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Effects of Contrast Therapy Using Infrared and Cryotherapy as Compared with Contrast Bath Therapy on Blood Flow, Muscle Tone, and Pain Threshold in Young Healthy Adults

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Funds Collection G

ABCDEFG 1 JinHong Kim
ABCDEF 2,3 HyunKyung Jung
ABCDEFG 2,3 JongEun Yim

1 Rehabilitation Clinical Research Center, Korea Worker's Compensation and Welfare Service, Incheon Hospital, Incheon, South Korea
2 Department of Physical Therapy, College of Health Science and Social Welfare, Sahmyook University, Seoul, South Korea
3 Department of Physical Therapy, The Graduate School, Sahmyook University, Seoul, South Korea

Corresponding Author: Jongeun Yim, e-mail: jeyim@syu.ac.kr
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Background: The aim of this research was to compare the effects of contrast bath therapy (CBT) and contrast therapy (CT) using infrared (IR) and cryotherapy (CR) on blood flow, muscle tone, and pain in the forearm.

Material/Methods: Twenty healthy individuals participated in this study. Each participant received 2 kinds of CT separated by a week. CBT involved immersion in hot water (38–40°C) for 4 minutes, followed by 1 minute of immersion in cold water (12–14°C) for four rotations. CT using IR and CR was performed in the same manner as CBT.

Results: The variables measured were blood flow, muscle tone, and pain before and after intervention. Both types of CT produced fluctuations in the blood flow ($P<0.05$). The pain threshold increased on both therapies; a significant increase was noted with IR and CR ($P<0.05$) therapies. Muscle elasticity was induced and stiffness was reduced with all therapies ($P<0.05$). IR and CR resulted in significant changes ($P<0.05$) in blood flow as compared with the CBT.

Conclusions: The results of this study suggest that CT using IR and CR is more effective in improving blood flow than CBT and has the same effect on muscle tone and pain. Nonetheless, using IR and CR is efficient with regard to mobility and maintaining temperature; therefore, it would be convenient to use these in clinical settings. Further studies involving CT should be carried out to determine whether our findings are clinically relevant.

MeSH Keywords: Muscle Tonus • Pain Measurement • Regional Blood Flow • Skin Temperature

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Background

Pain is an unpleasant feeling accompanied by physical, physiological, and psychological disability [1]. However, it is important not only as a protective response for the body but also as an assessment indicator of a patient's initial and post-treatment statuses in the clinic [2]. When medication is used to relieve pain, side effects such as digestive disorders, ulcers, gastrointestinal bleeding, and perforation of the duodenum may occur [3]. Therefore, to reduce or eliminate side effects, physiotherapy and non-drug therapies such as electrotherapy, thermal therapy, and cryotherapy (CR) are used.

Generally, CR used in acute treatment reduces tissue temperature, contracts blood vessels, and also reduces tissue metabolism, which result in decreased inflammation and edema [4,5]. CR also increases the pain threshold and dulls pain sensation. This is because it reduces the anti-noxious stimulant effect and muscle spasms through the gate control mechanism; at the same time, it also reduces the sensory nerve conduction velocity and post-injury edema [6]. On the other hand, thermal therapy increases intracellular fluid and blood flow and rapidly supplies nutrients to the tissues, increasing muscle strength and reducing muscle spasms [7]. Increased blood flow due to heat also helps reduce pain and muscle spasms by rapidly removing toxic metabolites [8].

Contrast bath therapy (CBT) using cold/hot alternation can treat acute and sub-acute injuries. It increases the blood flow by the pumping action caused by contraction and relaxation of the blood vessels, thereby reducing edema and inflammation in the areas with abnormal findings [9]. Additionally, increased blood flow facilitates the supply of extra oxygen and nutrition to the soft tissues and helps repair damaged tissue [10]. For this reason, CBT has been widely used for non-invasive physical therapy while training athletes, or for rapid recovery after games or pain relief for acute and sub-acute soft tissue injuries [11,12]. However, a large amount of water is used in CBT; therefore, there are limitations in mobility, location, and water temperature control. To overcome these limitations, we used IR and CR devices, which provided increased mobility and temperature control as compared to CBT.

