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The Influence of Calf Muscle Pumping and Resting Positions on the Volume of the Lower Leg during and/or after Whirlpool Therapy

Shimpachiro Ogiwara Katsuhiko Tachino Nobuhide Haida
Shigeharu Hamade Toshio Susaki Hitoshi Asai
Toshiaki Yamazaki Hiroichi Miaki

ABSTRACT

The purpose of this study was to investigate the oedema-preventing effect of calf muscle pumping (CMP) during and after whirlpool therapy (WT), and whether standing or sitting would affect the volume of the lower leg after WT. Twenty participants, with a mean age of 20.4 years, underwent 20 minutes of WT to the experimental leg while performing vigorous dorsi- and plantarflexion of the ankle. Post-treatment conditions consisted of: 1) standing; 2) sitting; 3) CMP in sitting for 10 minutes; and 4) CMP in sitting for 20 minutes. Volumetric measurement of the experimental leg was carried out before and after WT. Our mean volume increase was 1.8 % compared to one American study of 3.7 % with a lower water temperature of 2 ℃, suggesting that Japanese people seem to have a lowered sensitivity to warm water. It was also found that CMP during WT does not prevent swelling of the lower leg. However, the condition of WT • CMP followed by sitting resulted in the least amount of swelling. Therefore, CMP during WT and 10 minutes of CMP in sitting following it may be recommended to reduce post-treatment swelling of the lower leg.

KEY WORDS

whirlpool bath, swelling, calf muscle pump

INTRODUCTION

Whirlpool therapy (WT) for medical and surgical conditions has been commonly used in many countries since it originated in French military hospitals during World War I[1]. The effect of heat causes blood vessels of the immersed limb to dilate, bringing increased blood flow to the part being treated which results in swelling or oedema[2),3)] and may be detrimental to clients with circulatory disorders of the lower leg. Review of the literature indicates that calf muscle pumping (CMP) is effective in preventing such oedema or swelling[4),5)]. One such study used a cycle ergometer[4)].

In a pilot study employing healthy individuals, the authors investigated the oedema-preventing effect of CMP by means of active ankle exercise during and after WT. In addition, two different resting positions following WT were chosen in order to know if they would affect the volume of the lower leg.

METHODS

Participants

The participants were 20 physiotherapy students, consisting of 12 women and 8 men for this study. Their mean age was 20.4 years old, ranging from 18 to 26 years. They had no history of injury or circula-

Department of Physical Therapy

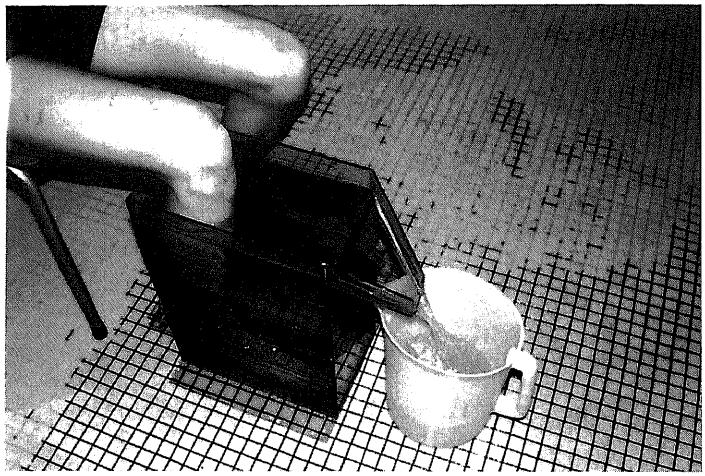

Fig. 1 Volumetric measurement of the lower leg

tory disorder of the lower limbs.

Measurement

Two identical volumeters made of polyvinyl chloride resin were used for the purpose of measuring the volume of the lower leg. The inside dimensions of each volumeter were 300 by 170 by 390 mm, and they were equipped with an overflow spout (Fig. 1). In order to know the reliability of the two volumeters measurement of each volumeter filled with tepid water was carried out 10 consecutive times by immersing an acrylate block of 1,000 cc with a precision of 0.05 mm into the volumeter. One volumeter yielded a mean volume of 980 ml with a standard deviation of 5.7 ml and a coefficient of variation of 0.6 %, and the other volumeter's mean volume was 980 ml with a standard deviation of 2.5 ml and a coefficient of variation of 0.3 %. The difference of 20 ml was most likely to be due to the fact that the overflowed water was collected for two minutes, the reason for this being described later. Because the coefficient of variation for both volumeters was less than 1 %, the intravolumeter reliability was considered sufficiently high for their use in this study[6),7)]. Further, comparison of two volumeters using the Student's t-test showed that the level of significance was 0.84 which was over 0.01, so that the intervolumeter reliability was sufficient for the authors to accept that both volumeters were identical. The reason why two identical volumeters were used was that the participants could be processed more rapidly and the experiment concluded sooner.

