Repetitive Dorsi-Plantar Flexion Exercises in Ankle Joint have Effects on the Muscle Tones of Triceps, Vastus Medialis and Gastrocnemius

INTRODUCTION

Recently, the number of patients suffering from musculoskeletal system diseases has been rapidly increasing(1). These musculoskeletal system diseases are caused by job related bad postures or bad daily life motions in many cases(2). Repeated and continued bad postures and motions may involve musculoskeletal system unbalance throughout the body along with abnormal loads on certain joints(3).

Along with the feet, the ankle joints contribute to the maintenance of balance in human bodies together with visual/vestibular organs(4), and play important roles in the stability of postures and the adjustment of balance(5). The ankle joints play the roles of absorbing impacts and providing forward movements of the body(6), and adjusting body movements and weight movements between the two feet during walking(4).

Stability is an ability to maintain the position of the body within a certain spatial area in order to maintain the center of gravity of human bodies(7).

Patients with unstable postures should be adjusted on the functions of their ankle joints including their feet and their musculoskeletal system(8). Unstability in the musculoskeletal system may bring about abnormal tension to the vertebrae and the distal joints of the limbs(3), and requires musculoskeletal system interventions throughout the body including the lumbar vertebra and the articulations of the hand(3).

Muscle tone refers to resistance to passive extension on which effects related with muscle's mechanical-elastic properties or reflex stimuli to muscles are reflected(9). Joint movements stimulate the nerves and receptors around joints to reflexly promote or suppress muscles surrounding joints(10).

Plantarflexion or dorsiflexion exercises of the ankle joints trigger the movements of the sagittal plane around the medial or lateral side of the joint as an axis of rotation. In this case, the gastrocnemius muscle which is a power plantarflexion muscle helps knee joint flexion when the knee joint does not support the weight while suppressing the dorsiflexion of...
the ankle joint when the knee joint support the weight with the feet fixed on the ground(11). As such, ankle joint dorsiflexion exercises promote the tone of the musculus tibialis anterior and suppress the tone of the soleus muscle and plantarflexion exercises which are of the opposite concept suppress the tone of the musculus tibialis anterior and promote the tone of the soleus muscle(12).

As a method to adjust the movements of the vertebrae and limb joints, repetitive exercise therapy relaxes surrounding muscles and centralizes pain to contribute to the recovery of the range of movement of joints and frequently activates motor mechanical receptors I, II to promote early recovery(3).

Since joints in human bodies are linked with each other and the movements of a joint trigger the movements of adjacent joints(13), ankle joints’ dysfunction affects the proximal or distal joints of the lower extremity or both proximal/distal joints(14). In the musculoskeletal system, with the muscle and joint link system throughout the body, distal joints can adjust proximal joints, proximal joints can adjust distal joints, the limbs can adjust the vertebrae and the vertebrae can adjust the limbs(3).

Previous studies of muscle tone are mainly studies of comparison of normal persons’ muscle tone or strength(15), studies to test the reliability of the biceps brachii muscle and the quadriceps femoris muscle(10) and studies of comparison of lower extremity muscle tone in relation to gait velocity(16).

The purpose of this study focused on the adjustment of muscle tone resulting from repetitive ankle joint exercises is to analyze changes in the muscle tone of the gastrocnemius lateral head, vastus medialis and triceps lateral head that affect the mobility of anterior, posterior foot, knee, main and hand joints before and after the application of intervention with a repetitive ankle joint dorsiflexion exercise model. That is, the purpose of the study is to analyze the effects of the intervention by repetitive ankle joint dorsiflexion exercises on the tone of the three limb muscles.

**METHODS**

**Subjects**

The subjects of this study were selected from female university students who had no history of diseases in the nervous/musculoskeletal systems, related joints and soft tissues in the past or at present among those who agreed to participate in the study after the purpose, method, content and procedure of the study, expected benefits, involved risks and their right to stop the study in the middle were explained.

