

# Effects of Transcutaneous Electrical Nerve Stimulation(TENS), Self-Stretching and Functional Massage on the Muscle Fatigue by Maximum Muscular Strength

The present study purposed to examine the effects of transcutaneous electrical nerve stimulation, self-stretching and functional massage on the recovery of muscle contraction force for muscle fatigue caused by sustained isotonic contraction. The subjects of this study were 45 healthy students. They were divided into transcutaneous electrical nerve stimulation group(n=15), self-stretching group(n=15) and functional massage group(n=15), and using Primus RS. We observed the pattern of changes in maximal voluntary isometric contraction force(MVIC) after causing muscle fatigue in quadriceps femoris muscle through sustained isotonic contraction. Maximal voluntary isometric contraction force(MVIC) were greatly increased after transcutaneous electrical nerve stimulation, self-stretching and functional massage. In the comparison of recovery rate of muscle contraction force for muscle fatigue caused by sustained isotonic contraction among the treatment groups, it did not show any significant differences. However, it showed that each treatment may be effective in recovery of muscle fatigue caused by sustained isotonic contraction.

Key words: *Muscle Fatigue; MVIC; TENS; Functional Massage; Self Stretching*

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## INTRODUCTION

The muscle fatigue after exercise refers to the muscle condition in which the tension, generated from the course of muscle contraction doesn't maintain the expected level of strength or lead to the generation of expected power(1). The continuous and strong contraction of skeletal muscle during exercise or physical activities brings about such muscle fatigue as the decline of contractility, the decrease of muscle contraction velocity and the delayed muscle relaxation, causing the change of metabolite such as H<sup>+</sup>(hydrogen ion), inorganic phosphate, ATP and ADP as well as the removal of Ca<sup>2+</sup> from sarcoplasmic reticulum and this may cause the decline of motor competency to give rise to the impediment to the normal activities(2). Effectively eliminating such muscle fatigue, we can relieve, to a great extent, the muscle pain or muscular spasm due to exercise and help professional athletes effectively get rid of muscle fatigue following a prolonged match and regain

their muscular strength(3).

Even though human body has the function of homeostasis, we need to consider adopting a more active recovery for the speedy and effective recuperation, after exercise(4). It is being presented to adopt the method of massage(5), stretching(6) and electrical stimulation in order to efficiently reduce the muscle fatigue after exercise in short term and these methods are considered to help us get rid of fatigue by calming down the agitation in central nervous system.

A massage brings about the excitement of nerve and muscle to enhance bodily function, soothes the tension and convulsion with muscular system and has effects on increasing the blood and alimentation, eliminating lactic acid and by products(7).

Park(8) maintained that the massage invigorates the circulation of blood and lymph in the part of human skin or damaged muscular tissue and alleviates the pain by relieving muscle convulsion. He also reported that massage eliminates the bodily wastes

rapidly and facilitates the smooth supply of oxygen and nutriment that human body requires, through expediting the blood circulation and our body's metabolism and ,in this way, massage is of big help to the muscle fatigue recovery and the prevention of athletic injury, It is reported that there have been a lot of researches on the positive effects of massage, in addition to this research.

On the other hand, a method, invented for more functional effects, is prevailing out of various ways of massage and that method is referred to as functional massage. The aim of functional massage, prevailing in the field of orthopedic physiotherapy, is same as the general massage in that it brings about tissue relaxation and blood circulation promotion. However, different from the general massage without any movement of joint part, the functional massage augments some functional aspects through conducting the joint mobilization exercise and vitalizing the joint receptors(9).

Stretching is conducted for the purpose of reducing the tension or pain of muscle after exercise, preventing an injury and extending the range of motion(10). When the muscle can not maintain its normal flexibility, there should be a change in muscle length-tension and losing flexibility may lead to the reduction of the muscle strength(11). The recent research by Eguchi(12) reported that the static stretching have an effect on the muscle fatigue caused by continuous muscle contraction, through easing muscle tension.

Electric stimulation that applies man-made external electricity to biological tissue, is being widely used for the various purposes such as retraining of denervated muscle, extending range of motion, expediting voluntary control, recovery and strengthening of the weakened muscle, the alleviation of muscle spasm and convulsion, the correction of contracture, pain relief and tissue healing as well as muscle fatigue recovery through the promotion of blood flow and etc. And various types of electric stimulation are being presented as a means of strengthening muscular strength(13).

As seen above, many previous researches executed a lot of study and verification with regard to the muscle fatigue recovery by means of massage, stretching and electric stimulation. But there has not been enough research both on which one of those therapies is more effective, compared to one another and on the curative value of the functional massage.

