occlusion may be applied throughout the workout before competitions and rest periods (Scott et al., 2016). Occlusion training appeared in sports science a few decades ago, since training performed at an intensity previously considered ineffective, single-rep concentric muscle contraction by 20-30%, also increased muscle cross-sectional area (Manimmanakorn et al., 2013; Luebbers et al., 2014; Yamanaka et al., 2012; Yasuda et al., 2004). This contradicts the fact that significant skeletal muscle hypertrophy can only be triggered by micro-ruptures in muscle tissue (Torma et al., 2018). The blood flow restriction (BFR) method increases growth hormone production and is associated with low protein breakdown and protein synthesis supporting gene expression (Radák, 2019).

*Application of blood flow restriction technique, occlusion training*

In the past ten years, a number of studies have investigated the application of occlusion training in healthy population (Brandner et al., 2015; Moriggi et al., 2015; Poton & Polito, 2015; Bunevicius et al., 2016; Pedon et al., 2022; Picón-Martinez et al., 2023) and in a clinical rehabilitation setting too (Werasiritat, & Yimlamai, 2022; Cristina-Oliveira et al., 2022; Chulvi-Medrano et al., 2023). One of the first reviews in this field was performed by (Pope et al., 2013). The researchers provided an extensive overview regarding the cardiovascular, neuromuscular, metabolic, and endocrine responses during the performance of blood flow restriction (BFR) training. They also discussed the safety issues of BFR training in various populations. Pope et al. demonstrated that BFR exercise training significantly increased muscular strength, hypertrophy, localized endurance, and cardiovascular capacity. They concluded that BFR exercise may benefit populations that cannot tolerate high-intensity resistance training. Popular areas of study were the effect of blood flow restricted resistance exercise on cardiovascular-hemodynamic and hormonal responses (Tanimoto et al., 2005; Takano et al., 2005; Rossow et al., 2011; Rossow et al., 2012; Viera et al., 2013; Neto et al., 2015; Neto et al., 2016b). Safety issues and possible areas of concern in BFR training have also been discussed by (Spranger et al., 2015; and Da Cunha Nascimento, Schoenfeld, & Prestes, 2020).

**Purpose**

The primary aim of our study was to investigate and analyze the beneficial effect of KAATSU training compared to traditional (dumbbell) techniques. Additionally, we investigated any functional hypertrophy using KAATSU training. Finally, we focused on the effect of KAATSU training on maximal strength (1 RM) performance in bilateral exercises.

We hypothesized that KAATSU training would increase athletes' strength and endurance capacity. We also hypothesized that KAATSU training would increase the functional hypertrophy of specific muscles. We further hypothesized that KAATSU training would influence the development of maximal strength (1 RM) when executing bilateral exercises.

**Material & methods**

*Participants*

The study involved 5-5 healthy volunteers from the Derecske Budo Youth, Sport, and Leisure Club. The participants represented the Shinkyokushinkai karate discipline. Their average training age was 17 years. We performed an anthropometric analysis of the participants (Table 1).

Table 1. Anthropometric data of the participants

| | Body height [cm] | Body weight [kg] | Age [years] | Training age [years] | Circumf. upper arm [cm] | Circumf. upper leg [cm] | Circumf. chest [cm] |
|---|---|---|---|---|---|---|---|
| **KAATSU group (average)** | 178.8 | 84.6 | 28 | 17 | 37.5 | 58 | 101.2 |
| **KAATSU group (SD)** | 7.3 | 10.3 | 5.6 | 6.7 | 1.7 | 3.6 | 6.1 |
| **Control group (average)** | 182.8 | 89.8 | 27 | 17 | 37.6 | 58.6 | 101.6 |
| **Control group (SD)** | 9.1 | 10.5 | 6.5 | 6.5 | 1.9 | 4.6 | 7 |

Before the initial measurement, each subject completed a medical questionnaire declaring they did not suffer from vascular, orthopedic and circulatory diseases that would pose a risk during training. All participants filled an informed consent. The participants did not change their lifestyle habits during the examination (nutrition, level of physical activity).

