

Effects of massage and compression treatment on performance in three consecutive days

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OBJECTIVE: To determine the effects of massage treatment plus 24 hours of elastic calf compression on delayed onset of muscle soreness following maximum calf-raise exercises during three consecutive days.

METHODS: Fourteen female students (aged 20–22 yr) who had regularly performed moderate exercise were submitted to maximum calf-raise exercises of 1 movement per 3 seconds till exhaustion. Seven subjects (T-group) received effleurage massage on both calf muscles immediately after the exercise plus 24 hours of elastic calf compression. The other subjects (C-group) received no treatment. We examined creatine-kinase, maximum calf muscle circumference, maximum voluntary isometric muscle contraction, perceived pain, maximum angle of dorsiflexion and one-leg long jumping before and immediately after treatment (T-group) or exercise (C-group) for 3 days of exercise plus 7 days of recovery. Subjects carried a step counter to count the number steps walked each day.

RESULTS: The number of calf-raise repetitions in both groups significantly decreased on days 2 and 3. Creatine kinase increased significantly in the T-group from day two of the exercise period to day five of the recovery period, and was tendentially higher than in the C-group. Maximum calf muscle circumference in T-group was higher post-treatment versus pre-exercise, and significantly higher in the C-group. Perceived pain was significantly lower and one-leg long jumping significantly better (by 5–10%) in T-group versus C-group.

CONCLUSION: Massage plus elastic calf compression minimizes the change of maximum calf muscle circumference, perceived pain, and one-leg long jumping after maximum calf-raise exercise. Perceived pain correlates with performance.

KEYWORDS: creatine kinase; isometric force; muscle soreness.

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■ INTRODUCTION

Previous studies^{1,2} have shown that unaccustomed or strenuous eccentric exercises result in delayed onset muscle soreness (DOMS). It is first reported between 8 to 24 hours after exercise, peaks in intensity between 24 to 72 hours^{3,4} and disappears after 5 days.⁵ The direct and indirect indicators of muscle damage include disruption of contractile tissue,⁶ cellular [Ca⁺⁺] accumulation,³ cellular infiltration,⁷ changes in ultrasound images,² release of muscle specific enzymes into serum,^{1,8} changes in voluntary isometric muscle strength and range of motion.^{1,8} In many studies,^{5,9,10} it has been shown that the forced lengthening of muscles generating maximal voluntary force induces severe muscle tissue damage. The tension generated during eccentric contraction is higher than that for either concentric muscle contraction or isometric muscle contraction, even though fewer motor units are recruited. During eccentric

contraction, the contracting muscle is forced to lengthen, and this induces DOMS.^{3,4} To induce muscle damage, the exercises which have been studied include downhill running,¹¹ plyometric drop jumping,¹² eccentric elbow flexion,^{1,8,13,14} and parallel squats.¹⁵ The symptoms and events occurring during DOMS can be explained by a cascade of events following structural damage to muscle proteins.¹⁶ Thus, the exercise with calf muscles, an instance of antigravity muscular activity that humans use during daily activities, should be examined in terms of DOMS generation.

After repeated bouts of the same exercise, the indicators of muscle damage showed modest changes. This response is known as “repeated bout effect”.^{1,17} These altered responses show that the changes in the indicators of muscle damage after the second bout of exercise are significantly smaller than those after the initial exercise, and the length of the adaptation effect required ranges from 3 days to 6 months to take place and to erase.¹⁸ Newham et al.¹³ reported that creatine kinase (CK) and muscle tenderness in a second bout

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of exercise one week after the initial bout, (at maximum force) was 50% lower when compared with that in the first bout of exercise.

The effect of adaptation was examined prior to full recovery of muscle damage indicators.^{17,19,20} The repeated bout of strenuous exercise with damaged muscle, which was performed in the initial bout, did not influence the repair or the recovery process. However, there are no studies reporting the effect of treatment on the repair process of DOMS following continuous exercises.

Many previous studies examined prevention or attenuation of DOMS by heat treatment,²¹ compression garment,¹² hyperbaric oxygen²² and ultrasound treatment.² Massage is also an easy and popular treatment method for soft tissue damage. Smith et al.²³ observed that 30 minutes of sport massage, applied 2 hours after eccentric exercise, reduced DOMS. In a recent study,²⁴ ten minutes of massage applied to the arms was effective in alleviating DOMS and reducing swelling with no effect on muscle function. Other studies, however, have shown that massage applied immediately after exercise was not an effective treatment for preventing DOMS^{25,26} nor for the protection of muscle function²⁷ following intense eccentric exercise. Reported research identified no trend between type and timing of massage and any specific outcomes.²⁸ In another study,¹² the combined treatment of massage and compression on lower limbs was effective in preventing DOMS. Kraemer et al.²⁹ concluded that compression clothing was effective to attenuate edema resulting from significant inflammation and as a recovery strategy following exercise-induced muscle damage. However, the compression pressure produced by compressive garment may not be strong enough to compress damaged muscles and to control swelling after prolonged maximal eccentric exercises. In the situation of sports injury, compression bandages are provided to prevent edema and inflammation and to minimize increased blood and fluid flow. We hypothesized that in comparison to control conditions, analgesic effects of the recovery modalities would reduce DOMS and maintain performance throughout days of continuous exercises.