Accordingly, this research aimed to investigate how effectively the transcutaneous electrical nerve stimulation(TENS), self-stretching and Functional

Massage help human body to recover from the muscle fatigue, caused by exercise and also intended to look into which one shows the best effects in the same time duration of treatment, if the 3 methods shows a discrepancy in terms of recovery level.

## METHODS

### Subjects

45 healthy male and female students, attending the department of physical therapy at N university in Cheonan City were chosen as the subject and this research was conducted. The subjects were randomly assigned to the TENS(transcutaneous electrical nerve stimulation)group, self-stretching group and functional massage group and the number of members of each group was 15 equally, non dominant legs of the research subjects were chosen for this research in order to compare the changes in maximum muscle strength, for the effects of exercise and treatment might become less as the subjects are all in their early 20s. The purpose and method of research were briefed to the subjects, prior to the commencement of experiment and all the subjects consented to the experiment voluntarily. Only those who have no nervous system disease, musculoskeletal disorders or cardiovascular disease and are not engaged in regular muscular exercise, were selected as the subjects.

### Experiment Tools

**Table 1.** Following appliances were used in this experiment

Name of electric apparatus	Product name	Manufacturer
Body composition analyzer	INBODY 720	Biospace
Functional apparatus for therapeutic exercise and estimation	Primus RS	BTE
Portable Low-Frequency therapeutic apparatus	Automote 101	3NS

### Experimental Method

In this research, the researcher applied the treatments of TENS, functional massage and self-stretching to the quadriceps femoris, of which muscle

fatigue was caused by isotonic exercise. And the researcher looked into the change of maximal voluntary contraction after these applications and intended to investigate which method of treatment worked most effectively for the recovery of muscle strength. Primus RS(BTE/USA) was adopted for isotonic exercise. Having fixed the tool at 70° of the bending angle of knee joint and linking the tool with the leg, ascertained to be non dominant, after having the subject seated on Primus RS and having the thoracic cage and femoral region of subject be fixed by Velcro fastener, the researcher had the subject conduct the extension exercise of knee joint. Upon having each treatment group undergo the respective treatment of TENS, functional massage and self-stretching for the fatigued quadriceps femoris, the research was executed by means of the following methods in order to investigate the change of muscle contraction.

#### **Measurement of maximum voluntary isometric contraction**

The researcher has measured maximum voluntary isometric contraction(MVIC) upon accomplishing the isometric contraction for 3 seconds, three times, and 2 minutes' relaxation was allowed per a contraction for 3 seconds to eliminate the influence of fatigue. The measurement was repeated 3 times and the average of measurement values was chosen as MVIC in case of no outlier. If we find an outlier, we adopt the average of the remaining 2 measurement values as MVIC, upon deleting the outlier.

#### **Causing muscle fatigue**

In order to arouse the subject's fatigue, the continuous isotonic exercise of quadriceps femoris was carried out, applying the resistance that comes under 50% of the subject's first MVIC. When the figure, displayed on the Computer Monitor, went down to the level below 75% of the original aim for 3 times and over, the isometric exercise was put to an end. Also, once the figure went down to the level below 50% of the original aim, the exercise was stopped.

#### **Measurement of MVIC before treatment**

All treatment groups underwent the measurement of MVIC in same way as the first measurement's, just after muscle fatigue had been aroused.

#### **Application of treatment with each experimental treatment group**

Measurement of MVIC before treatment was executed for all treatment group. Upon having measured the MVIC before treatment, the respective

method, assigned for each group, was applied.

#### **The application of TENS**

The equipment of Automote101(3NS/Korea) was used for TENS. This equipment, of which the pulse width is 50 $\mu$ s and the adjustable pulse rate ranges from 1Hz to 1000Hz has no hazardous effect on human body. The frequency of 1000Hz by which the subject might feel most comfortable, was applied in this research. While the treatment was applied, the researcher had the subjects take rest, lying on the physical therapy table. The muscle part to which the stimulation was applied, were the vastus medialis oblique portion, vastus medialis longitudinal portion, vastus lateralis and rectus femoris of quadriceps femoris.

#### **The application of functional massage**

The functional massage of 20 minutes was applied to the part of quadriceps femoris for massage treatment group. The subjects perched on a corner of physical therapy table, with their knees flexed and the experimenter made the subject's flexed knee extended. The experimenter flexed the subject's knee joint with one hand, while pressing down the subject's leg on the part of quadriceps femoris with his body weight. Treatment was applied to the part of vastus medialis, vastus lateralis and rectus femoris as the electric stimulation group and only one experimenter was allowed to conduct massage to make the experiment coherent.

