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Triceps surae exercises on standing with big toe side support emphasize peroneus longus activity

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ABSTRACT:

The purpose of this study was to investigate the activity patterns of the lower leg muscles and COP changes in representative cases when the loading point was varied, with the aim of helping to properly instruct the calf raise exercise.

On big toe side support, muscle activity and forward displacement of COP showed a biphasic pattern, and a small peak appeared in the middle of the movement in the vertical partial force. The same phenomenon could not be observed with 2nd and 3rd toe MP joint support.

The peroneus longus muscle was responsible for most of the heel elevation in the case of big toe side support, while all the muscles recorded in this study activated in the case of 2nd and 3rd toe MP joint support. In addition, the amount of muscle discharge was generally greater with the big toe side support than with the 2nd or 3rd toe MP joint support.

The results of this study showed that 2nd and 3rd toe MP joint support should be taught rather than big toe side support for calf raise exercise as a strengthening maneuver for leg muscle.

KEY WORDS triceps surae, peroneus longus, calf raise

INTRODUCTION

Triceps surae training on standing (calf raise exercise or heel raise exercise, hereafter referred to as "calf raise", Figure 1 (a)) is used not only for strength training of the triceps surae muscles, but also for training to safely assume a standing posture (1). When calf raise is performed with body weight loading on the side of the ball of the little toe (Figure 1 (b)), the ankle tends to adopt a varus position and the foot is easy to supinate. In addition, internal deflection of the calcaneus is induced. Since the activity of the peroneus muscle group is reduced in a foot with a varus position (2), loading on the ball of the big toe side is recommended for the prevention of inversion sprain and to promote ankle joint stability. On the other hand, when calf raise is performed by loading on the ball of the big toe (Figure 1 (c)), the lateral arch is raised during the movement, the activity of the tibialis posterior muscle is reduced (2), and the plantar flexion torque in the early phase of the movement does not properly translate into angular motion torque at the talocrural joint. In addition, support on the ball of the big toe side increases the tendency of the foot to pronate and induces the valgus of the calcaneus, which may decrease the activity of the tibialis posterior muscle and cause failure of the cross-support mechanism (3) that stabilizes the calcaneus. In any case, when performing calf raise, the triceps surae, which is the primary ankle plantar flexor muscle, must be activated while the loading point is being considered and the foot is being stabilized.

In this study, we examined the activity patterns of lower leg muscles when the loading point is varied, with the aim of assisting in appropriate instruction of calf raise exercise.

METHODS

The subjects were six healthy men who had never experienced calf raise intensively for a period of time. Their mean age, height, and weight were 29.2±5.0 (22-36) years, 169.2±3.8 (163-174) cm, and 69.5±15.8 (58-100) kg, respectively.

All study tasks were carried out in accordance with the Declaration of Helsinki. Prior to the experiment, according to the decision made in a board meeting of the institution of the first author, we explained in advance the outline and invasiveness of this experiment and the presence / absence and form of publication, and subjects who provided written consent were told of the purpose of this experiment.

Calf raise was performed with weight-loading by the hemi-lateral lower extremity, with the contralateral lower extremity lightly touching the floor with the toes and bilateral upper extremities lightly touching a wall in front of the body. In this study, two types of loading points were used: one was the ball of the big toe (big toe support) and the other involved the metatarsophalangeal joints of the 2nd and 3rd toes (2nd and 3rd toe support).

Surface electromyography (EMG) of the following muscles during calf raise was recorded using Myosystem2000 (Noraxon): peroneus longus (PL), tibialis posterior (TP), lateral head of gastrocnemius (GAS), and soleus (SOL). Electrodes were placed on the belly of each muscle with a distance of 2 cm between electrodes except for TP. The location of electrodes on TP was confirmed in the following steps. First, the electrodes on TP were placed at a distance of 1 cm between electrodes along the tibial border at 5 to 6 cm above the medial malleolus of the tibia. Second, the subjects performed ankle plantar flexion, toe flexion, and foot flexion. Then, the examiner verified that there were no mixed muscle discharges of the muscle groups near TP, such as the flexor digitorum longus, during these series of movements. The sampling frequency of EMG recordings was set at 1000 Hz, and the bandpass filter was set from 20 to 1000 Hz. The obtained waveforms were used to examine muscle discharge patterns in each muscle during calf raise. EMG recordings of each muscle during calf raise were synchronized with the recording of the horizontal coordinate trajectory of the Center of Pressure (COP) and floor reaction force using the JK-101 center-of-gravity balance system (Unimec Co., Ltd.).