The subjects in the ankle joint dorsiflexion exercise group were selected from those whose range of dorsiflexion was limited to be smaller than the normal range of motion, 0°~25° (Neumann, 2004) by at least 5° and the subjects in the ankle joint plantarflexion exercise groups were selected from those whose range of plantarflexion was limited to be smaller than the normal range of motion, 0°~50° (Neumann, 2004) by at least 10°. The numbers of study subjects assigned to the two groups were 15 in the dorsiflexion exercise group and 15 in the plantarflexion exercise group. However, two in the dorsiflexion exercise group and three in the plantarflexion exercises group who were absent without leave during the study were excluded from the study later.

The final subjects who completed the study that was conducted from March 28, 2009 through April 22, 2009 in the practice room of the physical therapy department of M University were 13 subjects in the dorsiflexion exercise group and 12 subjects in the plantarflexion exercise group. Their general characteristics are as shown in Table 1.

**Table 1.** General characteristics of the subjects

<table>
<thead>
<tr>
<th>Classification</th>
<th>ADEG(n=13)</th>
<th>APEG(n=12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age(years)</td>
<td>21.77±1.83</td>
<td>22.42±3.06</td>
</tr>
<tr>
<td>Height(cm)</td>
<td>164.15±6.74</td>
<td>167.5±6.22</td>
</tr>
<tr>
<td>Weight(kg)</td>
<td>58.38±11.32</td>
<td>58.33±10.21</td>
</tr>
</tbody>
</table>

ADEG: Ankle Dorsiflexor Exercise Group
APEG: Ankle Plantarflexor Exercise Group

**Measurement Scale**

A myotonometer (Neurogenic Technologies Inc, USA, Fig. 1) was used to compare, measure and analyze the results of the exercises in order to analyze the effects of the repetitive ankle joint dorsiflexion exercise model on the recovery of the balance of muscle tone of the three muscles around limb joints.

The myotonometer which is equipment to measure and evaluate muscle tone and the degrees of muscle rigidity electrically measures and computerizes the elasticity of tissues(9). This testing device is intended to evaluate muscle rigidity and tension and the elasticity of contracted or relaxed muscles by judging the state of muscle tone of relevant muscles using a
computer program. Since the state of muscle rigidity is linearly proportional to the strength produced by muscle contraction, data obtained during muscle contraction mean indirect muscle strength.

**Fig. 1.** Myotonometer

When a target muscle region is pressed by a Myotonometer measurement probe, since the outer cylinder is fixed, the inside cylinder goes into the outer cylinder as much as the relevant muscle region is pressed. Therefore, the distance between the internal and external cylinders changes in accordance with the resistance of the target muscle region and the changes in the distance is converted into 8 levels of muscle strength to measure the degree of dislocation.

**Procedure**

The muscle tone test regions were set to the gastrocnemius lateral head, the vastus medialis and the triceps lateral head as suggested by Geiringer SR(19)(Fig. 2, 3, 4). The gastrocnemius lateral head set as such was measured at a position five fingers away downward from the lateral fold of the hamstring(Fig. 2), the vastus medialis was measured at a position four fingers away upward from the superior medial angle of the patella(Fig. 3) and the triceps lateral head was measured at the rear of the deltoid muscle node(Fig. 4). The measurement was conducted three times repeatedly by one tester prepared in advance while pressing at a pressure of 1.5kg separately in a state of maximum relaxation followed by a state of maximum isometric contraction and the average values of the repeatedly measured values were automatically calculated by a computer program. This measurement was applied to all subjects in the two groups before and after applying the three week repetitive ankle joint dorsiflexion exercise intervention model.

**Fig. 2.** Myotonone measurement of gastrocnemius lateral head

**Fig. 3.** Myotonone measurement of vastus medialis

**Fig. 4.** Myotonone measurement of triceps lateral head

**Repetitive dorsiflexion plantar flexion exercise models of the ankle joint**

The repetitive exercise model was applied to both the dorsiflexion exercise group with limited ranges of ankle joint dorsiflexion and the plantarflexion exercise...
group with limited ranges of dorsiflexion three times a week for three weeks.

