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극초단파 심부투열을 적용한 장딴지근육의 스트레칭이 관절위치감각과 동적균형능력에 미치는 영향

Effects of Static Stretching of the Calf Muscle after Microwave Diathermy on Joint Position Sensation and Dynamic Balance Ability

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This study aimed to investigate the effects of static stretching of the calf muscle on ankle position sense and dynamic balance ability following microwave diathermy. Participants were 28 healthy young students in their 20 s, who were divided into a microwave diathermy stretching group (MSG) and a stretching group (SG). A microwave was emitted to the calf muscle area to participants in the MSG. Static stretching was performed by standing on a quadriceps board for 15 minutes. The angle of the wedge was set to a range of 15–25°, representing a level of pain and discomfort allowed by the subjects. Before and after intervention, ankle dorsi-plantar flexion joint position sense (JPS) and dynamic balance ability were measured. The group source affected JPS error of dorsi-plantar flexion ($p < 0.05$) and JPS error increased with the SG more than the MSG. There was an increase in the dynamic balance score in both groups after the intervention compared to before the intervention. Microwave therapy prior to stretching can preserve JPS and balance ability, thereby reducing the risk of injuries from activities after stretching.

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NOMENCLATURE

MSG = Microwave diathermy stretching group
SG = Stretching group
JPS = Joint position sense

1. Introduction

Stretching refers to movement intended to prevent injuries and improve quality of life by increasing muscle flexibility and joint range of motion by increasing the viscoelastic response of muscles and tendons.[1] However, stretching has also been reported to increase the potential for tissue injury from tissue and neurological changes.[2] Nevertheless, stretching is still widely used as a warm-up exercise prior to various physical activities;[3] other studies have reported that stretching allows the execution of muscle and tendon movements to be more refined[4] and is effective for preventing injuries.[5,6]

Receptors that provide important information related to joint position sense (JPS), including temporary changes in muscle-tendon length from stretching,[7] may be susceptible to histological changes due to stretching. Negative changes in JPS can increase the risk of falls and injuries during excessive movement of the joint. Even with a lower risk of falling, affected individuals may

make movements that are inaccurate and often unnecessary; the eventual accumulation of subtle injuries can affect balance.[8-11] Therefore, movements must be efficient, and any decline in JPS should be minimized to maintain balance. Therefore, it is necessary to develop stretching methods that minimize tissue and neurological micro-injuries or changes from stretching that impact JPS, while increasing the length of muscles and tendons to the extent needed. In particular, pre-stretching heat therapy applied to areas that require stretching increases the elasticity of muscles and tendons, softens tissues, and induces reflex relaxation in the muscles by promoting auto-inhibition,[12,13] which can reduce the risk of micro-injury during stretching and increase the joint range of motion to a greater degree than by stretching alone.[14,15]

Diathermy is one of the methods often used in clinical settings, as it is effective in selectively increasing muscle temperature.[11] Moreover, the high frequency used in microwave diathermy does not stimulate sensory or motor nerves, so it allows heat to be applied to a specific area of the body without causing discomfort or muscle contraction. However, to date, studies on the effects of stretching on ankle position sense and balance ability after microwave diathermy are lacking. Accordingly, the present study aimed to investigate the effects of static stretching of the calf muscle on ankle position sense and dynamic balance ability following microwave diathermy.

2. Methods

2.1 Subjects

The sample size was calculated a priori using the software G Power, version 3.1.5. We considered a statistical power of 90% and a significance level (i.e., α-value) of 5%, and we referred to the results of Yuk.[16] The minimum number of subjects to be considered was 24 people (12 per group), while the number of subjects in order to account for potential dropouts was 28 (14 per group). The Institutional Review Board of U1 University granted ethical approval for the study. All subjects were fully informed of the objectives and methods of the study beforehand and gave informed consent to participate. Only subjects with no musculoskeletal or neurological disorders affecting the upper or lower extremities, lesions, or history of surgery of the spine or upper or lower extremities were considered. A total of 28 healthy subjects were randomly selected from a group of people that responded to flyers that were strategically placed throughout the university campus and also to word-of-mouth. The subjects were randomly divided into a microwave diathermy stretching group (MSG) and a stretching group (SG).

Fig. 1 Electro-Goniometer attached

2.2. Measurement Method

The electro-goniometer used in this study operated with an MP150 (BIOPAC System Inc., Santa Barbara, CA, USA) data acquisition system. This apparatus is a basic device that digitizes the signal of the joint angle, and the extracted data were processed using a digital signal analysis program (AcqKnowledge 4.1, Santa Barbara, CA, USA) that ran on a personal computer.

