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Original Article

# Analysis of muscular elasticity according to infrared and ultrasound therapy by sonoelastography

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**Abstract.** [Purpose] The purpose of this study was to evaluate the effect of physical therapy on elasticity of muscles quantitatively by using sonoelastography equipment in infrared and ultrasound treatment commonly used in hospital physical therapy rooms. [Participants and Methods] We also investigated correlations among various variables such as height, weight, BMI (Body Mass Index), body fat mass, muscle mass, and basal metabolic rate. From July 30th 2017 to August 30th, 2017, muscular elasticity ratio was measured in 10 males in their 20s by comparing muscles of the upper and lower extremities before and after ultrasound and infrared therapy. [Results] Results showed that muscular elasticity was increased 1.55 ± 0.41 folds in forearm muscle region of the upper extremity in ultrasound therapy, which was significantly higher than the increase (1.23 ± 0.10 folds) in infrared therapy. Thus, ultrasound therapy and infrared therapy both would have good result in cardiac treatment for 1-cm away region. In ultrasound therapy and infrared therapy, elasticity increase rates in forearm region of the upper extremity were higher when body fat mass and BMI were increased. [Conclusion] Results of this study could be used as basic data for ultrasound and infrared therapy studies in the future.

**Key words:** Infrared therapy, Ultrasound therapy, Muscle

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## INTRODUCTION

As life is getting convenient due to improvement in economic status, advances in medical fields, and development of communication means in the modern society, musculoskeletal disorders are increasing due to poor personal habits, including heavy work, lack of exercise, and stress. People are experiencing pain in any form in their daily lives. Pain is an uncomfortable feeling confined to a part of the body with emotional and physical effects. People suffer from shoulder pain next to back pain. Pain ranges from acute pain by trauma to posture-induced structural chronic pain. Stress pain is caused by stressful work and overwork. Due to those various types of pain, therapeutic approaches are also very complicated and different[1)]. The development of modern science and benefits of civilization have both advantages by extending life span and providing comfortable living and disadvantages by causing diseases due to reduction in physical activity, instant food, and environmental pollution[2)]. As level of living improves with development of medical technology and healthcare field as well as continuous economic growth, both life expectancy of elderly people and chronic diseases are increasing[3)]. It is expected that the elderly population will increase to more than 14% by 2018 and reach super-aging society in 2026. Mortality rates have declined in spite of the fact that the number of deaths has increased in those aged over 80 years[4)]. In Korea, the proportion of the elderly aged 65 years or over is reported to be increased from 10.3% in 2008 to 12.7% in 2014. As back pain is the most common cause of absenteeism or early leave, it becomes an important issue in socioeconomic aspect as well as personal health

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aspect[5, 6]. For ultrasonic waves, the inverse wave is known to be more useful for acute low back pain patients than continuous waves because inverse wave has no thermal effect[7]. As interest in health increases, many medical devices are being used for treatment. Physical therapy can treat disease and improve life using physical phenomena often encountered in everyday life. Among types of physical therapy, infrared therapy using an electromagnetic device has effect on inflammation, neuralgia, and pain relief in patients suffering from blood circulation disorder while ultrasound therapy can relieve pain and muscular contractions in patients with joint stiffness, adhesions, pain, and muscular contractions as well as inflammation, thus promote healing. Far-infrared ray is an electromagnetic wave having a wavelength of 4 μm or more in long wavelength band of sunlight. Far-infrared rays contain the most heat energy among sun rays. They are known to help growth and development of life. Far-infrared rays are actively used for promoting the growth of plants and animals. They are also used for medical purposes[8]. Sonoelastography has become a useful method to detect tissue hardness in addition to conventional ultrasound imaging. It can measure and quantify the degree of deformation by applying mechanical force to the soft tissue to be treated. Despite these methods, currently published studies have only shown that infrared therapy and ultrasound therapy are most useful for treating patients. There is a lack of studies to quantitatively determine changes in muscle elasticity by these treatments. Therefore, the purpose of this study was to evaluate the effect of physical therapy on elasticity of muscles quantitatively by using sonoelastography equipment in infrared and ultrasound treatment commonly used in hospital physical therapy rooms.