There are no conflicts of interest to declare. There was no external financial support.

RESULTS

1. Muscle discharge patterns

Typical EMG waveforms in this study are shown in Figure 2. In all cases with big toe support, a biphasic discharge pattern was observed in PL, GAS, and SOL. In the 2nd and 3rd toe support, all muscles showed less discharge than on big toe support, and there was no clear biphasic activity as in big toe support.

2. COP coordinate trajectory in the horizontal plane and floor reaction force

Figure 3 shows the transition of COP displacement in the anteroposterior direction and the vertical component of the floor reaction force during calf raise. On big toe support, a double-peak pattern was observed in the forward direction. A small increase in the floor reaction force of the big toe support was observed in the valley of the double peak of COP

(a) (b) Little toe side weight-bearing (c) Ball of big toe side weight-bearing

Figure 1 Calf raise exercise

(b): Varus position: foot supination, internal deflection of calcaneus
(c): Valgus position: foot pronation, external deflection of calcaneus and raised lateral arch.

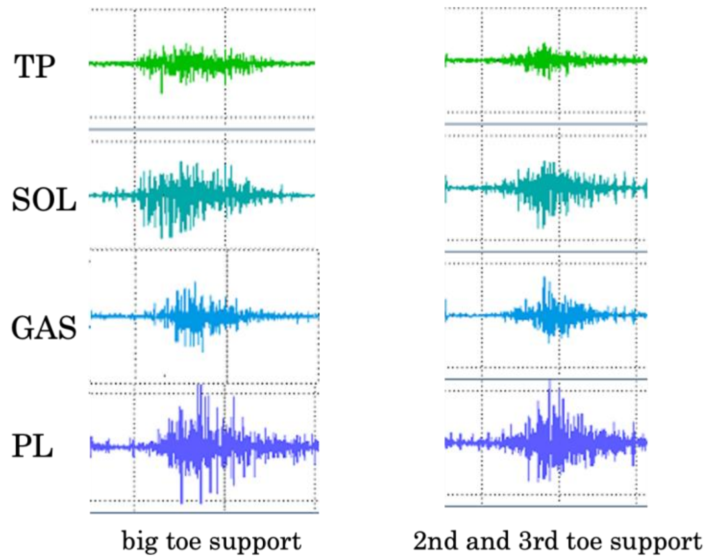

Figure 2 Typical EMG waveforms during calf raise in this study

TP: Tibialis posterior, SOL: Soleus, GAS: Gastrocnemius (lateral head), PL: Peroneus longus

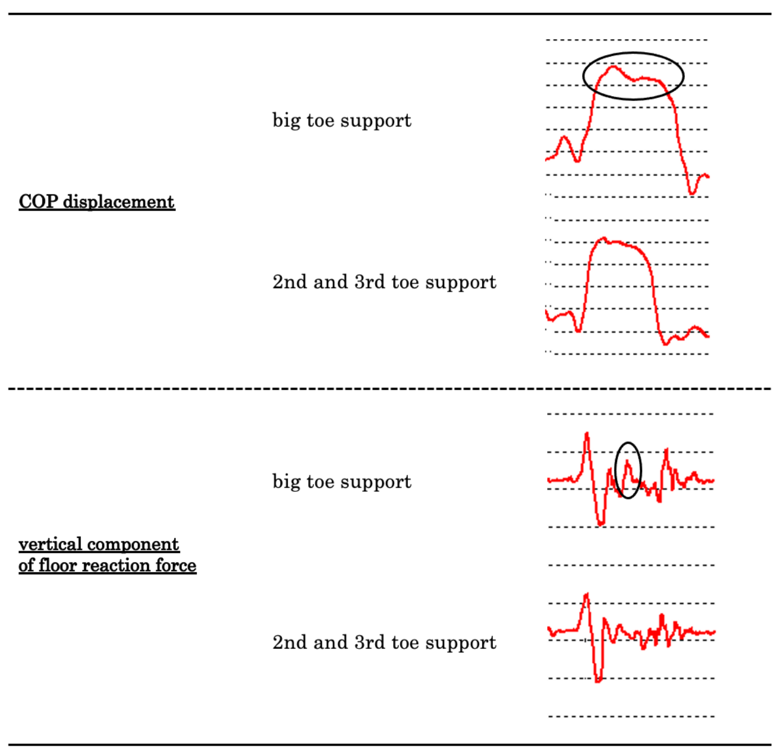

Figure 3
COP displacement and vertical component of floor reaction force during calf raise

A small increase in the floor reaction force on big toe support was observed in th valley of the double peak of COP (circled in the figure).