Therefore, the purpose of this study was to determine effects of massage with 24 hours of compression treatment on DOMS following maximum calf-raise exercises during three consecutive days.

METHODS

Subjects

Fourteen female college students (age 21.1 ± 1.3 years, height 158.22 ± 6.22 cm, weight 56.29 ± 10.13 kg) volunteered to participate in the present study and signed informed consent documents in accordance with the ethical standards of American College of Sports Medicine and approved by Ethical Committee of Osaka International University. They had regularly performed moderate exercise, but had not practiced weight training or received supplementation for at least 6 months before the present study. They were requested to and agreed not to attend any exercise and weight training, to refrain from ingesting alcohol, supplements, and nonsteroidal anti-inflammatory drugs, and to avoid therapeutic treatment and stretching during the present study period. Seven randomly selected subjects received massage and compression treatment after

the maximum calf-raise exercise (treatment group; T-group). Seven other subjects received no treatment (control group; C-group).

Exercise bout

Subjects stood on the step board (30 cm high) with both feet; the spacing between feet was as wide as their shoulder widths. Both forefeet were on the step board, with mid-foot and heels in the air. Subjects performed the maximum calf raise exercise at 1 movement per 3 seconds until they could not maintain speed of movement. During the first second of each movement, the subjects raised their heels as high as possible with the ankle positioned at maximal plantar flexion and supination. During the next two seconds, the subjects lowered the heels so that they were lower than the toes, in order to allow a greater stretch of the working muscles. The movement was to control the speed of the eccentric contraction during the lowering of the heels. Both groups exercised for three days consecutively (Ex-period). During the seven days of the recovery period (Re-period), T-group participants were measured their before their massaging sessions.

Treatment

Subjects in the T-group received 50 repeats of effleurage (stroking) from ankle to knee on both legs delivered by a sport trainer. The ankle was kept risen from the floor by 20 cm during the effleurage massage. Both calf muscles were covered by bath towels to reduce friction between the therapist's hand and the subject's skin. To minimize calf muscle swelling, subjects in the T-group were submitted to compression with an elastic thin bandage treatment on both calf muscles immediately after the maximum calf-raise exercise and massage. This sport elastic bandage was gently wrapped around both lower legs beginning at the ankle and progressing proximally to a point just below the knee joint; this remained in position until the measurement of the following day.

Measurements

In order to identify DOMS, the criterion measurements consisted of creatine-kinase activity, maximum circumference of calf muscle (CIR), maximum voluntary isometric muscle contraction (MVC), perceived pain (PAIN), one-leg long jumping (JUMP) and dorsiflexed ankle joint angles (D-flex) before and immediately after treatment for T-group. C-group participants took these measurements before and after exercise. Measurements were taken on each of the three days of Ex-period and at 24 hour intervals for the 7 days following the exercise period (Re-period). Both groups visited the laboratory between 11:00 AM and 1:00 PM for exercise and/or measurements. The subjects counted and reported the number of walking steps per day using a step counter (Citizen Co.Ltd., Tokyo, Japan).

Plasma creatine kinase (CK) activity was analyzed using the Reflotron System (Yamanouchi Pharmaceutical Co.Ltd., Tokyo, Japan): 50 μ L of whole blood was sampled from a fingertip into a heparinized glass capillary before and immediately after each exercise period during the three-day exercise period and during the next seven days of recovery. The collected whole blood samples were dropped onto the Reflotron CK analysis sheet (Roche Diagnostics K.K., Tokyo, Japan). All samples were analyzed in duplicate (coefficient of variance >0.9).

Circumference

The investigators measured the subject's largest lower leg circumference using a constant tension tape while the subjects stood with both feet on a table. In the initial measurement, the investigator marked the regions where measurements were made in each leg in order to measure the same region throughout the study. Measurement points were remarked throughout the study to insure precision of measuring sites. The mean value of the best circumference on each leg was calculated and used for further analysis.

