

Changes in Local Blood Volume During Cold Gel Pack Application to Traumatized Ankles

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It is a common practice to apply a cold modality to control soft tissue pain and edema following local trauma. The initial physiologic response to cold application is constriction of the local cutaneous and subcutaneous blood vessels (8). However, studies have reported that local reactive vasodilation can follow the initial vasoconstriction response (2-4,6). This reactive vasodilation would cause an increase in local blood volume and, coupled with the increase in local capillary permeability which is part of the inflammatory process associated with tissue trauma, would significantly impair the ability of a cold modality to control local swelling. It is conceivable that, due to reactive vasodilation, a cold modality may produce an increase in local swelling.

A more recent study does not support the occurrence of reactive vasodilation (5). Further review of the literature reveals inconsistencies regarding the recommended parameters for cold application following soft tissue trauma (7). It is evident that further, clarifying research is indicated.

The purpose of this study was to measure local blood volume change during application of a cold gel pack to acutely sprained ankles. The research hypothesis was that the application of a cold gel pack to a traumatized ankle would cause a significant,

Whether application of a cold modality following soft tissue trauma causes reactive vasodilation is an important clinical question since one goal of using a cold modality is to limit edema formation. The purpose of this study was to measure change in local blood volume during application of a cold gel pack following inversion sprain of the ankle. Fifteen volunteers participated as subjects (age range: 18-46 years, mean age: 22.2 years). A bilateral tetrapolar impedance plethysmograph was used with venous occlusion to measure the change in local limb volume at the ankle over a 20-minute period during two conditions: at rest and with cold gel pack application. A significant reduction in local blood volume occurred during cold gel pack application compared with rest. A significant vasodilation response was not observed. The lack of vasodilation response lends support to the clinical use of a cold gel pack following soft tissue trauma when applied to the ankle for a period of up to 20 minutes.

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sustained reduction in local blood volume.

METHOD

Subjects

Fifteen subjects volunteered for this study (10 males and five females). Ages of the subjects ranged from 18 to 46 years (\bar{X} : 22.2 years, SD: 6.7 years). Each subject had suffered a mild to moderate level inversion sprain of the ankle and was referred to the study following physician evaluation. Each subject was tested within 48 hours of sprain occurrence. Prior to participation in the study, each subject completed a

written questionnaire to rule out sensitivity to cold, history of ankle or foot problems, or orthopaedic surgery in the ankle region. The procedure was then verbally explained to each subject and informed consent was obtained. The study was approved by the Northern Arizona University Human Subjects Review Committee.

Instrumentation

Data were collected using a Model 720 Bilateral Tetrapolar Impedance Plethysmograph (Electro-Diagnostic Instruments, Burbank, CA). This plethysmograph measures changes in fluid volume in a given

body segment by recording bio-electrical impedance. The plethysmograph uses a 4 mA sinusoidal current at a frequency of 100 kHz, which is not perceivable by the subject nor will it produce muscular contraction. The current is sent from and received by a pair of surface electrodes. Another pair of electrodes placed in line between the first pair measures voltage. Impedance plethysmography is therefore based upon Ohm's Law, which states that resistance, or impedance, to current flow is directly proportional to voltage change: resistance = voltage/current. Between-trial reliability for the plethysmograph used in this study was previously established to be high with an intraclass correlation coefficient of .971 (9).

Procedure

Each session began with the subject sitting for approximately 10 minutes. Room temperature measurements were obtained. Each subject's resting blood pressure and heart rate values were also recorded since an increase or decrease in heart rate or blood pressure during the control or experimental condition could in itself produce a change in distal extremity blood volume. Therefore, each subject's heart rate was recorded throughout each condition via a heart rate monitor attached to the ear lobe. Each subject's blood pressure was also recorded prior to and following each session.

Each subject then laid prone for 10 minutes with knees positioned at 15–20° of flexion. This position was maintained for the entire session. A large blood pressure cuff was then placed around the thigh just proximal to the knee on the same side as the ankle sprain.

The lateral aspect of the subject's lower leg was cleaned with isopropyl alcohol and four 2.5 × 3.0-cm surface electrodes were placed on the lateral side of the ankle, two above the lateral malleolus and two

below the lateral malleolus (Figure 1). The placement of electrodes was based upon the subject's ankle circumference with the outer current electrodes placed apart at a distance equal to half of the ankle circumference measurement and the inner voltage electrodes placed apart at a distance equal to one-third of the ankle circumference measurement. These distances for electrode placement permitted measurement of a median tissue plane within the depth of the sampling field (10).

After approximately 10 minutes had passed and a relatively constant heart rate was obtained, resting data collection began. With the subject in the prone position, the thigh cuff was inflated and maintained at 20 mm Hg below the subject's resting diastolic blood pressure. At this cuff pressure, venous outflow was obstructed while still allowing arterial inflow. Therefore, an increase in limb volume occurred distal to the thigh cuff. The cuff was inflated every 2 minutes for 30 seconds so that 10 volume measurements were obtained during the 20-minute resting condition.

Following resting data collection, a cold gel pack taken from a ColPac Hydrocollator refrigeration unit (ColPac Hydrocollator, Chattanooga Pharmacal Co., Chattanooga, TN) maintained at a mean temperature

of -6.67°C (20°F) was placed in a damp pillow case and applied around the subject's ankle. Data collection, as described during the resting condition, began immediately following pack application for an additional 20 minutes.