IR devices emit heat through the vibrations of molecules and act on the surface of the skin. This method is widely used for the physiological effects of thermal heat in clinical practice because of its ease of usage, temperature control, and convenience of mobility. It also penetrates up to 2–3 cm into the skin without irritating the surface of the skin, and promotes blood circulation and metabolism. It is effective in reducing analgesia and muscle spasms; hence, it is widely used for rheumatism, neuralgia, back pain, and dysmenorrhea. The control of pain because of the thermal effect of IR is explained by the gate control mechanism [13].

Conventional CR with water and ice has been widely practiced. In recent years, a CR device with which nitrogen in the air is cooled to subzero temperatures and applied locally to the affected parts has been widely used [14]. This lowers the rate of transmission of pain fibers C and δ to reduce pain, and it also reduces the inflammatory response by reducing the activity of the enzyme [15]. The CR device has the advantages of maintaining a certain temperature for a long period of time, and ease of use by the therapist [16]. In addition, CR with a cold bath takes 20 to 30 minutes of treatment time, whereas the CR device is able to achieve the same effect within a few minutes [17].

Although many previous studies have discussed an alternate bath therapy using traditional immersion, research on contrast treatment (CT) with IR and CR devices is difficult to find. Therefore, in this study, we attempted to compensate for the disadvantages of CBT (i.e., difficulty in maintaining mobility and constant treatment temperature), we wanted to determine the effects of CT with IR and CR devices on blood flow, muscle tone, and pain. These devices are easy to move; the temperature is easily controlled, and these devices can be used for CT of hot and cold therapies.

Material and Methods

Participants

This study included healthy men and women who visited Incheon G Hospital. They were explained the contents of this study and agreed to study participation. We randomly assigned a treatment order to 20 participants who met the following selection criteria: healthy adults in their 20s and 30s without any complaints/fractures/disorders in their upper arm, shoulder, wrist, or skin. Exclusion criteria for the study subjects were open wounds, allergic reaction to CR, sensory abnormality, cardiovascular disorder, administration of pain medications within the last week, or administration of medications for cardiovascular disorders. This study received approved from the Sahmyook Institutional Review Board, IRB (no.2-1040781-AB-N-01-2016020HR), and the protocol was prospectively registered at *www.cris.nih.go.kr* (KCT0002986).

Procedure

We randomly assigned a treatment order to 20 study participants who were provided with a guidebook explaining the study. Ten participants were randomly divided into 2 groups: primary CT and CBT groups. In order to remove the residual effects of primary therapy, they had a week of rest [18]. A week later, the experimental treatment was conducted in the same environment and time as last week. CBT was performed on those who had a primary CT, and CT was performed on those

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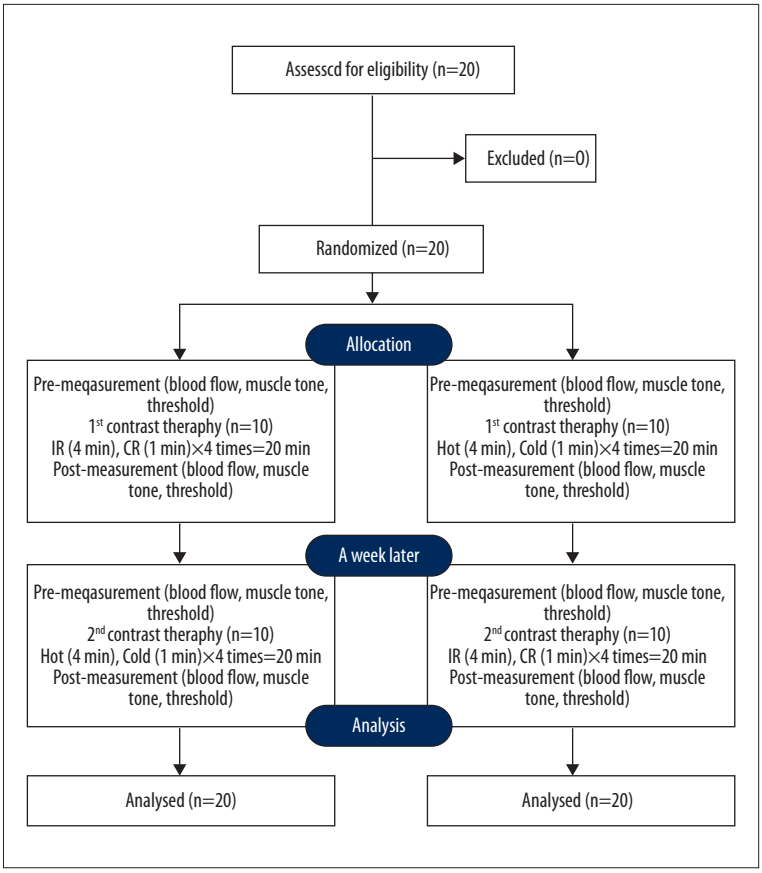