#### **The application of self-stretching**

The stretching of quadriceps femoris was conducted, having the subject lie in a prone position. The subject was fixed in a belt fastened around the pelvis in order to prevent the pelvis from moving and flexed the knee joint to the maximum by holding his ankle and pulling it up towards his back thigh for himself. The subject was allowed to have a rest for 30 seconds, upon holding the posture of knee flexion for 30 seconds, thus treatment was totally applied for 20 minutes, upon the repetition of this motion 20 times.

#### **Data Analysis**

Statistical analysis was performed by SPSS ver 12.0. and normal distribution for all the data was verified by K-S test(Kolomogorov-Smirnov Test). And descriptive analysis was performed to work out the general features of the subjects.

In order to compare the differences between groups per period, Two way ANOVA was used and Paired t-test was used in order to make a comparison before and after the respective treatment. The significant level was set at .05.

## RESULTS

### General Features of The Research Subjects

Total 45 subjects who were divided into 3 treatment groups of equal 15 subjects, participated in this experiment without any dropout. The average age of TENS group was 20,90 years and the average height and weight was 170,04cm and 65,45kg respectively. The average age of self-stretching group was 20,70 years and the average height and weight was 172,24cm and 66,78kg respectively. And the average age of functional massage group was 21,70 years and the average height and weight was 168,93cm and

62,00kg respectively. There was no significant difference between the groups, having worked out the general features(Table 2).

### The Change of Maximum Muscular Strength

There was a significant difference between the time of measurements in the comparison table of MVIC between the treatment types per time of measurement but there was no significant difference between the treatment types and no significant difference was found in the interaction of treatment with the time of measurement(Table 3).

The comparison between the figures before the treatment and after the treatment was shown in Table 4, where a significant difference was found between the time of measurements. In case of TENS group, the MVIC after the treatment has shown a significant rise, compared to the MVIC before the treatment. The same was found in case of functional massage group as well as self-stretching group.

Table 2. General features of the subjects

	TENS(n=15)	SS(n=15)	FM(n=15)	p
	Mean±SD	Mean±SD	Mean±SD	
Age(yrs)	20,90±1,52	20,70±1,05	21,70±1,33	.520
Height(cm)	170,04±10,51	172,24±9,56	168,93±9,38	.380
Weight(kg)	65,45±12,28	66,78±12,04	62,00±8,67	.350

TENS : Transcutaneous electrical nerve stimulation

SS : Self stretching

FM : Functional massage

Table 3. Comparison of MVIC between the treatment types per time of measurement

	TENS	FM	SS	P	F value		
	Mean±SD	Mean±SD	Mean±SD		Treatment	Time of measurement	Interaction
Before the treatment (2nd MVIC)	359,33±102,14	435,40±109,85	406,20±106,31	.153	2,094	7,492*	.362
After the treatment (3rd MVIC)	447,73±114,32	484,07±109,17	453,30±95,88	.608			

\*p < .05

TENS : Transcutaneous electrical nerve stimulation

SS : Self stretching

FM : Functional massage

**Table 4.** Comparison of MVIC before and after the respective treatment

	Before the treatment(2nd MVIC)	After the treatment(3rd MVIC)	p
	Mean±SD	Mean±SD	
TENS(n=15)	359.33±102.14	447.73±114.32	.000*
SS(n=15)	406.20±106.31	453.30±95.88	.026*
FM(n=15)	435.40±109.85	484.07±109.17	.009*

\*p &lt; .05

TENS: Transcutaneous electrical nerve stimulation

SS: Self stretching

FM: Functional massage

## DISCUSSION

In this research, the researcher has aroused the muscle fatigue using the program for isotonic exercise of Primus RS equipment and looked into the recovery aspect of muscle fatigue, based upon the measurement of MVIC after treatment. Two ways are to be used to determine whether the fatigue has occurred. One is the way in which the subject is to stop exercise for himself upon feeling the fatigue and the other one is the way in which the researcher is to measure the endurance of the subject from the perspective of researcher(14, 15). In this research, the researcher has measured the fatigue, having instructed the subject to maintain the extension power as long as possible at the level of 50 % of knee joint's maximum contraction(16). When the figure on the Computer Monitor, went down to the level below 75% of the original aim for more than 3 times or below 50 % once, the researcher regarded it as the signs of fatigue induction.