Maximal voluntary isometric muscle contraction

Maximal Gastrocnemius muscular strength was measured using a Tension meter (Takei Scientific Instruments Co., Ltd, Niigata, Japan) before exercise and immediately after treatment for T-group, and before and after exercise for C-group during the exercise-period and daily during the recovery-period. The subject was placed in a supine position and firmly attached with a belt to the bed. The attachment cable of Tension meter was placed to the subject's forefoot with 90 degree of the ankle. During measurement, both arms were crossed over the chest. Subjects were asked to sustain maximal effort for 10 seconds. The rest between maximal isometric contractions was 1 minute. The best of two maximal isometric contraction of plantar flexors for each leg was taken, and the average value of the maximal value for each leg was used as the value of MVC.

Scale of perceived pain

Perceived pain (PAIN) in the Gastrocnemius muscle during rest and walk were evaluated by visual analog scale (VAS) that had a 100-mm line with "no pain" on one end (0 mm) and "extremely painful" on the other (100 mm). Subjects marked their subjective scale of soreness on the line under the supervision of the examiner. The length of the line from 0 to the marked point provided a numeric measure of soreness. PAIN was evaluated before and immediately after treatment or exercise during the exercise-period and daily during the recovery-period.

One leg long jumping

The average of two long jumps by each leg was used to assess long jump performance. The subjects performed the long jump twice with each leg, resting for 1 minute between measurements. Subjects were encouraged to use their arms during the jump. The subjects needed to land with both feet. The shortest distance from the starting line to landing point was measured. The distance of the best jump for each leg was used as an indicator of one leg long jump performance.

Range of motion

The investigators fully dorsiflexed the subject's foot and measured the angle of ankle using a goniometer. The measurements of ankle joint angle were taken twice while the subjects were prone on the table with extended knee. The maximum angle in each leg was recorded and the average angle was used for analysis.

Statistical analysis

Condition differences were analyzed using two-way ANOVA. When ANOVA showed a significant effect, the Tukey post hoc test was used to identify the differences between each time point. Coefficients of correlation were

calculated using Person Product Moment Correlation for each data. All analyses were performed using Statistical analysis was using SYSTAT (version 11; SYSTAT software, Inc., Richmond, CA). Statistical significance was set at $p < 0.05$.

■ RESULTS

General

The number of Calf-raise repetitions on Day 2 and Day 3 decreased significantly as compared with the initial exercise. On Day 3, the number of Calf-raise repetition in C-group was less than that in T-group.

Creatine-kinase

Figure 1 shows that CK in T-group significantly increased in every measurement from Day 2 pre-exercise through Day 2 in Re-period ($p < 0.01-0.05$). There was no significant relationship between CK and the number of exercises in both groups. The levels in T-group on each day were higher than that in C-group, but there were no significant differences between the two groups in any day. The peak CK in both groups occurred on day 2 of the recovery period.

Number of Calf-raise repetition and daily walking steps

As shown in Figure 2, there were no significant differences in the number of Calf-raise repetition or in the daily walking steps between two groups. There were no significant relationships between the number of Calf-raise repetition and the number of daily walking steps, which were counted from after each exercise to before the next one. T-group subjects walked tendentially more than C-group subjects, but there were no significant differences between them. The daily walking activity did not affect the number of the Calf-raise repetitions in the following day.

Circumference

As shown in Figure 3, calf circumference in the T-group significantly increased on each exercise day after exercise and treatment ($p < 0.01-0.05$), but returned to pre-exercise values in the following day. Corresponding values in the C-group grew steadily during Ex-period and reached significance on exercise day three. During the recovery period, circumference remained steady throughout. Circumference was significantly larger in the C-group vs. T-group throughout ($p < 0.05$).

Perceived pain

As can be seen in Figure 4, PAIN values in both groups increased significantly during the exercise period, from Day 1 through Day 3. Peak values were reached in Day 3, pre-exercise for T-group, and on Day 3 post-exercise for C-group. During the recovery period, PAIN dropped, progressively returning to zero by day four of recovery for both groups. PAIN values in T-group significantly increased from Day 1 post-Tre in Ex-period to Day 2 in Re-period ($p < 0.01-0.05$), and those in C-group significantly and progressively increased from Day 1 Post-Ex to Day 3 ($p < 0.001-0.01$). PAIN values in T-group in each measurement were lower as compared with those in C-group. From Day 3 Post-Ex in Ex-period to Day 2 in Re-period, there were significant differences between C-group and T-group ($p < 0.01$ and 0.05).