Figure 1. Flow diagram of the experimental procedure.

who had CBT. Prior to performing each treatment, we allowed enough time for stabilization (30 minutes), considering the physical and psychological changes of the day. Both groups were tested before and after the experiment. To increase the reliability of the pre-post-test, all test procedures were performed in order of blood flow, muscle tone, and pressure pain threshold. The break was 30 seconds between tests (Figure 1).

Intervention

We randomly assigned 20 healthy adults to the experiment; 10 participants were treated with CT, using IR and CR devices and CBT, using immersion bath at intervals of 1 week.

CT using IR and CR devices

Measurements of the blood flow, muscle tone, and pain threshold were taken. The measurements were taken at the same spot before and after the experiment by placing a spot at the wrist flexor muscle, 5 cm below the elbow bend. As per the measurement posture, the elbows were stretched in the sitting position, and the palms were directed toward the sky on the examination table. The subjects' arms were photographed with their faces, to take pre- and post-measurements of other experiments to be performed 1 week later.

The blood flow was calibrated before each measurement with a laser Doppler imager (Moor LDI2-IR, USA, 2007), and then laser points were vertically aligned and measured. After positioning vertically to the spotted area, a muscle tone-measuring device, MyotonPRO (Myoton Muscle Diagnostics, Europe, 2011), was used at the measurement site. Only a single measurement was taken, and that value was used. Pressure was applied on a spot 0.5 cm away from the body where the spot was marked, using a pain threshold device Commander algometer (JTECH Medical, USA, 2010). When the participant felt pressure/discomfort or pain, he was asked to say "ah" and the pressure was removed immediately. The pressure was applied perpendicular to the site of measurement by the examiner [19].

CBT and both IR and CR devices used for CT were maintained at 38–40°C for heat and 12–14°C for cold. Both treatments were performed at the onset of heat for 4 minutes, followed by 1 minute of cold for a total of 20 minutes.

IR was performed using Infralux 300 (Wonsin Therapy Device, Korea, 2009); after the arm was spread on the table, the brachial joint was stretched, and the arms were in a supination position.

The IR device was placed vertically at a distance of 35 cm around the marked spot, and the IR intensity was set using an

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air thermometer (SDT25, Summit Company, Korea, 2016) so that the temperature could be maintained at 38–40°C at a distance of 0.5 cm from the skin. When the subject said it was too hot during the treatment, the intensity of the IR light was lowered. The CR device used was Crais (AM-L08G1, Century, Korea, 2005), and the test was performed at the same position as IR treatment.

The CR device was preheated 40 seconds before use, and the intensity was set to 6. After placing an air thermometer 0.5 cm away from the skin, the test was performed by changing the irradiation distance to maintain the temperature at 12–14°C. The temperature was set using an electronic thermometer at 0.5 cm intervals from the skin.