Following removal of the cold gel pack, the electrodes were removed and the subject was allowed to sit up. A final blood pressure was taken and the skin was inspected for damage due to the application of the cold gel pack. With normal vital signs and no evidence of skin damage, the subject was allowed to leave.

Data Analysis

Blood volume increase in the lower leg was produced for each of the 10 measurement points during the two conditions. The volume increase was measured as an increase in percent impedance. There is a direct linear relationship between percent impedance change and percent blood volume change when an impedance plethysmograph utilizes a 100 kHz current frequency (1). A percent blood volume change was therefore obtained at 10 intervals over each 20-minute condition for each subject.

The means for percent blood volume change for the 15 subjects were then calculated at each 2-min-

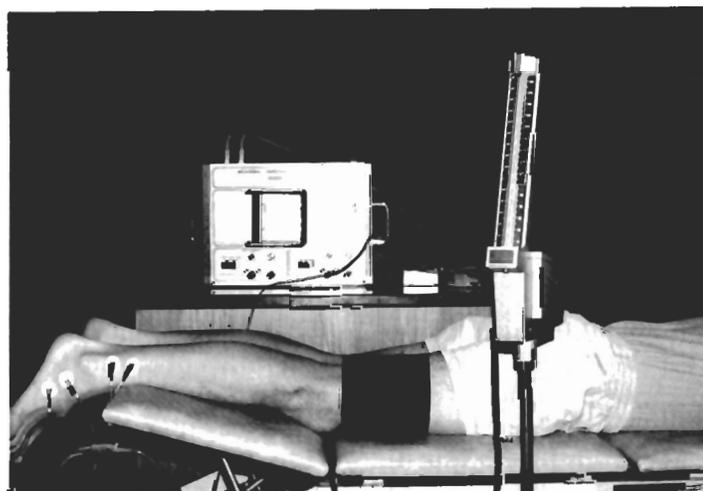


FIGURE 1. Electrode configuration around the ankle.

ute time interval during the rest and cold gel pack conditions. The 2-minute interval means were then compared for the two conditions using a two-way repeated measures analysis of variance (ANOVA).

Heart rate means during the two conditions and blood pressure means before and after the session were calculated and paired *t*-tests were used to compare changes. An alpha level of .05 was used for all tests of statistical significance.

RESULTS

Means and standard errors of the mean for percent blood volume change at each of the 10 time intervals for the two conditions are shown in Figure 2. The results of the ANOVA comparing mean percentage of blood volume changes over time for the two conditions showed a statistically significant difference for condition.

The results of the paired *t*-tests comparing mean systolic and diastolic blood pressure changes before and after the testing session revealed no statistical significance [systolic: $t(14) = 1.06$, $p = 0.31$; diastolic: $t(14) = -1.33$, $p = 0.20$]. A second two-tailed *t*-test comparing mean heart rates during each of the two conditions also revealed no statistical significance [$t(14) = 0.83$, $p = 0.42$].

DISCUSSION

In this study, reactive vasodilation was not observed at any time during the cold gel pack application. However, blood volume data following removal of the cold gel pack was not obtained as part of this study. It is possible that vasodilation may occur after the removal of the cold gel pack, but additional work is needed to clarify the local vascular response,

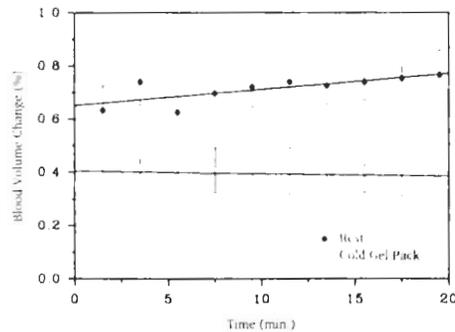


FIGURE 2. Changes in blood volume during rest and cold gel pack application.

if any, following cold gel pack removal.

The increase in local limb volume was approximately 50% less when the cold gel pack was applied compared with volume increase data during the resting condition. In other words, when the cold gel pack was applied, the increase in volume at the ankle that resulted from thigh cuff inflation was about 50% less than the increase in volume measured during thigh cuff inflation during the resting condition. We believe this smaller increase in ankle volume during cold gel pack application is due to two simultaneous reasons: first, the occurrence of reflex vasoconstriction of the local vasculature in response to the cold stimulus and, second, the external compression force exerted by the weight of the pack. This proposal is based on the results of a previous study in which a gel pack at room temperature and then a cold gel pack were applied to a series of nontraumatized ankles (9). The results of this study showed that the room-temperature gel pack decreased ankle volume over the resting volume level, but the cold gel pack further reduced the ankle volume over the resting level. It was concluded, therefore, that the reduction in ankle volume increase during cold gel pack application was a result of the combined effect of the gel pack weight and temperature.

CONCLUSIONS

The results of this study indicate that application of a cold gel pack following inversion sprain of the ankle will produce an immediate and sustained vasoconstriction response during the application time period. The use of a cold gel pack as a therapeutic intervention following an inversion sprain of the ankle is therefore supported within the application time and pack temperature parameters used in this study. JOSPT

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