Procedure

Upon entering the hydrotherapy room the participant wearing gym shorts was given an explanation of the purpose and procedures for the experiment, and asked to sit comfortably for 10 minutes 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 then to immerse it slowly into a volumeter. As the plantar surface of the foot gently touched the bottom of the volumeter the water overflowed into a plastic jug and was subsequently collected for a period of two minutes (Fig. 1). The reason for a water overflow of two minutes was that it was found to be the shortest time during which most of water drained out of the volumeter. The amount of water that had overflowed was immediately weighed, using an electronic scale (Mettler-Toledo Ltd, Switzerland) which has a precision of 0.02 g. The scale was calibrated beforehand, using a balance weighing 2,000 g and which had an allowable error of 10 mg. The water temperature for calibration was set between 36.5 ℃ and 37 ℃. The weight of the water in grams was converted into millilitres by multiplying it by one because the volume of water equals the weight of water at its maximum specific gravity. In addition, the water temperature was set between 36.5 ℃ and 37 ℃ which is equivalent to normal body temperature so that the shock of cold water did not cause the

participant to have vasoconstriction. In addition, with this small range in temperature, fluctuation in the specific gravity could be maintained at a minimum. It is a known fact that the specific gravity of water is maximum when the water temperature is 4 ℃, but the exact specific gravity of the water temperature between 36.5 ℃ and 37.0 ℃ was unknown. However, the temperature was kept constant within a small range of 0.5 ℃.

The participant underwent 20 minutes of WT to the experimental leg with the water temperature at 42 ℃, using a podiatric whirlpool bath. Although 36 ℃ to 40 ℃ is generally recommended as the optimum temperature of water used for WT[5], the temperature of 42 ℃ was chosen because, generally, Japanese people are familiar with having a hot bath and so do not regard a temperature of 40 ℃ as warm enough, and the authors also wanted to facilitate a physiological response to this experiment. The level of the water was maintained at the fibular head and agitated throughout the treatment session by an electric ejector, maintaining a constant flow of air bubbles to all participants. Two methods of treatment 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 and this was interrupted with a one-minute-forty-second rest period every 20 repetitions. With a firm and assertive voice and by watching a timer the experimenter provided the participant with the accurate rhythm and vocal encouragement for CMP.

The average decrease in water temperature at the end of treatment was 0.9 ℃, ranging from 0.3 ℃ to 2.0 ℃. Upon completing 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 of which two were as follows: 1) Standing for 50 minutes during which time the volumetric measurements were taken every 10 minutes in sitting, 2) Sitting for 50 minutes during which time the volumetric measurements were taken every 10 minutes in the same position. The reasons for choosing these positions were that sitting and standing are often common resting positions after WT for many clients; they either sit or stand around the waiting room following treatment or go home in an ambulance or car. Unlike sitting, in standing, the thigh as well as the lower leg is perpendicular to the ground so that the venous blood and lymph flow against gravity, hence the reason for choosing standing as a control resting position after WT. A period of 50 minutes for resting is based on the fact that an increase of blood flow following WT to the forearm is maintained approximately for 45 minutes[1]. The other two post-treatment conditions were, 1) CMP in sitting for 10 minutes followed by final volumetric measurement, and 2) CMP in sitting for 20 minutes followed by a final volumetric measurement. The method for CMP was the same as that used for WT. The reason for choosing 10 and 20 minutes of CMP was so that the results could be compared with those of 10 and 20 minutes of sitting.

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 into 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, 16.3 ℃ ranging from 8.4 ℃ to 25 ℃. Considering the intra-day variability of the lower leg volume, the experiment was carried out between 1600 and 2000 hours.

Statistical Analysis

The data were analysed using the Student's t-test. A comparison of the lower leg volumes was made before and after WT with and without the CMP, during five 10-minute intervals in standing and sitting, and with and without the CMP in sitting for 10 and 20 minutes following WT. The level of statistical significance was set at 0.05.

RESULTS

WT both with and without the CMP for all the experiments resulted in a significant increase in the limb volume. Specifically, the mean limb volume for the WT condition before treatment was 2,905 ml and for

