Calf Muscle Pumping and Rest Positions during and/or after Whirlpool Therapy

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Abstract. This study investigated the oedema-preventing effect of calf muscle pumping (CMP) during and after whirlpool therapy (WT), and whether or not supine lying with or without elevation of the leg would be effective in preventing swelling of the lower leg following WT. Twenty participants underwent 20 min of WT to the experimental leg while performing CMP by means of vigorous dorsi- and plantarflexion of the ankle. Post-treatment conditions consisted of supine lying with or without CMP and supine lying with the experimental leg elevated with or without CMP. Volumetric measurements of the experimental leg were carried out before and after WT. The results showed no effect of CMP on prevention of swelling in the lower leg during WT. However, WT followed by supine lying with the experimental leg elevated resulted in the least amount of swelling. These findings were attributed to increased venous return augmented by gravity. Contrary to the results of a previous study, there was no apparent effect of CMP during and after WT on swelling in the lower leg. A rest period of 10 minutes in supine lying with the leg elevated is recommended following WT to reduce post-treatment swelling of the lower leg.

Key words: Whirlpool bath, Calf muscle pumping, Leg elevation.

INTRODUCTION

Whirlpool therapy (WT) for medical and surgical conditions has been commonly employed in many countries since its origin in French military hospitals during World War I¹). The effect of heat causes the blood vessels of the immersed limb to dilate, bringing increased blood flow to the part being treated which results in swelling or oedema², ³) and may be detrimental to clients with circulatory disorders of the lower leg. A review of the literature indicates that calf muscle pumping (CMP) is effective in preventing such oedema or swelling⁴–⁶). One such study used a cycle ergometer⁵).

In a previous pilot study employing healthy individuals, the authors investigated the oedema-preventing effect of CMP by means of plantar- and dorsiflexion of the ankle during and after WT⁶). Also in addition to this, two alternative rest positions of sitting and standing following WT were chosen in order to find out if either one of them would affect the volume of the lower leg. The results showed that CMP during WT and also sitting for 10 min to be most effective in preventing post-WT swelling of the lower leg. The present study focused on the post-WT rest position of supine with or without the experimental leg elevated following WT. The author hypothesized that gravity, together with CMP, would aid venous return from the lower leg by means of its elevation above the cardiac level.
METHODS

Participants
The participants were a volunteer group of 12 female and 8 male student physiotherapists. Their mean age was 20.4 years old (range 18–26). They had no history of injury or circulatory disorder of the lower limbs.

Measurement
Two identical volumeters made of clear polyvinyl chloride resin were used to measure lower leg volume. The inside dimensions of each volumeter were 300 × 170 × 390 mm, and they were equipped with an overflow spout (Fig. 1). Volumeter reliability was checked by filling each with tepid water and an acrylate block of 1,000 cc with a precision of 0.05 mm was immersed into the volumeter and an overflow measurement was taken. This procedure was carried out 10 consecutive times. One volumeter yielded a mean volume of 980 ml (± 5.7) with a coefficient of variation of 0.6%. The other had a mean volume of 980 ml (± 2.5) and a coefficient of variation of 0.3%. The difference of 20 ml in the result from the original volume of 1,000 cc for the acrylate block can be explained by the fact that the water was collected only over a 2-min period as specified in the procedure. Because the coefficient of variation for both volumeters was less than one per cent, the intra-volumeter reliability was considered sufficiently high enough for their use in this study7, 8). Further, comparison of the two volumeters using a paired t test showed that the level of significance was 0.84 indicating a probability of less than 1%, so that the inter-volumeter reliability was sufficient for the author to accept that both volumeters were identical. Two identical volumeters were used so participants could be processed more rapidly and the experiment concluded sooner.

Procedure
Upon entering the hydrotherapy room the participants who were wearing gym shorts were given an explanation of the purpose and procedures for the experiment and were asked to sit comfortably for 10 min to stabilise the circulatory dynamics of the limb.

An initial volumetric measurement of the lower leg was carried out as follows. The seated participant was asked to choose whether or not to have the right or left leg as the experimental leg throughout the study and was then asked to immerse it slowly into a volumeter. Water temperature was set equivalent to normal body temperature so that the shock of cold water did not cause the participant to have any vasoconstriction. The experimental leg was inserted into the volumeter until the plantar surface of the foot gently touched the bottom of the volumeter and the water overflowing into a plastic jug was collected for a period of two minutes (Fig. 1). Two minutes was determined as the shortest time during which most of water overflowed out of the volumeter. The collected water was immediately weighed, using an electronic scale (Mettler-Toledo Ltd, Switzerland) with a precision of 0.02 g. The scale was calibrated beforehand, using a balance weighing 2,000 g, which had an allowable error of 10 mg. The water temperature was calibrated between 36.5°C and 37°C. The weight of the water in grammes was converted into millilitres by multiplying it by one because the volume of water equals the weight of water at its maximum specific gravity. With this small range in water temperature, fluctuation in the specific gravity could be kept to a minimum. The specific gravity of water is at its maximum when the water temperature is 4°C, but the exact specific gravity of water temperature between 36.5°C and 37.0°C was not determined. However, the water temperature was kept constant within a small fluctuation of 0.5°C.