*Procedures*

All participants completed a six-week training program. We implemented two measurements (pre and post-tests) during the training program. One group of participants (KAATSU group) performed the workouts twice a week using a KAATSU Cycle 3.0 device (Figure 3), with KAATSU Air Bands placed on the arms and legs. These devices were set according to the Optimal SKU (the pressure exerted by the KAATSU device) depending on the fitness level and tightness of the applied pneumatic band.


Figure 3. KAATSU C3
(Source: https://kaatsu.com/?action=store.details&pid=34)

The other group (control) performed traditional weight training twice weekly with optimal intensity calculated for each individual. The rest time between sets was measured with a stopwatch. Before the training, the maximal strength of individuals was assessed using the 1 RM method. We set the intensity required for strength endurance at 40 percent of 1RM.

The participants started the warm-up with an SMR roller, loosening the soft connective tissue structure, fascia (muscle fascia), then continued with mobilization exercises to increase the necessary locomotor potential and finished the warm-up with trunk activation movements. After that, the KAATSU group performed the KAATSU Cycle (Figure 4) using a pneumatic air band arm device (KAATSU Air Bands). The Optimal SKU was individually set for the entire examination.

Figure 4: KAATSU Cycle and a C3 device

Two basic exercises, the Bench Press and the Back Squat, were performed with an Olympic bar (20kg). Only the complete movements (no compensatory executions) were included in the final analysis (Table 2).

Table 2. Pre-test values of the participants

| | Bench Press 1RM (kg) | Back Squat 1RM (kg) | Bench Press 40 percent of the 1RM (kg) | Back Squat 40 percent of the 1RM (kg) | Bench Press 40 percent of the 1RM (repetitions) | Back Squat 40 percent of the 1RM (repetitions) |
|---|---|---|---|---|---|---|
| **KAATSU group (average)** | 90 | 108 | 37 | 44 | 47 | 48 |
| **KAATSU group (SD)** | 8.3 | 7.5 | 3 | 3.7 | 4.6 | 4,6 |
| **Control group (average)** | 85 | 102 | 34 | 41 | 41 | 46 |
| **Control group (SD)** | 10 | 7.4 | 3.9 | 3.7 | 5.8 | 5.8 |

Subsequently, after performing the warm-up session, the Bench Press and the Back Squat exercises (Figure 5-6) were performed for six weeks. We gradually increased the intensity every two weeks. We set an initial intensity at 20 percent, finishing at 25 percent by the end of the exercise routine. In general, the repetitions of the first set were between 30-40, the second and third sets between 20-30, and then in the last set between 10-20 repetitions. We implemented a 20-second rest between each set. The optimal SKU and the intensity were adapted to the individual's fitness level. Since the trained athletes perform the exercises at a relatively lower intensity, the


Figure 5. Bench press with pneumatic armbands (initial phase)

Figure 6. Bench press with pneumatic armbands (final phase)

In the next phase, We removed the pneumatic armbands and applied the leg bands (Figure 7). Also, we set the Optimal SKU for the members of the KAATSU group. Back squat exercises (Figure 8) were performed similarly to the Bench Press exercise earlier (Table 3). Cool-down was performed using the KAATSU Cycle, followed by SMR foam roller exercises and static stretching.