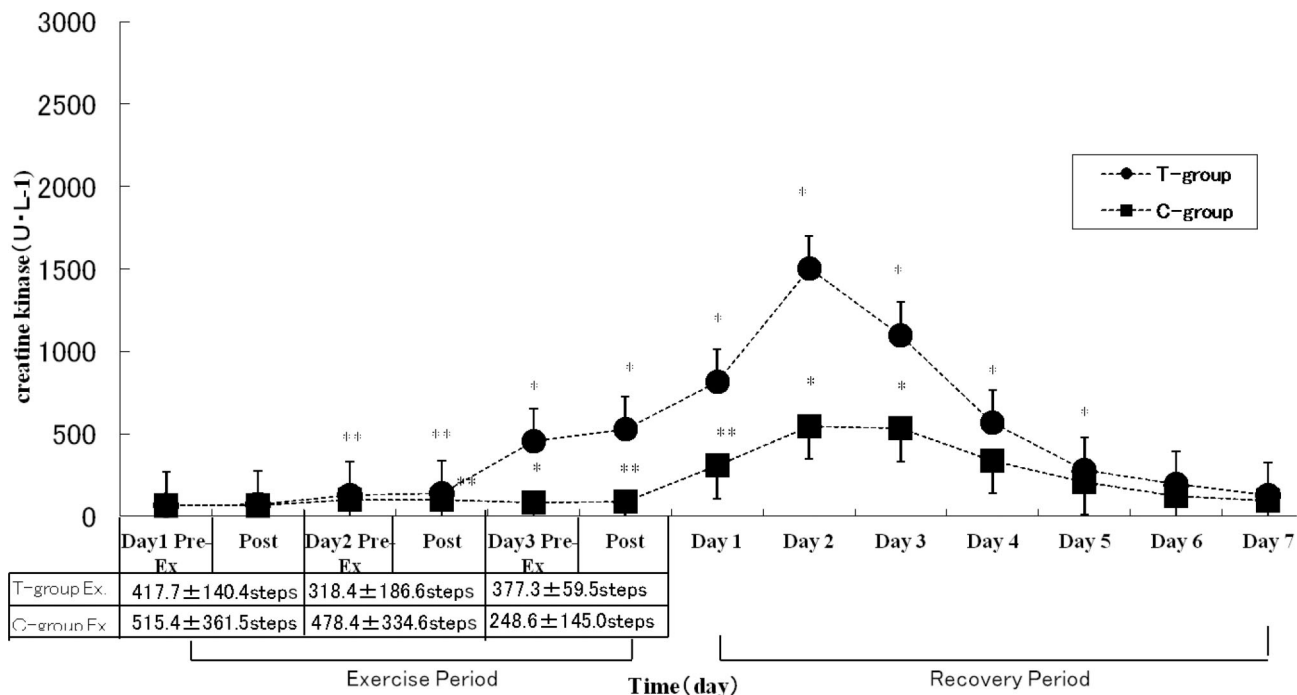


Figure 1 - Stepping number of the heel raise exercise and changes in creatine-kinase activity (CK) before and after maximum heel raise exercise for 3 days of exercise period and for 7 days of recovery period. Values are means (SD). *: $p < 0.05$, **: $p < 0.01$ vs Day 1 Pre-Ex.