## PARTICIPANTS AND METHODS

Participants were recruited at 500-bed hospital in Jeju from August 1st, 2017 to August 31st, 2017. Ten men without previous medical history in forearm in the upper extremity or and lower calf in the lower extremity were selected as participants. Average age of these participants was 22.15 ± 7.75 years. The general characteristics of the participants are shown in Table 1. All participants signed a written informed consent form approved by the Institutional Review Board at Cheju Halla University. Ultrasound Therapy Machine (Gymna US 204, Belgium) was used. Participants were treated at high frequency of 1 MHz with 1W/cm$^2$ r intensity for 7 minutes and 30 seconds by one radiological technologist. After treating region from anterior compartment of forearm of the upper extremity to brachioradialis muscle and lateral gastrocnemius muscle in posterior compartment of leg of the lower extremity with ultrasound for 7 and a half minutes, ultrasonically treated and untreated areas were measured four times by setting ROI (Region of Interest) at 1-cm to compare muscular elasticity. IR-880 was used as infrared equipment and infrared rays were taken at a distance of 30 cm. After treating region from anterior compartment of forearm of the upper extremity to brachioradialis muscle and lateral gastrocnemius muscle in posterior compartment of leg of the lower extremity with ultrasound for 10 minutes, treated and untreated areas were measured four times by setting ROI at 1-cm to compare muscular elasticity. To perform sonoelastography, Philips EPEX 5 was used. 2D and Elasto images were displayed on the screen side by side after ultrasound and infrared treatment. ROI was set at 1-cm away from the treated and untreated region. Gel was applied and the probe was compressed to measure the strain ratio when the transducer bar was green. Body measurements were taken after 8 hours of fasting with gown on. Height, weight, body mass index, waist circumference, and body composition were also measured. To examine body composition, fat mass, muscle mass, and basic metabolism were measured. Participants' gender, age, and height were entered together. Participants were barefooted on the measuring instrument and measured for about 1 minute in an upright posture. Measured height, body mass, body mass index, muscle mass, body fat mass, and basal metabolic rate were recorded. Automatic measuring machine was used to measure height and body weight. Body fat percentage and muscle mass were measured using Inbody X-scan (Jawon Co., Korea), a body mass spectrometer, with minimum clothing (no shoes, socks, or metal objects). For ultrasound measurement, Philips EPIQ 5G was used. Elasticity values of the forearm of the upper limb and the calf of the lower limb before and after the infrared and ultrasound treatment were compared. For infrared treatment measurement, circular ROI 1-cm away from anterior compartment of forearm to brachioradialis muscle of the upper extremity before and after infrared treatment was measured four times (Fig. 1). For infrared treatment measurement, circular ROI 1-cm away from lateral gastrocnemius muscle of posterior compartment of leg of the lower extremity before and after infrared treatment was measured four times (Fig. 2). In terms of comparing ultrasound treatment, circular ROI 1-cm away from anterior compartment of forearm to brachioradialis muscle of the upper extremity before and after treatment was measured four times (Fig. 3). In measuring ultrasound treatment, circular ROI 1-cm away from lateral gastrocnemius muscle of posterior compartment of leg of the lower extremity before and after infrared treatment was measured four times (Fig. 4). Statistical analysis was performed using SPSS ver. 18.0 software

**Table 1.** General characteristics of study participants (n=10)

| | |
|---|---|
| Height (cm) | 173.63 ± 6.07 |
| Weight (kg) | 75.12 ± 10.85 |
| BMI (kg/m$^2$) | 24.84 ± 2.49 |
| Fat mass (kg) | 19.28 ± 5.11 |
| Muscle mass (kg/m$^2$) | 53.48 ± 5.19 |
| Basal metabolism (kcal) | 1576.5 ± 123.2 |

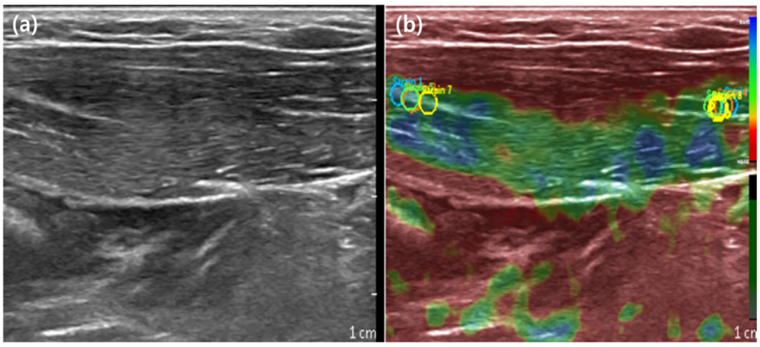


**Fig. 1.** Ultrasound image (A) and Elasto image (B) of forearm after infrared therapy. ROI 1-cm away from anterior compartment of forearm to brachioradialis muscle of the upper extremity.