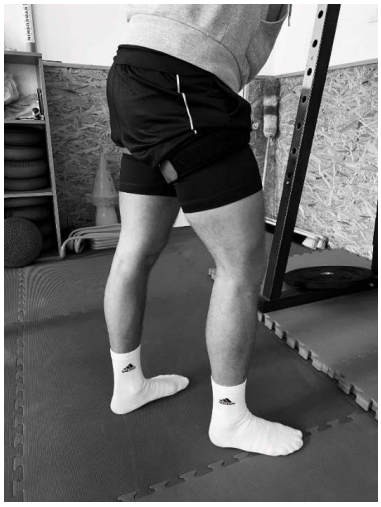

Figure 7. Application of the pneumatic leg band

Figure 8. Back Squat exercises with pneumatic leg band

Table 3. Six-week training program for the KAATSU group

| Period | Exercise | Volume | Intensity | Resting time | Opt. SKU |
|---|---|---|---|---|---|
| **Week 1-2.** | Bench Press | 30-40<br>20-30<br>20-30<br>10-20 | 20% | 20sec | 250-260 (individually set) |
| | Back Squat | 30-40<br>20-30<br>20-30<br>10-20 | 20% | 20sec | 340-370 (individually set) |
| **Week 3-4.** | Bench Press | 30-40<br>20-30<br>20-30<br>10-20 | 22.5% | 20sec | 250-260 (individually set) |
| | Back Squat | 30-40<br>20-30<br>20-30<br>10-20 | 22.5% | 20sec | 340-370 (individually set) |
| **Week 5-6.** | Bench Press | 30-40<br>20-30<br>20-30<br>10-20 | 25% | 20sec | 250-260 (individually set) |
| | Back Squat | 30-40<br>20-30<br>20-30<br>10-20 | 25% | 20sec | 340-370 (individually set) |

The control group also performed weight training twice a week. They performed traditional weight training for the first two weeks at 30% over four sets, starting with 20 reps per set in the first week. For the first three weeks, they worked at 30% intensity, increasing the number of repetitions by two times per week in both exercises. The rest time between sets was 30 seconds in the first week, then increased by 5 seconds per week in proportion to the increase in repetitions.

From week 4, the intensity increased to 35%, but the volume was reduced again to 20 repetitions, and then the number of repetitions increased by two per week. The rest time between sets was similar for those employed in the first three weeks (Table 4). At the end of the exercise routine, the control group performed SMR foam roller exercises and static stretching.

Table 4. Six-week training program for the control group

| Period | Exercise | Volume | Intensity | Resting time |
|---|---|---|---|---|
| **Week 1** | Bench Press | 4x20 | 30% | 30sec |
| | Back Squat | | | |
| **Week 2** | Bench Press | 4x22 | 30% | 35sec |
| | Back Squat | | | |
| **Week 3** | Bench Press | 4x24 | 30% | 40sec |
| | Back Squat | | | |
| **Week 4** | Bench Press | 4x20 | 35% | 30sec |
| | Back Squat | | | |
| **Week 5** | Bench Press | 4x22 | 35% | 35sec |
| | Back Squat | | | |
| **Week 6** | Bench Press | 4x24 | 35% | 40sec |
| | Back Squat | | | |

**Results**

***Results of the maximal (1 RM) Bench Press***

There was no difference in the results of the maximal (1 RM) Bench Press and the (40 percent of 1 RM) Bench Press exercises between the two groups. The KAATSU group demonstrated an average 1 percent improvement in maximal (1 RM) Bench Press performance, while the control group demonstrated a 2 percent improvement (Figure 9). Bench Press performance increased from 90 kg to 93 kg in the KAATSU group and 85 kg to 88 kg in the control group.

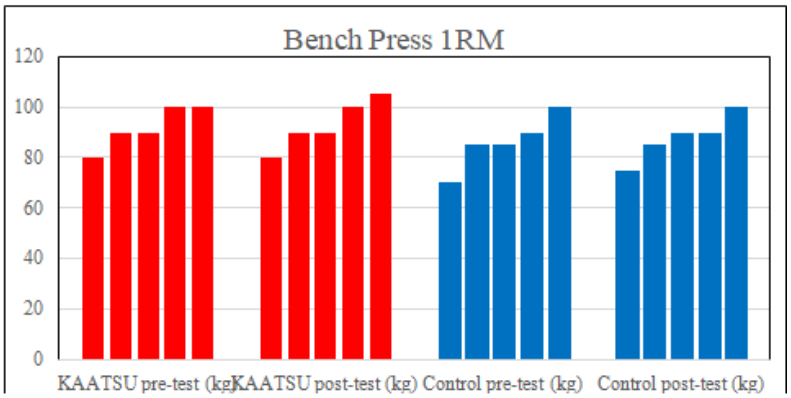


Figure 9: Results of the maximal (1 RM) Bench Press exercise

***Results of the Bench Press (40 percent of the 1RM)***

All participants performed better after the completion of the six-week training program. The KAATSU group demonstrated a 9 percent improvement, while the control group members demonstrated a 10 percent improvement (Figure 10). The average repetitions increased from 47 to 52 and 41 to 45 in KAATSU and control groups, respectively.