The JPS assessment was performed while the subjects were positioned in a sitting posture, and their maximum dorsi-flexion and plantar flexion range of motion of the dominant side ankle were determined. The electro-goniometer was attached to sensors at the front and back of the lateral malleolus of the ankle joints (Fig. 1). During the JPS measurement, the subjects wore shorts and used eye patches and ear plugs in order to minimize sensory compensation. The subjects were only allowed to move the ankle following given instructions, while the rest of the body remained at rest. Before the measurement process started, the subjects were given an explanation of the entire process. Then, a demonstration of the measurement process was shown, followed by a smooth start of the process itself. The subjects were asked to maintain the position at a random target degree within the range of motion of their own ankle dorsi-plantar flexion, and they were asked to remain in that position for 10 seconds. After this, they were asked to return to the initial position and progressively move towards the target degree. The JPSs of dorsi-plantar flexion of ankle joint retests were also processed, following the test-retest method. The difference in degrees between the preset target angle

Fig. 2 Balancing ability measurement using biodex balance system

Table 1 General characteristics of the subjects

	Mean ± SD		P-Value
	MSG	SG	
Sex (M/F)	8 / 6	8 / 6	
Age (yr)	25.5 6.01	23.423.357	0.48
Height (cm)	171.33 7.69	173.40 8.73	0.70
Weight (kg)	72. 11.70	74.78 19.12	0.35

MSG: Microwave diathermy stretching group, SG: Stretching group

Table 2 Range of motion of full dorsi-flexion

	Mean ± SD (unit: degree)		Z	P
	MSG	SG		
Pre.	22.379 6.754	22.824 3.895	-1.011	0.329
Post.	24.676 7.321	25.494 4.783	-0.643	0.541
Diff.	-2.297 3.401	-2.669 4.439	-0.414	0.701
Z	-2.291	2.040		
P	0.022*	0.041*		

*p < 0.05, **p < 0.01
MSG: Microwave diathermy stretching group, SG: Stretching group,
Pre.: Pre-Intervention, Post.: Post-Intervention, Diff.: Difference (Pre.-Post.)

and the angle reproduced is defined as the JPS error, meaning that the smaller the JPS error, the better the JPS achieved. The intraclass correlation coefficient was greater than 0.80 for the measurement of JPS errors using an electrogoniometer.[17]

To determine balance ability, the Biodex Balance System (Biodex Medical Systems Inc., Shirley, NY, USA) was used. In this system, the stability of the footing ranged from levels 1 to 12 in ascending order of instability. We used level 8, repeated the measurements 3 times, and calculated the average values. A higher score indicated worse balance (Fig. 2).

2.3. Intervention Method

Subjects in both the MSG and SG laid in the prone position for 15 min on a therapeutic bed prior to stretching, and the microwave diathermy probe was placed on top of the calf. However, microwave was emitted to apply heat to the calf muscle area only to participants in the MSG.

The heat applied was set to a moderate level that could be tolerated by the subjects based on their subjective sense of heat.

Static stretching was performed with reference to the study of Yuk.[16] Static stretching was performed by standing on a quadriceps board for 15 minutes. For safety reasons, stretching was performed at a position close enough to lean against a wall, but the subjects were instructed not to lean against the wall, if possible, while the angle of the wedge was set to a level within the range of 15-25°, representing a level of pain and discomfort allowed by the subjects, to prevent excessive tissue injury.

2.4. Statistical Analysis

SPSS version 12.0 was used for statistical analysis. A significance level of 5% ($p < 0.05$) was set.

The Mann-Whitney U-test was performed to compare the range of motion of full dorsi-flexion, dynamic balance ability of the MSG with those of the SG. The Wilcoxon signed-rank test was used to investigate changes in the range of motion of full dorsi-flexion, dynamic balance ability of each group pre- and post-intervention. The analysis of covariance (ANCOVA) was performed to compare the JPS error of dorsi-plantar flexion of the MSG with those of the SG. The covariance was pre-intervention value.

3. Results

3.1. General Characteristics of the Subjects

The subjets' general characteristics are presented in Table 1.