As a starting posture, the subjects took of their shoes in front of the wall, stood with their feet completely in contact with the floor while reaching their arms to gently touch the wall with their hands as shown in Fig. 4 in order to prevent compensation and secure stability(Fig. 5). Then, all the 21 subjects in the dorsiflexion exercise group were instructed to perform dorsiflexion of their two ankle joints up to their maximum range of movement, maintain the position 30sec, and then relax their ankle joints for 30min to establish a dorsiflexion exercise model. The application of this model three times was defined as one set and three sets were performed each time. Based on a suggestion by Delome(20) indicating that efficient number repetition of exercises is 10, the number repetition of an exercise model a day was established as three sets which are 9 repetitions. All the 21 subjects in the plantarflexion exercise group were instructed to perform plantarflexion of their two ankle joints up to their maximum range of movement, maintain the position 30sec, and then relax their ankle joints for 30min to establish a plantarflexion exercise model and the model was applied in the same method as used in the dorsiflexion exercise group.

![Fig. 5. Dorsi-plantar flexion exercise models of the ankle joint](image)

**Data Analysis**

Data collected from the 25 subjects in the two groups were processed using SPSS Version 12.0. The active ranges of motion before and after the experiment in each group were compared using paired t-tests and the amounts of changes made through the experiment were compared between the two groups using independent t-tests.

## RESULTS

### Pre–Post Muscle Tone Comparison of the Ankle Dorsiflexion Exercise Group

The changes in muscle tone through the experiment in the dorsiflexion exercise group applied with the relevant exercise model were compared and analyzed as follows, Regions where muscle tone increased after the experiment were right vastus medialis relaxation, left vastus medialis relaxation, right vastus medialis contraction, left vastus medialis contraction, left gastrocnemius relaxation, right gastrocnemius relaxation and right vastus medialis relaxation in order of precedence from the largest increase and none of the increases was significant (p>0.05). Regions where muscle tone decreased after the experiment were right triceps relaxation, right triceps contraction, left triceps contraction, left vastus medialis contraction, left triceps relaxation and right gastrocnemius contraction in order of precedence from the largest decrease and none of the decreases was significant (p>0.05)(Table 2).

### Table 2. Pre–post muscle tone comparison of the ankle dorsiflexion exercise group

<table>
<thead>
<tr>
<th>MR (N=13)</th>
<th>Pre–Test M±SD</th>
<th>Post–Test M±SD</th>
<th>p</th>
</tr>
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<tbody>
<tr>
<td>Lt Triceps C</td>
<td>7.17±1.34</td>
<td>6.51±1.77</td>
<td>.654</td>
</tr>
<tr>
<td>Lt Triceps R</td>
<td>8.33±1.61</td>
<td>8.16±1.51</td>
<td>.638</td>
</tr>
<tr>
<td>Rt Triceps C</td>
<td>6.77±1.16</td>
<td>5.95±1.25</td>
<td>.622</td>
</tr>
<tr>
<td>Rt Triceps R</td>
<td>9.45±4.20</td>
<td>7.78±1.09</td>
<td>.331</td>
</tr>
<tr>
<td>Lt GC C</td>
<td>5.66±1.68</td>
<td>5.59±1.39</td>
<td>.791</td>
</tr>
<tr>
<td>Lt GC R</td>
<td>7.30±.85</td>
<td>7.58±.98</td>
<td>.439</td>
</tr>
<tr>
<td>Rt GC C</td>
<td>5.57±1.12</td>
<td>5.43±1.60</td>
<td>.231</td>
</tr>
<tr>
<td>Rt GC R</td>
<td>7.13±.89</td>
<td>7.38±1.70</td>
<td>.239</td>
</tr>
<tr>
<td>Lt VM C</td>
<td>7.18±.87</td>
<td>6.80±.75</td>
<td>.837</td>
</tr>
<tr>
<td>Lt VM R</td>
<td>7.18±.92</td>
<td>10.02±2.15</td>
<td>.765</td>
</tr>
<tr>
<td>Rt VM C</td>
<td>7.03±.94</td>
<td>7.64±1.90</td>
<td>.832</td>
</tr>
<tr>
<td>Rt VM R</td>
<td>7.07±.95</td>
<td>9.97±1.44</td>
<td>.875</td>
</tr>
</tbody>
</table>