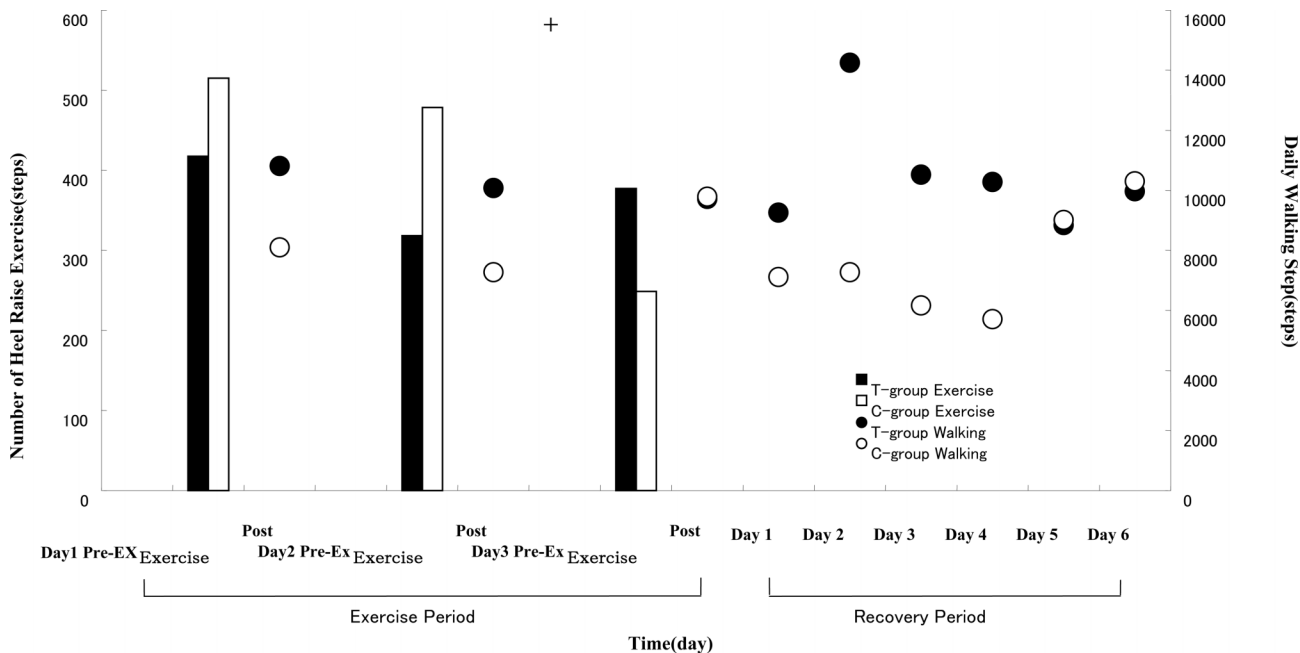


Figure 2 - Stepping number of Calf-raise exercise and stepping number of daily walking after maximum heel raise exercise for 3 days of exercise period and for 7 days of recovery period. Values are means (\pm SD). **: $p < 0.01$ vs initial exercise.

One leg jumping

Figure 5 shows results for one leg jumping.

In the **Control group** one leg jumping decreased very slightly during the exercise period, reaching significance versus initial values in the last three measurements; it

remained low, but gradually returned to the initial value on Day 4 of recovery.

In the **Test group** one leg jumping decreased from after the first exercise to Day 3 post-treatment and returned to base line on the first day of the recovery period. During recovery,

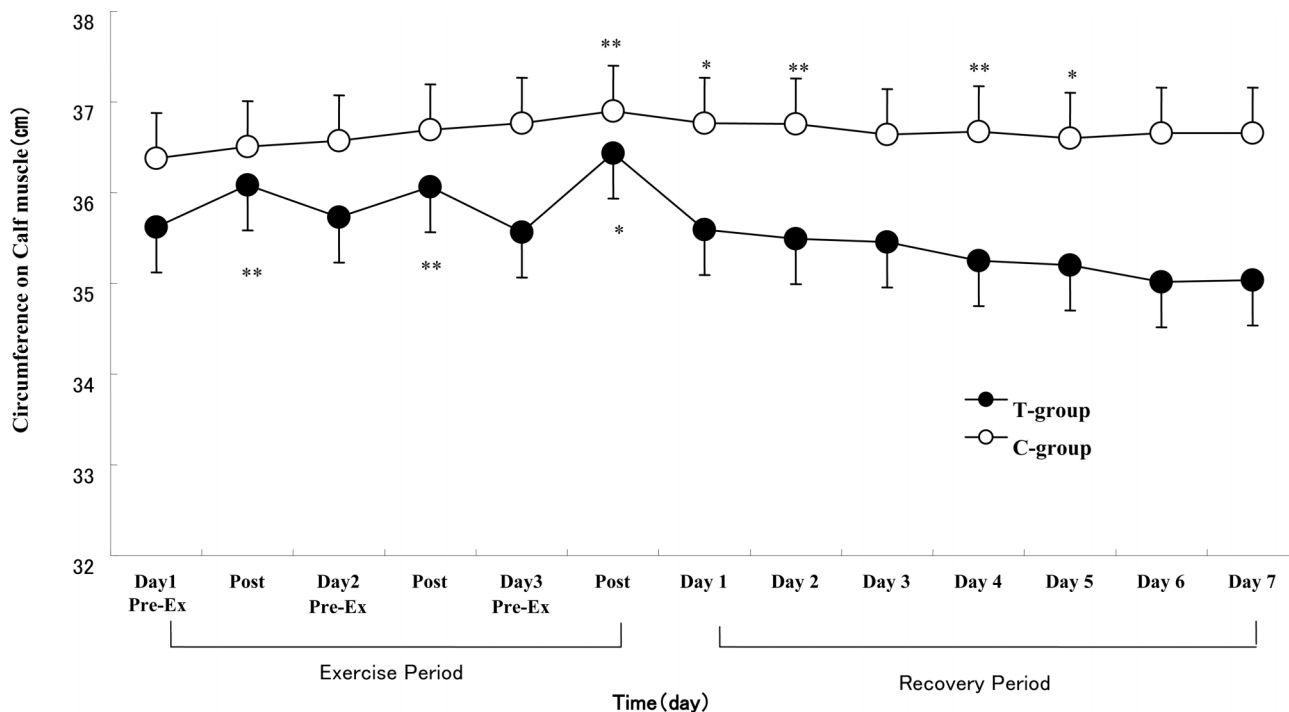


Figure 3 - Changes in circumference in lower leg before and after daily maximum heel raise exercise for 3 days of exercise period and for 7 days of recovery period. Values are means (\pm SD). *:p < 0.05, **:p < 0.01 vs Day 1 Pre-Ex.