CBT in immersion bath

CBT was performed spreading the elbows in the sitting position on the side of the immersion bath, and immersion in water up to the upper arm was attained. Two water immersion baths were used to set the temperature of the water to 38–40°C and 12–14°C, respectively. The water temperature measured from time to time to maintain the set temperature. The CBT was also immersed by alternating 4 minutes of warm water and 1 minute of cold water, starting from hot water with total immersion of 20 minutes. Pre- and post-examination was performed in the same way as in the CT procedure.

Measurements

Blood flow

Laser Doppler Imaging is the latest blood flow measurement device, which is a non-invasive, dynamic approach that can scan the skin surface and measure micro-blood flow. This method is different from the method of measuring blood flow using conventional skin temperature measurement. This tool has the advantage of being non-touching and non-invasive; it is used in many areas, such as rheumatism, tissue restoration, and burns [20]. In this study, the blood flow was measured at the spot marked using a laser Doppler imager (Moor LDI2-IR, USA, 2007). CT and CBT were performed at intervals of 1 week; the blood flow was measured immediately before and immediately after each experiment. The blood flow meter was calibrated before measurement, and the arm was positioned so that the laser point and the pen mark were matched. The measurement device was set at a speed of 10 ms/pix, and the blood flow was measured in the scan mode; then, the blood flow of 3 cm x 3 cm was analyzed based on a spot around the center.

Muscle tone

The device for measuring muscle tone is a non-invasive, low cost tool for measuring musculoskeletal tone, which is easy to carry [21]. It is also useful for assessing changes in the muscle tone due to aging and changes in stroke patients [22]. In this study, muscle tone was measured using MyotonPRO (Myoton Muscle Diagnostics, Europe, 2011). The muscle tone measurement device was placed vertically on the spot; the measurement site and the device were kept vertical during the measurement. The program setting of the muscle tone device was set to a multi-scan mode [23], which shows the average value of 10 taps. The result of a single measurement in multi scan mode was used as the value of this study result. The correlation coefficient between the measurements was 0.97–0.99, showing a high credibility for the measurements of the muscle tone of the upper arm bicep and muscle quadratus [24].

Pressure pain threshold

Pressure pain threshold can be determined when the pain is felt by holding the machine in hand and applying pressure. The tool used can quantify local pain with pressure as an objective and repetitive measurement [19]. This device has been used for many years to measure muscle pressure pain in patients with fascia syndrome and to compare the effects of various musculoskeletal disorders before and after treatment [25].

In this study, the pressure pain threshold was measured using the Commander algometer (JTECH Medical, USA, 2010). The average of the 2 measurements was obtained by placing the measuring instrument toward the body at a position of 0.5 cm away from the point marked. The pain threshold was the point at which unpleasant sensations or pain began when pressure was applied to the subject. Increasing the pain threshold means reducing pain. Intrarater reliability was almost perfect (ICC=0.94–0.97), interrater reliability was substantial to near perfect (ICC=0.79–0.90), and test-retest reliability was substantial(ICC=0.76–0.79) [26].

Statistical analyses

Data were analyzed using SPSS version 18.0 for Windows (SPSS Inc., Madison, WI, USA). Results are presented as mean±standard deviation. Prior to training, the normality of the data was assessed with the 1-sample Shapiro-Wilk test. To compare the pre- and post-intervention differences between the 2 groups, a paired *t*-test was used. Independent t-tests were performed to compare the pre- and post-test scores and the difference by time for the 2 groups. A *P* value less than 0.05 was considered to indicate a statistically significant difference.

Results

General participant characteristics are described in Table 1.

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Table 1. General characteristics of the participants.

	Participants (n=20)
Sex (Male/Female)	6/14
Age (year)	23.50±3.50*
Height (cm)	164.35±7.98
Weight (kg)	61.50±16.80
BMI(score)	22.59±4.28

* Values are presented as mean±standard deviation.

Blood flow

There were significant differences in the blood flow before and after CBT and CT in both groups ($P<0.05$). Furthermore, the mean difference in blood flow before and after intervention showed a significant difference between the 2 groups ($P<0.05$) (Table 2).

Table 2. Pre- and post-program changes in blood flow (N=20).