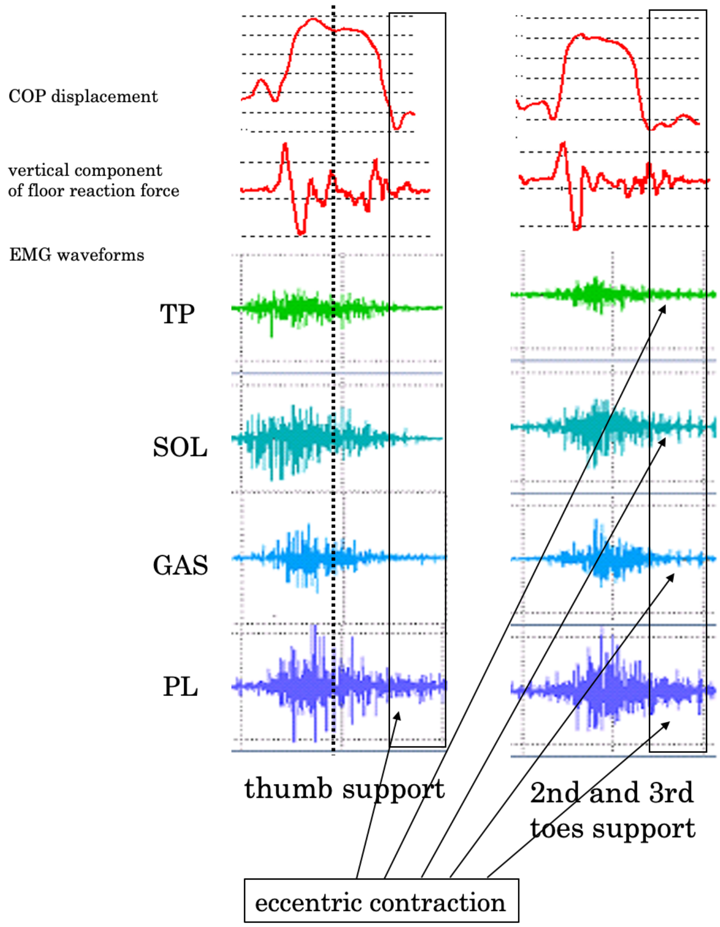

Figure 4
COP trajectory, floor reaction force, EMG waveforms

DISCUSSION

In the case of big toe support, the activation of PL facilitates the forward shift of the load point, and the calcaneus is easily raised in the early phase of calf raise. However, because the activation of PL elevates the lateral arch, the reaction force from the floor increases, and forward movement with upward displacement of the center of gravity is braked after the middle phase of the movement. Therefore, it was considered necessary to supplement the upward shift of the center of gravity with an upward movement, as typified by knee extension. This resulted in a biphasic muscle discharge pattern, as the calf raise presented the aspect of a biphasic movement. This can be inferred from the fact that COP moved linearly forward from the start of the movement, but moved backward once during the middle phase of the movement and then moved forward again (double-peak pattern, Figure 4). Furthermore, in 2nd and 3rd toe support, eccentric contraction for limb position retention was observed in each muscle in the late phase of calf raise, but only in the peroneus longus muscle with big toe support (Figure 4). If the muscle that holds the heel at the highest position contracts with an eccentric component in the late phase of the movement to hold that limb position against gravity, it can be interpreted that it is mostly the peroneus longus that is mobilized to hold the limb position with the heel raised by big toe support. In other words, calf raise with big toe support does not cause plantar flexion of the talocrural joint via the calcaneus by the contractile force of the triceps surae in the standing position, which is inappropriate as an ankle joint plantar flexion exercise in the loading position. From the above-mentioned findings, although calf raise with big toe support may be effective to achieve a large muscle discharge, when performing calf raise as training for the purpose of mobilizing various muscles as an ankle plantar flexion exercise and also for maintaining the standing position, it is considered that 2nd and 3rd toe support should be recommended rather than big toe support.