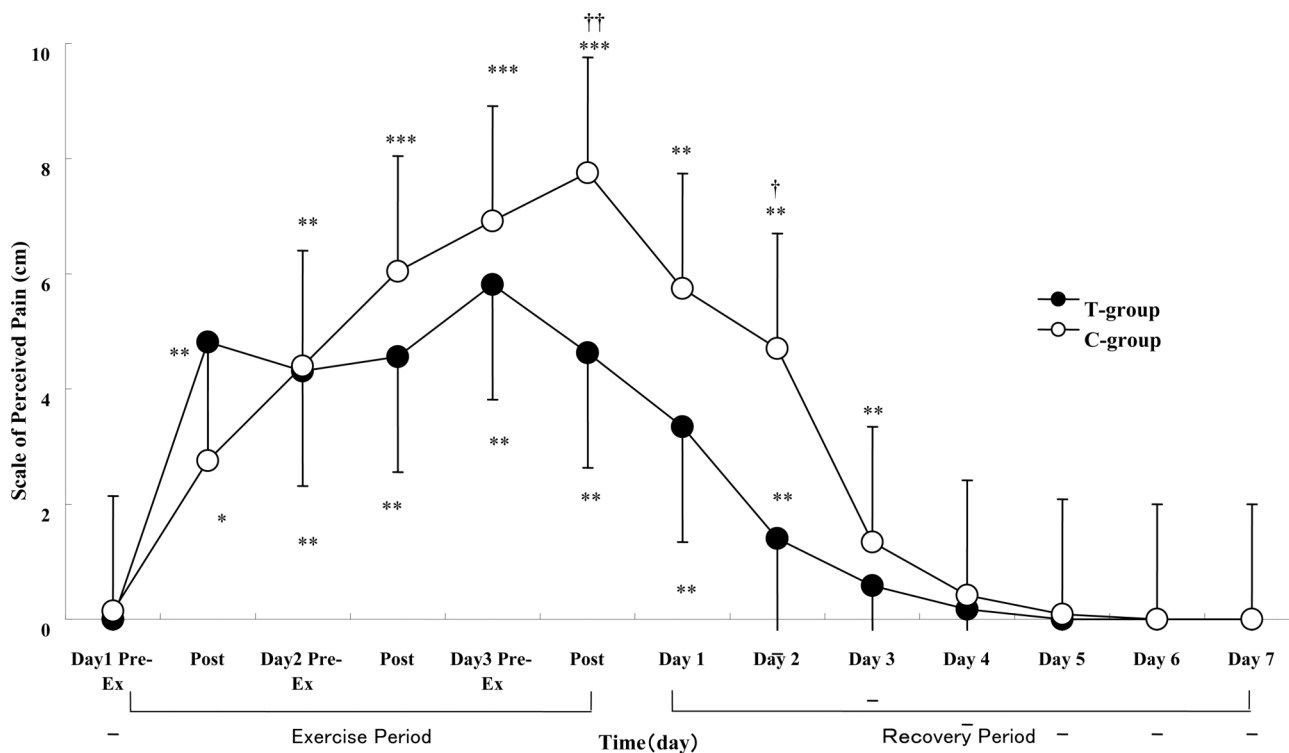


Figure 4 - Changes in perceived pain scale for 3 days of exercise period and 7 days of recovery period. Values are means (\pm SD). *:p < 0.05, **:p < 0.01, ***:p < 0.001 vs Day 1 Pre-Ex. †:p < 0.05, ††:p < 0.01 T-group vs C-group in each measurement.