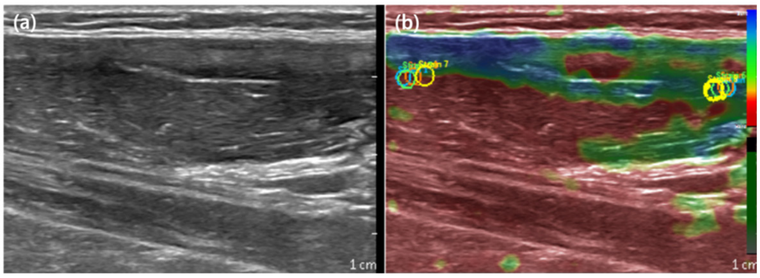


**Fig. 2.** Ultrasound image (A) and Elasto image (B) of calf after infrared therapy. ROI 1-cm away from lateral gastrocnemius muscle of posterior compartment of leg of the lower extremity.

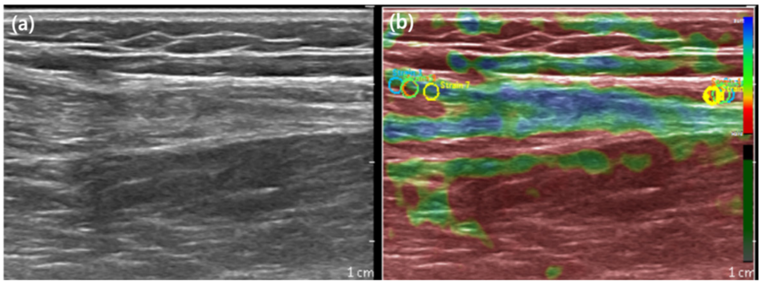


**Fig. 3.** Ultrasound image (A) and Elasto image (B) of foream after ultrasound therapy. ROI 1-cm away from anterior compartment of forearm to brachioradialis muscle of the upper extremity.

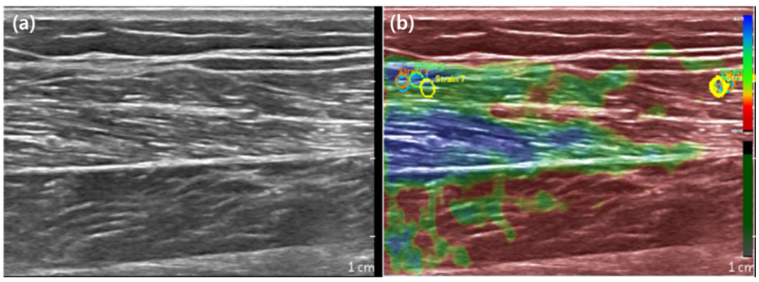


**Fig. 4.** Ultrasound image (A) and Elasto image (B) of calf after ultrasound therapy. ROI 1-cm away from lateral gastrocnemius muscle of posterior compartment of leg of the lower extremity.

(USA, Chicago). Significance level was set at $p<0.05$. Statistical analysis methods are as follows. First, we measured the elasticity of the muscle in the forearm region and the calf region in ultrasound and infrared treatment using independent t-test. The increase in elasticity of forearm and calf area and Pearson correlation between factors were then analyzed.

## RESULTS

Table 2 shows the rate of increase in muscle elasticity in the forearm and calf areas by ultrasound and infrared therapy. Elasticity of forearm area was increased 1.55 ± 0.41 folds in ultrasound therapy and 1.23 ± 0.10 folds in infrared therapy. Consequently, ultrasound therapy is more elastic than infrared treatment ($p<0.05$). However, there was no significant ($p>0.05$) difference in the rate of increase in elasticity between ultrasound treatment and infrared treatment for the calf area. Table 3 shows correlations between the increase rate of elasticity of the forearm area and the calf area and each factor. There was a negative correlation ($r= -0.52$) between infrared treatment in the forearm and the calf ($p<0.05$).