The participants underwent 20 min of WT to the experimental leg with the water temperature at 42°C, using a podiatric whirlpool bath. Although 36°C to 40°C is generally recommended as the optimum temperature of water used for WT3, the temperature of 42°C was chosen in this case because, in general,
Japanese people are familiar with having a hot bath and so do not regard a temperature of 40°C as warm enough. In addition, the authors also wanted to facilitate a physiological response. The water level was maintained at the fibular head. The water was agitated throughout the treatment session by an electric ejector, maintaining a constant flow of air bubbles on the participant’s limb. Two separate experiments were carried out during the WT, that is, one with CMP and the other without.

The CMP was activated by means of the strongest-possible dorsi- and plantarflexion of the ankle and repeated two hundred times at one per second. This was interrupted with a one minute forty seconds rest period every 20 repetitions. The rest period occurred after 20 sequential repetitions of CMP completing a two-minute cycle of which there were a total of 10 in the 20-min treatment period. With a firm and assertive voice and by watching a timer the experimenter provided the participant with accurate rhythm and vocal encouragement for CMP.

On completion of the treatment the limb was gently patted dry with a bath towel without rubbing and a volumetric measurement was immediately taken. The participant was then assigned to one of the four post-treatment conditions as follows: 1) Supine lying for 50 min during which time the volumetric measurements were taken every 10 min in a sitting position; and 2) Supine lying with the leg elevated for 50 min during which time the volumetric measurements were taken every 10 min also in a sitting position. These two positions were chosen because supine lying with or without the leg elevated is often a common resting or treatment position for clients with lower limb oedema. It is well known that in supine lying with the leg elevated, venous circulation and lymph flow is aided by gravity, hence the reason for choosing supine lying as a control rest position after WT. A period of 50 min rest was based on the report of Cohen et al. who stated that an increase of blood flow following WT to the forearm was maintained for approximately 45 min. During supine lying a roll of elastic bandage was inserted under the knee to prevent the calf from pressing against the surface of the plinth thereby causing possible interference to circulation. During supine lying, the hip of the elevated leg was kept in 30 degrees of flexion, and the knee and lower leg were supported by pillows to prevent hyperextension, and hence discomfort, of the knee. The reason for choosing 30 degrees of hip flexion was that the internal pressure of the hip joint is at a minimum between 30 and 65 degrees of hip flexion, nullifying any negative effect on circulation. The other two post-treatment conditions were, 1) CMP in supine lying for 10 min followed by final volumetric measurement, and 2) CMP in supine lying with the leg elevated for 10 min followed by a final volumetric measurement. The method for CMP was the same as that used in the whirlpool. The reason for choosing 10 min of CMP was that the results of a preliminary study indicated that 10 min of CMP was required to prevent swelling following WT. Explanations of the eight conditions are provided in Table 1.

The total number of WT treatments administered amounted to eight per participant with the sequence of procedures randomised. Instead of assigning all the participants randomly to the experimental conditions, they were used as their own control throughout the study. Each treatment session was separated by approximately 24 hours so as to nullify...
the effect of swelling which may have occurred as a result of the previous WT. The ambient temperature of the hydrotherapy room was, on average, kept at 20.9°C but fluctuated in the range of 16.0°C to 25.0°C. In consideration of intra-day variability of lower leg volumes, the experiment was carried out between 1600 and 2000 hours. The procedures and risks of the study were explained to the participants before the experiment took place, and their informed consent was obtained.

**Data analysis**

Employing a two-tailed paired t test, a comparison of the lower leg volumes was made before and after WT with and without the CMP, also at 10-min intervals in supine lying with and without the leg elevated, and with and without CMP in supine lying with and without the leg elevated following WT. A p-value of less than 0.05 was considered to be significant.