MR: Measurement region, C: Contraction, R: Relaxation, GC: Gastrocnemius, VM: Vastus Medialis

### Pre–Post Muscle Tone Comparison of the Ankle Plantarflexion Exercise Group

The changes in muscle tone through the experiment in the plantarflexion exercise group applied with the
group (-3.2 ± 1.49) although the difference was not significant (p = 0.05). The muscle tone of the dorsiflexion exercise group (2.85 ± 2.59) increased less in left vastus medialis relaxation than the plantarflexion exercise group (3.24 ± 1.66) although the difference was not significant (p = 0.05). The muscle tone of the dorsiflexion exercise group (6.1 ± 2.27) increased more in right vastus medialis contraction than the plantarflexion exercise group (5.4 ± 2.17) although the difference was not significant (p = 0.05). The muscle tone of the dorsiflexion exercise group (2.90 ± 1.95) increased less in right vastus medialis relaxation than the plantarflexion exercise group (3.2 ± 1.59) although the difference was not significant (p = 0.05) (Table 4).

**DISCUSSION**

As clinical test methods to assess muscle conditions, certain muscle tone assessment scales such as TAST (Tone Assessment Scale)(21), manual muscle strength tests, muscle strength testers, electromyography, biofeedback tests(22) and isokinetic motor tests(23) are utilized. Of them, Myotonometer(10) measures muscle tone while muscles are relaxed or contracted and indicates the results as numerals through computerization and thus this tester is used to assess the effects of motor therapy of physical therapy(18, 24). This equipment is also usefully used in measuring muscle rigidity or spasticity or changes in soft tissues with lesions such as edema, cysts, or hematoma(15). One of the advantages of this equipment is that this equipment can measure muscle conditions without causing joints to move, this equipment can be effectively used in patients accompanying pain or those with a limited range of motion(10).

Balance is an ability to maintain the center of gravity on one’s base plane in a given environment(25), which is an essential element that is the most basic in human’s daily lives or in conducting activities with objectives(26).

Since the ankle joints adjust postures(27), and contribute to the stabilization of postures together with hip joints(5), the triceps muscle of calf and the muscle tibialis anterior play important roles in maintaining balance of the entire body(28).

Brown et al, reported that if lower extremity muscle strength would be reduced, gait velocity, balance and the ability to go up stairs would decline(29) and Dietz et al, reported that when confusion was given in order to break balance, among calf muscles, the contractile power of the gastrocnemius increased while that of the musculus tibialis anterior decreased(28). Whipple et al, suggested that when dorsiflexor was weakened the balance ability would decline(30). As such, they warned that weakening of calf muscles would limit the range of motion of the ankle joints along with unbalanced lower extremity alignment, and become a cause of chronic feet instability such as damage to the ligament and joint adhesion or dynamic changes in the musculoskeletal system(31).

The triceps long head acts to extend the brachium, the vastus medialis is a muscle that extends knee joints and thus is activated in the first part of the stance phase when the feet come into contact with the ground and the gastrocnemius is a muscle that mainly acts when the heel is taken off the ground which is the last part of the stance phase(32). The active joint motion exercise selected in order to control changes in the range of motion of joints may contribute to voluntary exercises and balance control with movements within the range of motion of body sections that is not limited made by active contraction of muscles that cross the joint(33).

Norkin and Levangie suggested that since joints in human bodies are connected continuously to each other, changes in the structure or function of a certain joint will cause changes in the functions of adjacent joints and that limited movements of ankle joints will lead to increases in the mobility of adjacent joints and the increase in the mobility of the adjacent joint will lead to decreases in the mobility of other adjacent joints to lead to joint motion increase/decrease patterns of the entire body(13). Therefore, joints in human bodies have great influences on each other(34).