3.2. Range of Motion of Full Dorsi-Flexion

There was a significant increase in the range of motion of full dorsi-flexion in the two groups after the intervention compared to

Table 3 JPS error of dorsi-plantar flexion

	Mean ± SD (unit: degree)		[1)]Pre F(p)	[2)]Group F(p)
	MSG	SG		
Pre.	3.189 ± 1.211	2.445 ± 0.812	1.392 (0.256)	13.348** (0.002)
Post.	2.828 ± 1.264	4.744 ± 2.716		
Diff.	0.361 ± 0.743	-2.298 ± 3.037		

*p < 0.05, **p < 0.01

MSG: Microwave diathermy stretching group, SG: Stretching group, Pre.: Pre-Intervention, Post.: Post-Intervention, Diff.: Difference (Pre.-Post.)

[1)]Pre-Intervention source, [2)]Group source

Table 4 Dynamic balance score

	Mean ± SD (unit: score)		Z	P
	MSG	SG		
Pre.	3.264 ± 1.905	3.767 ± 1.977	-0.988	0.329
Post.	3.829 ± 1.952	4.867 ± 1.809	-1.517	0.137
Diff.	-0.565 ± 1.264	-1.1 ± 1.384	-1.080	0.280
Z	-1.538	-2.480		
P	0.124	0.013*		

*p < 0.05, **p < 0.01

MSG: Microwave diathermy stretching group, SG: Stretching group, Pre.: Pre-Intervention, Post.: Post-Intervention, Diff.: Difference note, A higher score indicates worse balance

that before the intervention ($p < 0.05$). There was no significant difference in the range of motion of full dorsi-flexion between groups ($p > 0.05$) (Table 2).

3.3. JPS Error of Dorsi-Plantar Flexion

The pre-intervention source did not affect the JPS error of dorsi-plantar flexion of post-intervention ($p > 0.05$).

The group source affected JPS error of dorsi-plantar flexion of post-intervention ($p < 0.05$) (Table 3).

3.4. Dynamic Balance Score

There was an increase in the dynamic balance score in the two groups after the intervention compared to that before the intervention, but the difference was only significant in the SG ($p < 0.05$).

Dynamic balance score increased significantly more in the SG than in the MSG following the intervention, but it was not statistically significant ($p > 0.05$) (Table 4).

4. Discussion

The objective of the present study was to investigate the effects of applying microwave diathermy during static stretching of calf muscles on JPS and dynamic balance ability according to the application of microwave diathermy.

In the present study, the application level of the platform test using the Biodex Balance System was set to 8, as it represented the highest degree of difficulty that allowed measurements to be completely safe with the subjects' arms gathered and without falling in previous studies. Babault et al.[18] indicated that applying stretching for 15 min can induce structural changes in muscles while excluding any neurological factors, and as such, the present study applied static stretching for 15 min.

Avela et al.[8] and Lima et al.[9] assumed that stretching can cause changes in mechanical receptors of muscles and tendons, as well as skin and joints. To explain this, Park et al.[11] described a significant increase in muscle receptors among the factors that can change the JPS. Moreover, a study by Docherty et al.[10] reported that JPS may change from sustained static stretching. In the present study, there was a significant difference between the two groups with respect to dorsi-plantar flexion JPS error ($p < 0.05$), and in particular, a increase in JPS error was found in the SG. It is believed that this increase was due to changes in JPS from injury involving increased mechanical receptors due to stretching.[8-11] On the other hand, the MSG did not show increase in JPS error. It is believed that this was due to the effects of heating causing increased muscle and tendon elasticity, softening of tissues, and promoting auto-inhibition, which facilitated reflex relaxation of the muscles that decreased the risk of micro-injury during stretching.[12,13]

Park et al.[11] reported that heat therapy showed significant improvement in JPS in knee extension exercises, and although the applied area was different than that of the present study, the fact that heat therapy during stretching can contribute to preserving JPS was similar to the findings in the present study.

The ankle joint makes a major contribution in maintaining balance. Changes in the tension and proprioception in the tissues around the ankle can cause balance disorders.[18-20] In particular, ankle JPS has a clear association with balance. Also, in the present study, JPS decreased during stretching and balance ability decreased accordingly as well. On the other hand, when stretching was applied after heat therapy with microwave, JPS was not decreased and balance ability was preserved.

This study enrolled only healthy subjects in their 20 s from a certain geographic area. Therefore, future studies should include a wider variety of subjects in terms of region, age, and disease.

5. Conclusions

The objective of the present study was to investigate the effects

of applying microwave diathermy during static stretching by examining the effects of static stretching of calf muscles on JPS and dynamic balance ability according to the application of microwave diathermy. The findings in the present study suggest that applying microwave therapy prior to stretching can preserve JPS and balance ability, reducing the risk of injuries from activities after stretching.

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