	CT (n=20)	CBT (n=20)	*t*(*P*)
Blood flow (flux)			
Pre	98.91±31.21*	88.29±30.97	
Post	481.48±217.68	142.47±59.28	
Post-pre	–382.57±221.89	–54.18±65.46	–6.348 (0.000)
t(*P*)	–7.710 (0.000)	–3.701 (0.002)	

CT – contrast therapy; CBT – contrast bath therapy. * Values are presented as mean±standard deviation.

Table 3. Pre- and post-program changes in muscle tone (N=20).

	CT (n=20)	CBT (n=20)	t(P)
Elasticity			
Pre	0.08±0.15*	0.86±0.10	
Post	214.45±58.16	211.65±47.81	
Post-pre	–213.57±12.99	–210.79±47.75	0.165 (0.870)
t(*P*)	–16.443 (0.000)	–19.741 (0.000)	
Stiffness (N/m)			
Pre	206.15±51.61	217.75±53.07	
Post	1.10±0.11	1.10±0.11	
Post-pre	205.05±51.69	216.65±53.13	0.700 (0.488)
t(*P*)	17.741 (0.000)	18.237 (0.000)	

CT – contrast therapy; CBT – contrast bath therapy. * Values are presented as mean±standard deviation.

Table 4. Pre- and post-program changes in pain threshold (N=20).

	CT (n=20)	CBT (n=20)	*t*(*P*)
Pain threshold (kg/cm^2)			
Pre	46.96±15.86	45.95±13.20	
Post	50.60±16.07	48.96±16.10	
Post-pre	–3.64±5.32	–3.01±13.02	–0.188 (0.852)
t(*P*)	–3.042 (0.007)	–1.041 (0.311)	

CT – contrast therapy; CBT – contrast bath therapy. * Values are presented as mean±standard deviation.

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Muscle tone

Muscle elasticity

The results indicating muscle tone are shown in Table 3. Comparison of the muscle elasticity before and after CBT and CT revealed a significant difference in both groups ($P<0.05$). There were no significant differences between the 2 groups ($P>0.05$) (Table 3).

Muscle stiffness

A significant difference was observed in the muscle stiffness before and after CBT and CT in both groups ($P<0.05$). In the comparison of the difference between the 2 groups, we found no significant difference ($P>0.05$) (Table 3).

Pain threshold

There was a significant difference in the pain threshold with CT before and after ($P<0.05$), but no significant difference was observed with the CBT ($P>0.05$). There were no significant differences between the 2 groups ($P>0.05$) (Table 4).

Discussion

Pain is defined by the International Association for the Study of Pain (IASP) as "direct or potential damage or an uncomfortable feeling and emotional experience due to these injuries." The CBT is a non-invasive treatment method that relieves pain by alternating application of heat and cold. It can be applied to patients with acute and sub-acute impairments, unlike heat treatment. It has been used especially for quick recovery and tissue healing in athletes [4,11]. CBT shrinks peripheral blood vessels to increase blood flow and is effective in reducing edema, pain, and muscle tone [27,28]. However, the use of CBT via submersion in a bathtub is quite limited because temperature control is not easy and mobility is limited. Therefore, considering these limitations, we examined the effects of CT using IR and CR devices on the blood flow, muscle tone, and pain.

The purpose of this study was to investigate the effects of CT using IR and CR devices and CBT using an immersion bath on blood flow, muscle tone, and pain in healthy adults visiting Incheon G Hospital. Increased blood flow and muscle elasticity and decreased stiffness were significant ($P<0.05$) findings of both CT and CBT. The pain threshold increased in both treatments, and there was a significant difference on treatment with IR and CR devices ($P<0.05$). The changes in pain threshold, muscle elasticity, and stiffness were similar on CT and CBT, but CT was more effective than CBT in changing the blood flow ($P<0.05$).