In this research, the MVIC after the treatment of TENS turned out to be significantly improved, compared to the MVIC before the treatment. It seems to mean that the treatment of TENS had an effect on the recovery of muscle fatigue. Chang(17) had confirmed the TENS had a positive effect on the recovery of muscle fatigue, in a research comparing the blood lactate concentration after anaerobic exercise with the Changes in Median Frequency. Park(18) has observed that TENS group had shown a significant drop of lactic acid, compared to the passive recovery group, making both the TENS and passive recovery carried out during the recovery period after anaerobic exercise. Based on this observation, he reported the TENS has brought about the raise of blood flow that is normally to be caused by the light exercise

and this has led to the elimination of lactic acid.

The researcher considers that the treatment of TENS has an effect on the recovery of muscle fatigue because it can regulate and relieve the pain, stimulating sensory nerve electrically and it can also alleviate the muscle pain by fatigue owing to its effect of slight fever, massage effect and its effect on relieving muscle contracture.

Massage has been used in the fields of medical treatment and sports for a long time since the dawn of civilization(19) and it plays an important role in controlling and maintaining the body condition after exercise. Also Moraska(7) has reported the sensory receptor was stimulated to alleviate the pain when we give continuously a strong stimulation to our skin. Harris(20) and Furlan(21) reported a massage removes the waste product and harmful substance by expediting the flow of blood and limp in muscle and makes the fresh blood, thus promoting the metabolism of oxygen and nutrient to improve the contractile force and sustaining power. Based on this, they maintained that the massage is a method which can increase the motor ability of muscle and make the muscle fatigue eliminated.

The MVIC after treatment with the functional massage group in this research also showed a significant rise, when it was compared to the MVIC before treatment.

There is a thread of connections between this result and the research of Tiidus & Shoemaker(22) who reported that a massage improves the muscle function owing to the increase of blood flow into muscle and rapid supply of oxygen and that, specially, the alleviation of muscle tension in the recovery stage is due to the rapid removal of metabolic by products through the enhancement of the speed of venous return.

The functional massage, carried out in this research,

is considered to have a positive effect on the fatigue recovery in that the maximum contraction of this research's subjects has shown a significant increase after the treatment of functional massage as the tenor of the research Tidus & Shoemaker conducted.

The stretching has an effect not only on the improvement of body flexibility and the prevention of injury during sports activities but also on the enhancement of psychological condition like diversion or refreshment(23). Also the stretching as warming-up and cool down has an effect on the prevention of muscle spasm and the prevention of overuse syndrome from the overuse of muscle(24).

Bandy & Irion(25) reported that all the static stretching, applied to hamstring muscles were effective to ROM despite some degree of difference in the wake of the timing and frequencies.

Also the self-stretching group in this research showed a significant rise after the treatment, in terms of MVIC, compared to the MVIC before treatment. That is, this treatment of self-stretching expedites the transmission of information to brain through stimulating the motor nerve, exerts influence on skeletal muscle and prevents the accumulation of fatigue through a continuous stimulation on soft tissue, so this treatment can be considered to be as effective as the TENS or functional massage in getting rid of fatigue.

As explained in the previous part, a significant rise was found with all the 3 methods of treatment when we compare them before and after the treatment. From this fact, we might describe that the 3 methods are all effective in making people recover from the fatigue. But we can not determine which treatment is more effective over same time duration, because the differences among the 3 methods were not found to be statistically significant.

Consequently, it is considered to be more effective that we should rather apply the treatment which is apposite to the respective situation, than cling to a method, in order to get rid of fatigue.

This research has some limits in that not many subjects have participated, the frequency and time of exercise were not sufficient and the time requirement for the physiological change after the respective treatment was not considered thoroughly. Hence, the researcher considers that the experiment in the future is required to be designed so that it might secure the experimental measures more precisely. Also, it is suggested a research should be executed, considering various significant factors, in order to prove that the treatments of TENS, functional massage and self-stretching have an effect on

the recovery of maximum muscle strength.

## CONCLUSION

This research was conducted to investigate the difference among 3 treatment methods in terms of the ability to regain the maximum muscle strength, after the researcher had aroused the muscle fatigue by isotonic exercise. 45 healthy adults in their 20s were selected as the subjects and the maximum muscle strength was measured before arousing muscle fatigue, after arousing muscle fatigue by isotonic exercise and after the application of treatment for 20 minutes, respectively. Thus, the results were concluded as following.

1. The MVIC after treatment was found to be significantly higher than the MVIC before the treatment with all treatment methods after the occurrence of muscle fatigue( $p < .05$ ).
2. No significant difference was found among the respective treatments in terms of the recovery results( $p > .05$ ).

Putting above results together, the researcher made a conclusion that all the treatments of TENS, self-stretching and functional massage have positive effects on the recovery of fatigue, though no difference among 3 methods were found in terms of the extent of recovery.

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