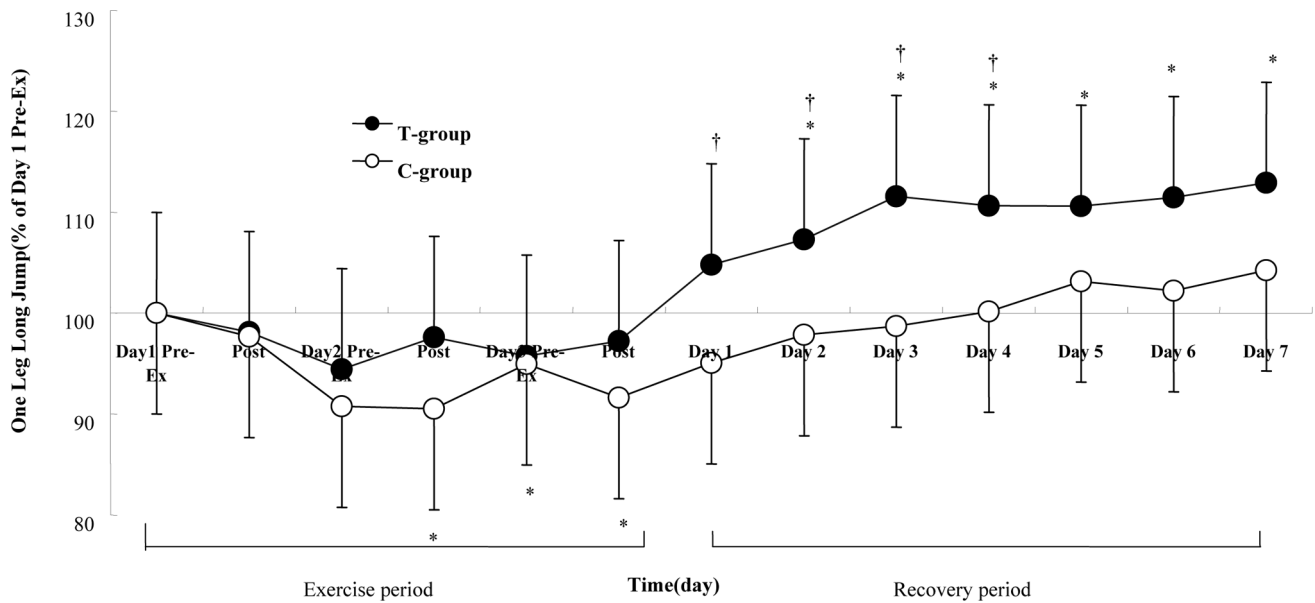


Figure 5 - Changes in one leg long jumping before and after daily maximum heel raise exercise for 3 days of exercise period and for 7 days of recovery period. Values are means (\pm SD). *:p < 0.05 vs Day 1 Pre-Ex. †:p < 0.05, ††:p < 0.01 T-group vs C-group in each measurement.

one leg jumping increased steadily and significantly in T-group, compared to baseline and to C-group.

When **Test and Control groups** were compared, significant differences were recorded between the two groups on Day 1, Day 2, Day 3, and Day 4 in the recovery period (p < 0.05). There was a significant negative relationship between PAIN and one leg jump in both groups (r = -0.91; p < 0.05).

Range of motion (ROM) and maximal voluntary isometric muscle contraction (MVC)

There were significant differences in MVC and ROM (dorsiflexed ankle joint angle) between both groups in this study.

DISCUSSION

The first finding in this study was the inducement of DOMS in the muscles groups that a person contracts regularly and the recovery from DOMS after the 3 days of consecutive exercises. In former studies to produce DOMS, subjects eccentrically performed elbow flexion,^{1,8,13} down-hill running,¹¹ down-hill walking,²⁷ squat exercise,¹⁵ and plyometric jumping.¹² Regarding the endurance muscle contraction with light loads to produce DOMS, 40 minutes of intermittent down-hill running¹¹ and 2 hours of elbow flexion exercise³⁰ were combined. In general, the person who does not exercise regularly experiences DOMS after walking and/or jogging or weight training against his/her own body weight. The calf-raise exercise used in this study was likely to be similar to the strain experienced in normal day to day muscle activities such as push-offs during walking and/or climbing stairs. In this study, the peak CK levels after calf-raise exercise in control group were higher than the normal level (500 IU*L⁻¹), which a former study had identified.³¹ CIR and performance also changed significantly

after the calf-raise exercise against body weight. Thus, these subjects damaged their gastrocnemius muscles, which are less susceptible to eccentric exercise induced muscle damage than elbow flexors. DOMS is first felt between 8 to 24 hours after exercise, peaks in intensity between 24 to 72 hours^{3,4} and disappears after 5 days.⁵ According to the recovery process of DOMS after Calf-raise exercise, the peak DOMS in C-group was registered two days after the initial exercise. DOMS diminished in 72 hours after exercise and recovered by six days after the initial exercise. The recovery patterns in this study are the same as those in the former studies.³⁻⁵ This effect is referred to as a repeated bout effect in continuous exercise sessions.¹⁷ Thus, there was no additional DOMS when both groups exercised with DOMS in this study.