**RESULTS**

Whirlpool therapy both with and without the CMP in all the experimental conditions resulted in a significant increase in limb volume, but thereafter, the limb volume decreased for all of the conditions. Table 2 shows the mean and standard deviation for all of the conditions. In comparing the amount of increase in limb volume during WT between the non-CMP (Conditions A, C, E, and G) and CMP conditions (Conditions B, D, F, and H), both showed a significant increase between ‘immediately before’ and ‘immediately after’, but there was no significant difference between them, though conditions with CMP tended to produce less swelling of the lower leg (Fig. 2).

As for the temporal change following WT, the
limb volume for Condition A gradually decreased with no significant difference for the first 10-min period, but there was a significant decrease between ‘immediately after’ and ‘20-min after’ (*1 of Fig. 3). However, for Condition B, the amount of decrease was smaller, and a significant decrease was achieved only between ‘immediately after’ and ‘50-min after’ (*2 of Fig. 3). For Condition C, a significant decrease occurred between ‘immediately after’ and ‘10-min after’ (*3 of Fig. 3), and between ‘20-min after’ and ‘30-min after’, (*4 of Fig. 3). For Condition D, there was a significant decrease between ‘immediately after’ and ‘10-min after’ (*5 of Fig. 3), and between ‘40-min after’ and ‘50-min after’, (*6 of Fig. 3). Figure 4 shows changes in limb volume for Conditions with post-WT CMP with no evidence of any significant difference in the first 10-min period.

There was a significant decrease in limb volume for Condition C compared to Condition B for all of the 10-min rest periods (Fig. 5). There was no significant change in terms of difference in rest positions for all the post-CMP conditions (Fig. 6).

Table 3 shows that, between Conditions A and B, a non-significant decrease became apparent after 20 min compared to ‘immediately before’ for the latter, but this was apparent after 10 min for Conditions C and D. Also Condition C yielded a significant decrease after 30 min and Condition D after 50 min. Among Conditions E, F, G, and H the latter two did not show any significant decrease between ‘immediately before’ and ‘10-min after’.

DISCUSSION

There are four likely reasons for the increase in limb volume on the completion of WT with or without CMP: 1) There may have been no effect from CMP on swelling of the lower leg during WT; 2) Even if there had been such an effect, the increased blood flow might have overwhelmed it; 3) The frequency and/or vigour of the CMP might not have been optimal and did not produce the desired effect; 4) Swelling of the lower leg is brought about...
not only by vasodilatation but also by the fact that pooling of blood in the lower limb occurs because of the dependent lower leg exerting a downward force on the thigh causing pressure on its posterior aspect during WT thus inhibiting venous and lymph return to the thigh^{9}).

A previous study^{6)} demonstrated a tendency towards a decrease in limb volume after WT when CMP was carried out during WT. However, contrary to the above finding, the present study showed that the non-CMP conditions both during WT and rest in supine with or without the leg elevated achieved a greater decrease in limb volume following WT. Further, the CMP condition during WT resulted in an increase in limb volume 30 to 40 min after WT, but the CMP conditions during supine lying showed a greater decrease in volume when accompanied with CMP during WT. Thus, unlike the result of our previous study^{6)}, these findings demonstrated that CMP during WT seems to have conflicting effects on the volume of the lower leg. Nevertheless, the fact that swelling could not be controlled even in normal healthy individuals during WT while performing CMP should sound a warning for such treatments for clients with circulatory disorders of the lower leg.

When we compared volumes with or without the leg elevated in supine lying in terms of a decrease in limb volume following WT, leg elevation was effective; i.e. it took more than 20 min for the limb volume to decrease to the pre-WT level in supine lying with no leg elevation, but only 10 min were required for supine lying with the leg elevated. Further, the limb volume during rest in supine with the leg elevated decreased significantly after 30 min and thereafter compared to that before WT. This fact is attributable to the increased venous return augmented by the gravity-assisted position of the experimental limb. The elastic bandage roll placed under the knee in slight flexion during supine lying may have, to a small extent, interfered with the superficial venous return for the condition of rest in supine lying only.
CONCLUSION

Based on all the results of our study, it can be concluded that: 1) CMP during WT does not seem to be effective in preventing swelling of the lower leg; 2) supine lying with the leg elevated during the post-WT period seems to reduce swelling of the lower leg. However, these findings cannot be extrapolated directly to clients because participants with no vascular or musculoskeletal pathology were employed in this study. Since WT is often applied to clients with circulatory disorders or decompensation of their circulatory system, attention should be paid to the possible danger of this therapeutic medium. In addition, further studies will be required to elucidate the effect of CMP vis-à-vis WT.

REFERENCES


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Table 3. Statistical summary of the temporal change in limb volume (IS: significant increase; DS: significant decrease; NS: not significant)

Table 3. Continued