In this study, it was indicated that the repetitive exercise control of the ankle joints affected muscles along the joint chain to change muscle tones of the triceps brachii muscle of the upper extremity and the Vastus Medialis and the Gastrocnemius of the lower extremity as shown in Tables 2~4.

In Table 4 that shows comparisons of muscle tones between the two groups, the magnitude of decreases in the triceps brachii muscle in the dorsiflexion exercise group were the largest in right relaxation, followed by right contraction, left contraction and left relaxation in order of precedence, The magnitude of decreases in the triceps brachii muscle in the plantarflexion exercise group was the largest in left contraction followed by right contraction, left relaxation and right relaxation in order of precedence,
The magnitude of increases in the gastrocnemius in the dorsiflexion exercise group was the largest in left relaxation followed by right relaxation. The magnitude of decreases in the peroneal muscle was the largest in right contraction followed by left contraction. The magnitude of increases in the gastrocnemius in the plantarflexion exercise group was shown only in right relaxation and the magnitude of decreases in the peroneal muscle was the largest in right contraction followed by left contraction and left relaxation in order of precedence.

The magnitude of increases in the vastus medialis in the dorsiflexion exercise group was the largest in right relaxation followed by left relaxation and right contraction in order of precedence. The magnitude of decreases in the vastus medialis appeared only in left contraction. The magnitude of increases in the vastus medialis in the plantarflexion exercise group was the largest in left relaxation followed by right relaxation and right contraction in order of precedence. The magnitude of decreases in the vastus medialis appeared only in left contraction.

Although not significant, these results mean that only ankle joint movements will affect the muscle tone of upper/lower extremity muscles to contribute to the control of limb joint movements.

This study analyzed the effects of repetitive ankle joint dorsiflexion and plantarflexion exercise models on the muscle tones of three limb muscles of healthy female university students. This study has some limitations to generalize the results as the models were applied to a target group in a certain age group and only the muscle tone tests of the triceps, vastus medialis and gastrocnemius were compared and analyzed. Therefore, it is considered that, based on the results of this study, studies of changes in muscle tones of muscles around the vertebrae and limb proximal-distal joints should be continued.

CONCLUSION

This study was conducted in order to examine the effects of the intervention by repetitive ankle joint dorsiflexion and plantarflexion exercises on the muscle tones of three limb muscles and the following conclusions were obtained.

1. In the dorsiflexion exercise group applied with repetitive dorsiflexion exercise models, the magnitude of increases in muscle tone was the largest in right vastus medialis relaxation followed by left vastus medialis relaxation, right vastus medialis contraction, left gastrocnemius relaxation and right gastrocnemius relaxation in order of precedence and the magnitude of decreases was the largest in right triceps relaxation followed by right triceps contraction, left triceps contraction, left vastus medialis contraction, left triceps relaxation, right gastrocnemius contraction and left gastrocnemius in order of precedence and none of the differences was significant (p > 0.05).

2. In the plantarflexion exercise group applied with repetitive dorsiflexion exercise models, the magnitude of increases in muscle tone was the largest in left vastus medialis relaxation followed by right vastus medialis relaxation, right vastus medialis contraction and right gastrocnemius relaxation in order of precedence and the magnitude of decreases was the largest in left triceps contraction followed by right triceps contraction, left triceps relaxation, right gastrocnemius contraction, left vastus medialis contraction, right triceps relaxation, left gastrocnemius contraction and left gastrocnemius relaxation in order of precedence and none of the differences was significant (p > 0.05).

3. Differences in the magnitude of muscle tone increases between the dorsiflexion exercise group and the plantarflexion exercise group were shown to be the largest in left vastus medialis relaxation and the smallest in right gastrocnemius relaxation although none of the differences was significant (p > 0.05).

4. Differences in the magnitude of muscle tone decreases between the dorsiflexion exercise group and the plantarflexion exercise group were shown to be the largest in right triceps relaxation muscle and the smallest in left vastus medialis contraction although none of the differences was significant (p > 0.05).

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