Blood flow increased with heat therapy, using a heating device or ultrasonic waves and when heat was applied to the painful area; the skin temperature increased and the blood vessels in the skin expanded to increase the blood flow [29]. Increased blood flow facilitates the recovery process by promoting nutrient supply. It also promotes pain relief and healing by rapidly removing the inflammatory metabolites, such as prostaglandin, bradykinin, and histamine [30]. In this study, all patients (those who received the CT and those who received CBT) showed increased blood flow. According to a study on blood flow volume, blood flow increased in both groups as a result of CBT in healthy subjects in their 50s and 20s [28]. Another study also showed that blood flow to the feet increased when CBT was administered to healthy adults [31]. In this study, the increase in blood flow as a result of CBT was consistent with the findings of previous studies. Furthermore, CT improved blood flow more than CBT did. Therefore, radiant heat is better than heat transfer in heat conduction because blood flow with CT increased more than it did in CBT even at the same temperature.

Muscle tone refers to the resistance felt when an external force is applied during a willful resting state of the muscle [32]. The increase in muscle tone refers to the abnormality of the musculoskeletal system as well as the abnormality of the nervous system in a patient; it is also used as an indicator of the state of the muscle [33]. In this study, we measured the muscle elasticity by the logarithmic decay rate of the original vibration of the muscle. Muscle elasticity refers to the ability of a muscle to return to its original shape after contraction, and stiffness is measured by resistance to contraction [23]. In this study, we showed that subjects who received the 2 types of treatment (CT and CBT) had significantly higher muscle elasticity and lower stiffness than that of before treatment. In one study, subjects with acute back pain underwent thermal therapy. The muscle stiffness decreased and flexibility increased compared to the group without treatment and the group taking medications [34]. Another study measured the stiffness and elasticity of muscles when they felt pain after chewing gum. Then, after administering microwave irradiation as a heat treatment, it was shown that stiffness decreased and elasticity increased. This demonstrates that heat therapy has the effect of increasing muscle elasticity and reducing stiffness [35].

Pressure pain threshold refers to the minimum pressure that causes pain or discomfort, and the concept was established by Libmann in 1934. Since then, pressure pain threshold has been used extensively in studies relating to the perception of pain and the effects of therapeutic intervention [36,37]. The results of our study showed that the pain threshold increased in both groups (CT and CBT), especially in the CT group. In another study, patients with fascia syndrome showed increased pain thresholds after being treated with surface heat and ultrasound

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as compared to the pain thresholds before any treatment [38]. In another study, the pressure pain threshold at the shoulder of a non-pain-affected subject was measured; after the administration of heat and cold therapy, pain threshold increased in both groups after treatment compared with the before treatment [39]. This supports the possibility of managing pain by increasing the threshold during heat treatment. In another study, delayed muscle pain was induced in healthy adults by leg press exercises. Then, after exercise, CBT, cold treatment, and heat treatment were performed at 24, 48, and 72 hours. As a result, only the CBT group showed a significant decrease in pain at 24 hours, 48 hours, and 72 hours after exercise [11]. In our study, the pain threshold increased with CBT, but there was no statistically significant difference. However, there was a significant increase in pain threshold with CT. This suggests that CT and CBT have a positive effect on pain, which is consistent with the findings of previous studies. In particular, the pain threshold significantly increased with CT; therefore, it is considered that CT would be a complementary treatment for CBT. In contrast to the previous studies, there was no significant difference in pain after CBT. We believe that this is because of the difference between the number of treatments and the previous studies [40].

The limitations of this study are as follows. The results of the study cannot be generalized because the number of study subjects was not large. More studies will be needed in the future. In addition, there was a limit in predicting the clinical effect of pain thresholds in healthy subjects. Therefore, in the future, comparative studies with larger number of subjects, measuring the effects of different therapies in both healthy subjects and individuals with pain/problems are needed. Also, classification by gender and age is considered necessary.

Conclusions

This study showed that both CT and CBT were effective in increasing blood flow, reducing muscle stiffness, increasing muscle elasticity, and relieving pain. Especially, CT using IR and CR devices was more effective in increasing blood flow than CBT. Because CT using IR and CR devices is efficient in terms of mobility and temperature control, it would prove convenient in clinical applications. Future studies will be needed to determine whether treatment with IR and CR devices is the appropriate in the clinical settings.

Conflicts of interest

None.

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