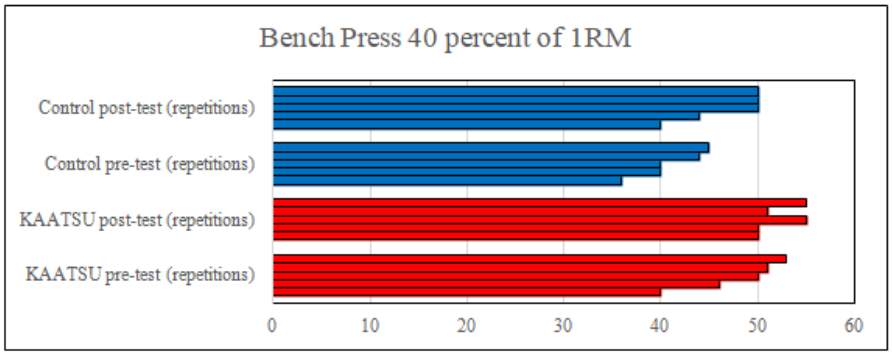


Figure 10: Results of the (40 percent of 1 RM) Bench Press exercise

***Results of the maximal (1 RM) Back Squat***

All participants performed better after completion of the six-week training program. However, the improvement was far more significant in the KAATSU group. Participants of the KAATSU group showed an average 6 percent improvement, while the performance of the control group increased only by 1 percent (Figure 11). The maximal performance of the participants of the KAATSU group varied from 108 kg to 114.5 kg. In this group, all participants improved by at least +2.5kg compared to the original performance. The average performance in maximal Back Squat increased from 102 kg to 103 kg among the control group participants.

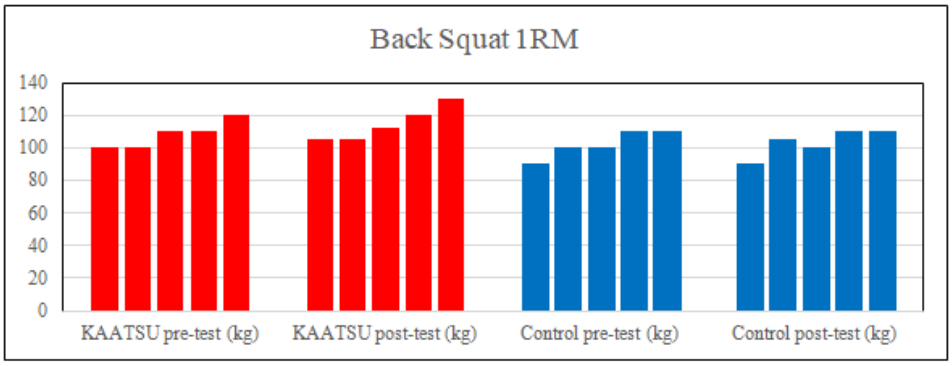


**Figure 11: Results of the maximal (1 RM) Back Squat exercise**

***Results of the Back Squat (40 percent of 1 RM)***

We experienced an average 32 percent improvement in the number of repetitions among the participants of the KAATSU group. The number of repetitions also increased by 18 percent in the control group. The average number of repetitions increased from 48 to 64 among the members of the KAATSU group. We measured an increase in repetitions from 46 to 55 among the control group members (Figure 12).