The second finding in this study was to identify the effect of massage and compression treatment on DOMS. The massage therapy is probably the most ancient and widely used treatment of the human body. The purpose of massage therapy was to increase blood flow speed and blood flow volume, which could potentially alter delivery and removal of substances essential for energy metabolism, and the increase in lymph flow which is effected through the mechanical pressure to the muscle^{23,26} and tends to prevent extracellular and intracellular edema.²⁵ Brummit et al.³² note that former studies consisted of one session of massage for 8 min to 30 min and at 0 h to 8 h following eccentric exercise to prevent DOMS. With massage applied immediately after eccentric exercise, the larger muscle groups such as quadriceps did not exhibit any change the blood flow,³³ nor was there improved recovery of speed or muscle power,²⁵ nor were CIR and DOMS minimized.^{26,34,35} However, massage therapy 2 to 3 hours post-exercise effected the reduction of DOMS and recovery of isometric strength.^{23,24,27,36} In the present study, T-group participants received 5 minutes of the effleurage massage, which is one of the most common techniques for gastrocnemius muscle

groups immediately after calf-raise exercise. The massage applied in the present study might increase inflammation, because it was applied immediately after the strenuous exercise. However, T-group ladies recovered CIR in the next day of pre-exercise, and had less PAIN during this study as compared with the corresponding C-group. This result is supported by other former studies^{12,24,37} regarding the attenuated DOMS. It is interesting that walking in the C-group minimized the change of CIR, MVC, and D-flex after the calf-raise exercise. This light exercise was projected to increase blood and lymph flow, to prevent edema and/or swelling and to improve lactic clearance from the exercised muscles.³⁸ Thus, the massage and/or the light muscle activity for the calf muscles during the daily activity such as walking might increase blood flow and lymph flow and control swelling after prolonged strenuous exercise.

The last finding in this study was to present the relationship among DOMS and performance after calf-raise exercise. Zainuddin et al.²⁴ concluded that the 2h post-exercise massage was effective in alleviating DOMS and minimizing the change of MVC and slowing isokinetic strength, but it had no effect on muscle function. Jakeman et al.,¹² however, suggested that the compression clothing was an effective recovery strategy following damaging exercise to minimize localized edema and to control limb blood flow. It is possible that CIR significantly increased in the T-group immediately after the damaging exercise because the blood and fluid on the exercising calf muscles might have flown more easily after the bandage was removed. T-group participants exhibited less decrease in JUMP and less PAIN as compared with C-group. These results suggest that PAIN affects the performance during induced DOMS because there is a significantly negative relationship between PAIN and JUMP. The result in this study was supported by the study of Sakamoto et al.²⁰ CK responses after the eccentric exercise typically track poorly with other criterion markers of DOMS, even though it is a good criterion for the occurrence of muscle damage.³⁹ Five minutes of effleurage massage and compression with the elastic bandage treatment may attenuate PAIN and minimize the decrease in performance.

CONCLUSION

The result of this investigation suggests that

- (1) DOMS did not appear to slow the recovery rate, even though the peak CK was recorded 4 days after the initial maximal Calf-raise exercise.
- (2) five minutes of effleurage with the 24hrs of compression treatment minimized the change of perceived pain following the maximum Calf-raise exercise.
- (3) perceived pain affected the one leg long jump performance.
- (4) one leg long jump was improved in the massage treated group.

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RESUMO

OBJETIVO: Determinar os efeitos do tratamento de massagem, complementado com 24 horas de compressão elástica sobre a dor muscular tardia após exercícios máximos elevação das panturrilhas durante três dias consecutivos.

MÉTODOS: Quatorze estudantes do sexo feminino (com idade entre 20–22 anos) que no passado tinham apenas realizado regularmente exercícios moderados foram submetidos a exercício máximo de elevação das panturrilhas (uma elevação a cada 3 segundos) até a exaustão. Sete participantes (grupo teste) receberam massagem “effleurage” nos músculos das panturrilhas imediatamente após o exercício, complementado com 24 horas de compressão elástica. As outras participantes (grupo controle) não receberam tratamento algum. Medimos creatina-quinase, circunferência da musculatura máxima da panturrilha, contração muscular isométrica voluntária máxima, dor percebida, ângulo máximo de flexão dorsal e salto em distância de uma perna antes e imediatamente após o exercício mais tratamento (grupo teste) ou após exercício (grupo controle) durante 3 dias de exercício e 7 dias de recuperação. Os pacientes portaram um contador de passos para contar passos a cada dia.

RESULTADOS: O número de repetições de elevação de panturrilha diminuiu significativamente em ambos os grupos nos dias 2 e 3. Os níveis de creatina quinase aumentaram significativamente no grupo teste entre o dia dois do período de exercício e o dia cinco do período de recuperação e mostraram-se tendencialmente mais elevados do que no grupo controle. A circunferência muscular máxima da panturrilha no grupo teste foi maior, a cada dia no período pós-tratamento versus pré-exercício; na fase de recuperação esta circunferência foi significativamente maior no grupo controle. Os níveis de dor percebida foram significativamente menores e o salto em distância significativamente melhor (por 5–10%) no grupo teste.

CONCLUSÃO: A massagem mais compressão elástica minimiza a mudança de circunferência máxima da musculatura da panturrilha, a dor percebida, e maximiza o salto em distância, após o exercício. A dor percebida correlaciona com desempenho.

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