## DISCUSSION

Currently, many people experience a lot of physical illnesses. The number of people on physical therapy is increasing. For pain, heat treatment is the primary treatment except for inflammation pain. Heat therapy can improve circulation of the body and relax muscles to reduce pain. In terms of ultrasound intensity, tissue temperature rise due to absorption depends on the frequency. At a frequency of 3.0 MH, the energy is absorbed mostly at 1–2 cm from the skin. At low frequencies of 1.0 MHz, there is less attenuation in the superficial tissue while more energy is absorbed in the deep tissue. Ultrasound experiments on amphibians have shown that tissue temperature is elevated and the length of amphibian tendon is also increased.

**Table 2.** The rate of increase in muscle elasticity in the forearm and calf areas by ultrasound and infrared therapy

| Site | Therapy | Average ± SD |
|---|---|---|
| Forearm | Ultrasound | 1.55 ± 0.41 |
| | Infrared therapy | 1.23 ± 0.10 |
| Calf | Ultrasound | 1.59 ± 0.80 |
| | Infrared therapy | 1.60 ± 0.37 |
| **Therapy** | **Site** | **Average ± SD** |
| Ultrasound | Ultrasound | 1.55 ± 0.41 |
| | Infrared therapy | 1.59 ± 0.80 |
| Infrared therapy | Ultrasound | 1.23 ± 0.10 |
| | Infrared therapy | 1.60 ± 0.37 |

**Table 3.** The correlations between the increase rate of elasticity of the forearm area and the calf area and each factor

| | | Forearm Ultrasound | Forearm Infrared therapy | Calf Ultrasound | Calf Infrared therapy |
|---|---|---|---|---|---|
| Forearm Ultrasound | Pearson correlation coefficient | 1.00 | −0.25 | −0.14 | 0.21 |
| Forearm Infrared therapy | Pearson correlation coefficient | −0.25 | 1.00 | −0.26 | −0.58* |
| Calf Ultrasound | Pearson correlation coefficient | −0.14 | −0.26 | 1.00 | −0.01 |
| Calf Infrared therapy | Pearson correlation coefficient | 0.21 | −0.58* | −0.01 | 1.00 |
| Height | Pearson correlation coefficient | 0.18 | −0.05 | 0.10 | 0.38* |
| Weight | Pearson correlation coefficient | 0.36 | 0.16 | −0.03 | 0.31 |
| BMI | Pearson correlation coefficient | 0.37* | 0.30 | −0.09 | 0.14 |
| Fat mass | Pearson correlation coefficient | 0.46* | 0.56* | −0.21 | 0.10 |
| Muscle mass | Pearson correlation coefficient | 0.07 | 0.12 | 0.03 | 0.29 |
| Basic metabolism | Pearson correlation coefficient | 0.25 | 0.09 | 0.06 | 0.38* |

*$p<0.05$.