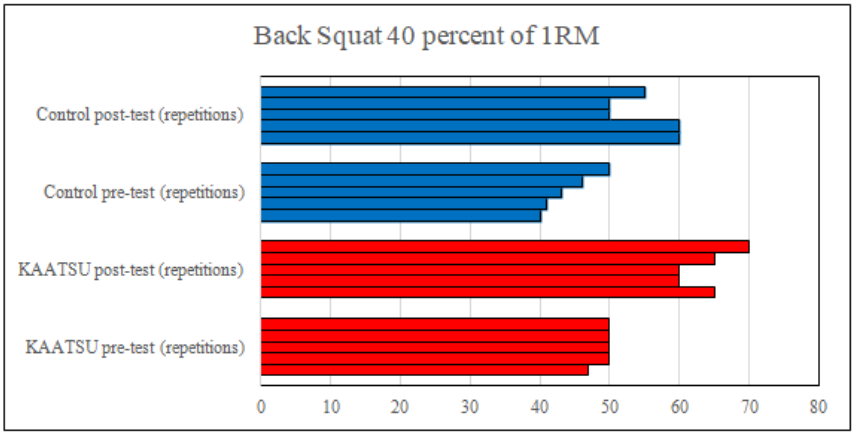


Figure 12: Results of the (40 percent of 1 RM) Back Squat exercise

The KAATSU group had an average increase in upper arm circumference of 1.2 cm, chest circumference by 3.7 cm, and thigh circumference by 2 cm during the six-week training program.

***Discussion***

KAATSU training may be an optimal method for gaining or regaining muscle mass, not only for competitive athletes returning from injury but also for ordinary people and those of the older age group (Abe et al., 2004; Manimmanakorn et al., 2013; Nakajima et al., 2011). Due to its high metabolic effect and low intensity (weight) demand, it benefits joints. Due to its low risk of injury, it can be fully integrated into the training plan of competitive athletes (Torma et al., 2018; Takarada et al., 2000).

We hypothesized that Bench Press performance has not improved as much because performance enhancement is more difficult in this type of human movement pattern, and a more pronounced improvement takes longer than the training program lasted. We assume a gradual increase in exercise intensity is critical in maximal strength development. In contrast to the two large bilateral basic exercises (Deadlift and back/Front Squat), we decided to increase the weight by +2.5kg every 2-3 weeks. Weekly elevation of intensity seems insufficient (too fast) for proper adaptation. Adaptational processes are influenced by participants' fitness and nutritional status, body composition, and many other factors.

Specific anthropometric (chest, upper, and lower limb circumferences) data reveal modest functional hypertrophy on the effect of KAATSU training. The synergistic muscles are likely activated during the performed movement patterns, reducing the risk of injury (Takarada et al., 2002).

Based on participants' observations and prior experiences, KAATSU training resulted in a more pronounced muscle activation than traditional weight-lifting protocols (Karabulut et al., 2007). One of the major benefits of KAATSU training is that it activates phasic muscles that are underactive or weaker (Sato, 2004a; Sato, 2005). Due to the lower intensity, participants could compensate for fatigue more effectively. Participants reported a more intense upper-body muscle soreness, especially during the first sets of exercises.

They adapted relatively quickly to the given intensity, as muscle soreness appeared from the first two occasions of each odd-numbered week, lasting 1-1.5 days. We must note that all participants had considerable prior experience in Bench Press and Back Squat exercises.

**Conclusions**

The KAATSU training resulted in a significant improvement in the strength-endurance level of the participants, especially in terms of lower body muscles. It is probably due to the extent of hypoxia in the working muscles involved in KAATSU training. Overall, the KAATSU training did not significantly contribute to the development of the participant's maximal (1 RM) performance. KAATSU training is probably not the most efficient way to enhance maximal strength in Bench Press and Back Squat exercises, at least in our population.

We incorporated KAATSU training with high-intensity methods performed with 1RM 90-95%, with a maximum volume of 10 repetitions, with a rest period of 3-5 minutes, where the set multiplied by the number of repetitions totals = 10 (e.g., 3x3, 2x5, 5x2). We conducted a pilot study; generalization of our results is therefore limited. In the future, conducting examinations involving more participants would be beneficial. Competitive athletes from various sports, young adults, and older people should be involved too.

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