From another point of view, our study reveals that hyper-activity or shortening of PL causes lateral arch elevation and limitation of the range of ankle dorsiflexion in a closed kinetic chain (4). Because calf raise with big toe support contributes to overuse and shortening of PL, marked consideration should be given to the degree of big toe support when performing and teaching the calf raise exercise. In addition, when the results of this study are applied to strength training in the open kinetic chain, the plantar flexion movement with big toe side as the action point is exactly analogous to the movement with PL as the main movement: a depression head of the first metatarsal (5) (Figure 5). Therefore, in the case of suppressing the predominance of peroneus longus activity, the point of action should be taken into consideration. Furthermore, because the triceps surae attaches to the calcaneus, the ankle joint plantar flexion movement caused by the original activity of the triceps surae is considered to begin with calcaneus movement. If the normal pattern is for calcaneal motion to be followed by mid- and forefoot motion, resistance should be applied to the calcaneus, not forefoot, in resistance exercises aimed at strengthening the triceps surae (Figure 6).

This research is expected to have the following applications in the field of sports and training instruction.

1. The activity of PL is predominant in the loading on the ball of the big toe, which has the following disadvantages: 1.

(1) Weak output during kicking, such as when turning back.

(2) PL-dominant activity raises the transverse arch and reduces the ankle joint's dorsiflexion range of motion during movement.

Figure 5

Plantar flexion exercise in open kinetic chain with big toe side as the point of action

Exactly analogous to the movement with the peroneus longus as the main movement: plantar flexion with foot eversion and depression of the head of the first metatarsal.

2. Calf raise v

muscle discharg

effective for training atrophic muscles.

3. when teaching the use of the ball of the big toe during the movement, especially during the process of stepping into and kicking out, the normal pattern of displacement of the load point from heel contact should be understood, and instruction in the form of supporting the foot with the ball of the big toe should be avoided for the time being.

In conclusion, activity of lower leg muscles, COP, and floor reaction force during calf raise as a training method for the triceps surae were examined when the loading point was changed to the big toe side and 2nd and 3rd toe side.

In big toe support, overuse of the peroneus longus muscle and biphasic anterior component of COP were observed. Calf raise with big toe support and ankle plantar flexion resistance exercises with the big toe ball as the action point may induce overuse of the peroneus longus muscle.

When performing plantar flexion exercises to train the triceps surae, the point of loading (point of action) must be carefully considered.

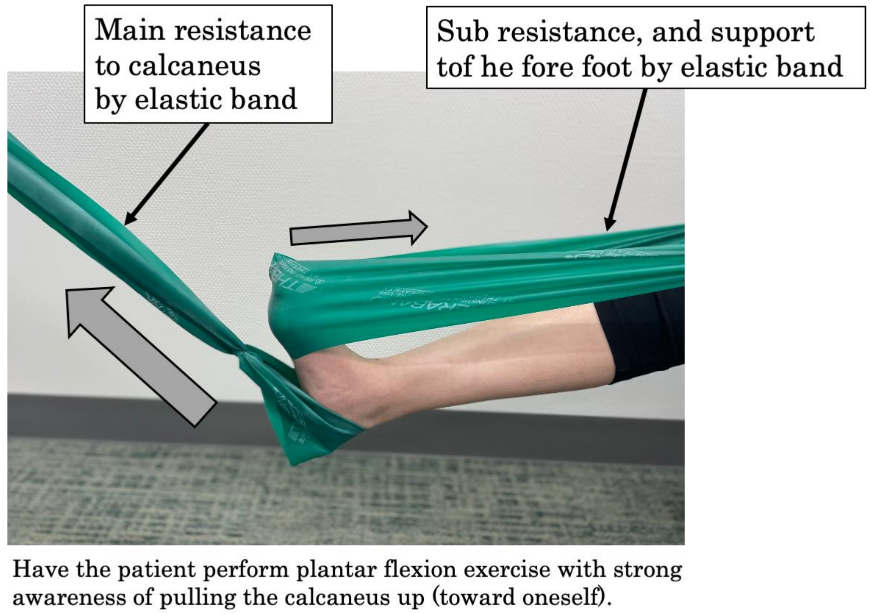

Figure 6
Triceps training in open kinetic chain with consideration of resistance position and prevention of overuse of peroneus longus muscle

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