Furthermore, when the temperature is raised, it stretches the length of the tendon[9]. In mammals, it has been reported that tissue temperature is increased by applying water treatment and stretching together[10]. Ultrasound intensity at 2.0W/cm$^2$ or more and continuous wave treatment for 10–20 minutes at 1.0 MHz frequency can increase musculoskeletal temperature and blood flow[11]. Results of blood flow measurement for treated region in extremities vary among many studies. This is because methods used to measure blood flow changes such as intensity, frequency, and exposure time of ultrasound application are not the same for all studies. Thus, it is difficult to conclude that ultrasound therapy is clinically useful. Ultrasound has been used for studying biological effects of tissue as well as diagnosis in medicine and physical therapy. It has effects on the body, including pain reduction, subacute and chronic inflammation reduction, muscle axis, and thermal effect on the collagen tissue of joints. Far-infrared energy has the characteristic of absorbing resonance by raising the temperature in the living body. It also has a characteristic that can be activated according to energy level of the human body. In addition, it has hyperthermia effect due to absorption of far-infrared rays into the skin tissue. These warming effects are known to increase the temperature in deep parts of the body, thus promoting muscle relaxation and blood circulation and activating metabolism. It can be used to treat chronic diseases such as fatigue and stress. Far infrared rays irradiated to human body by resonance of far-infrared rays are absorbed into the skin, thereby raising the temperature of skin tissue and stimulating heat and nociceptive receptors to feel warmth and relieve pain. It has also been reported that irradiation of musculoskeletal patients with infrared rays can increase circulating blood flow in muscles and improve muscle stiffness and pain. There are many causes of shoulder stiffness and back pain, ranging from simple muscle fatigue to central nervous system, skeletal torsion, and intestinal disease. Infrared is a heat ray as well as an electromagnetic wave. It can penetrate into deep part of skin tissue, thereby dilating blood vessel and improving circulation. Infrared therapy can improve blood circulation disorder as its penetration and thermal effect can warm the body. It also affects shoulder joint deeply by good circulation[12]. In the case of plantar flexor muscle stiffness due to cerebral palsy, the antagonist muscle has been treated with functional electrical stimulation therapy and far infrared therapy. As a result, modified Ashworth scale of progressive decrease in stiffness was decreased to 20 after 10 treatments. Such results persisted at 24 hours after treatment. Such result is considered to be due to relaxation and sedative effects of far-infrared rays and increase of muscle efficiency for rapid contraction and relaxation of fibers. Such relaxation of the antagonistic muscles can free the action of main muscles[13]. In the present study, we analyzed muscular elasticity in region from anterior compartment of forearm of the upper extremity to brachioradialis muscle forearm and region 1-cm away from lateral gastrocnemius muscle calf of posterior compartment of leg in the lower extremity by using sonoelastography according to infrared and ultrasound therapy. We also investigated correlations among various variables such as height, weight, BMI, body fat mass, muscle mass, and basal metabolic rate. In terms of increase rate in muscular elasticity in ultrasound and infrared therapy, elasticity in forearm muscle region of upper extremity was increased $1.55 \pm 0.41$ folds in ultrasound therapy and $1.23 \pm 0.10$ folds in infrared therapy. Consequently, elasticity was increased more ($p<0.05$) in treatment with ultrasound. However, there was no significant ($p>0.05$) difference in the rate of increase in elasticity between ultrasound treatment and infrared treatment for the calf area. Thus, both ultrasound therapy and infrared therapy would have good results in cardiac treatment for 1-cm away region. In terms of the rate of increase in muscle elasticity in the forearm and calf areas by therapy, elasticity was increased $1.23 \pm 0.10$ folds in the forearm area and $1.60 \pm 0.37$ folds in the calf area. Consequently, elasticity in the calf region was increased more ($p<0.05$) with infrared treatment that in the forearm area. However, there was no significant ($p>0.05$) difference in the rate of increase in elasticity between forearm and calf area with ultrasound treatment.

Table 2 shows correlations between the increase rate of elasticity of the forearm and the calf area and each factor. There was a negative correlation ($r= -0.52$) between the infrared treatment in the forearm and the calf ($p<0.05$). In analysis of correlation between elasticity increase rate of the forearm region and each factor in ultrasound therapy, there were positive correlations with body weight ($r=0.36$), BMI ($r=0.37$), and body fat ($r=0.46$). With increasing body weight, fat mass, and BMI, elasticity was also increased ($p<0.05$). In analysis of correlation between elasticity increase rate of the forearm region and each factor in infrared therapy, there were positive correlations with body BMI ($r=0.30$) and body fat ($r=0.55$). Consequently, elasticity was increased ($p<0.05$) with increasing body fat mass and BMI. There was no significant ($p>0.05$) correlation between elasticity increase rate of the calf region in ultrasound therapy and each factor. In analysis of correlation between elasticity increase rate of the calf region in infrared therapy and each factor, there was a positive correlation with basal metabolic rate ($r=0.38$). As a result, with increasing basal metabolic rate, the degree of elasticity was also increased ($p<0.05$). In this study, the relationship between ultrasound and infrared therapy and elasticity of muscles, correlations with various variables, and quantitative values were determined. The usefulness of ultrasound and infrared therapy was confirmed. As the study was done on participants at certain age and the measurement was not done for various regions or depth, more research is needed in the future to objectify results of this study. The number of patients with pain due to frequent muscle disorders in daily life is rapidly increasing and their index of happiness is falling. There is a growing interest in ultrasound therapy and infrared therapy. This study investigated the relationship between muscular elasticity of upper and lower extremities in ultrasound and infrared therapy as well as factors such as height, weight, BMI, muscle mass, and basal metabolic rate. Results of this study confirmed that there was a significant difference between ultrasound and infrared therapy in increasing the elasticity of muscle of the upper extremity. However, there was no significant difference between ultrasound and infrared therapy in increasing the elasticity of muscle of lower extremity. This might be because blood circulation in the lower extremity muscles is less than the upper extremity muscles. To objectify these results, a large-scale study should be conducted in the future to investigate the change in elasticity of muscles by depth.

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Yeong-Jun Park and Hae-Kag Lee contributed equally to this work.

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### *Conflict of interest*

None.

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