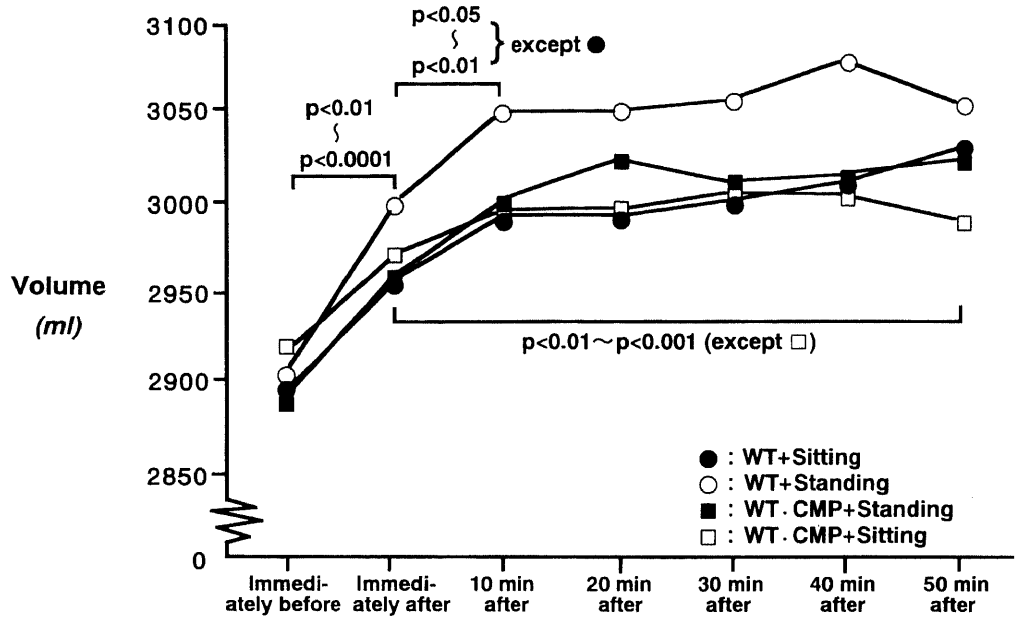

Fig. 2 Change in limb volume before and after whirlpool therapy (WT: whirlpool therapy; CMP: calf muscle pumping)

the WT • CMP condition before treatment 2,895 ml, for the WT condition after treatment 2,973 ml and for the WT • CMP condition after treatment 2,959 ml. Consequently, the mean volume increase was 68 ml for the WT condition and 60 ml for the WT • CMP condition. But the difference in increase was not statistically significant.

The limb volume for the first post-treatment 10-minute interval showed a significant increase for all the conditions except for the WT condition followed by sitting (Fig. 2).

The limb volume decreased in the final 10-minute interval to the immediate post-treatment level only in the condition for which the participant did CMP during WT followed by sitting (Fig. 2).

In comparing the two resting positions, the increase in limb volume with the WT condition followed by sitting was significantly smaller than that obtained by the WT condition followed by standing during the entire post-treatment period except for the final 10-minute interval (Table 1). However, there was no significant difference in the limb volume between post-treatment standing and sitting in the condition with WT • CMP (Table 1). Thus, the condition with WT • CMP followed by sitting showed least swelling up to the fourth 10-minute period, followed by the conditions with WT • CMP followed by standing, WT followed by sitting, and, finally, WT followed by standing (Fig. 2).

The result of 10 and 20 minutes of CMP and the resting position in sitting after WT is as follows: Compared to the immediate mean post-treatment volume for the condition with WT, the mean limb volume increased by 22 ml for the 10 minutes of CMP, by 25 ml for the 10 minutes of sitting, by 13 ml for the 20 minutes of CMP, and significantly by 28 ml for the 20 minutes of sitting. Further, compared to the immediate mean post-treatment volume for the condition with WT • CMP, the mean limb volume increased by 19 ml for the 10 minutes of CMP, significantly by 24 ml for the 10 minutes of sitting, again significantly by 40 ml for the 20 minutes of CMP, and again significantly by 29 ml for the 20 minutes of sitting. The summary of these findings is shown on Table 2.

DISCUSSION

A few comments can be derived from these findings: 1) There may be 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

Table 1 Summary table comparing increase in the limb volume rate of 20 participants according to resting positions following whirlpool therapy (WT: whirlpool therapy; CMP: calf muscle pumping; NS: non-significant)

Experimental Conditions	Whirlpool Therapy						
	Immediately before	Immediately after	10 min after	20 min after	30 min after	40 min after	50 min after
WT							
Sitting vs. Standing	NS	NS	p<0.05	p<0.05	p<0.05	p<0.05	NS
WT · CMP							
Sitting vs. Standing	NS	NS	NS	NS	NS	NS	NS

WT : whirlpool therapy; CMP:calf muscle pump
NS : non-significant

Table 2 Mean limb volume of 20 participants (ml) according to length of time sitting and calf muscle pumping (WT: whirlpool therapy; CMP: calf muscle pumping; Sitt: sitting; NS: non-significant)

Limb volume of 20 subjects in *ml* (mean)

	WHIRLPOOL THERAPY			WHIRLPOOL THERAPY · CMP		
	pre-WT	immediate post-WT	post-WT CMP/Sitt	pre-WT	immediate post-WT	post-WT CMP/Sitt
10-min CMP	2914	2970	2992	2875	2935	2954
	p<0.01	p<0.01	NS	p<0.01	p<0.01	NS
10-min sitting	2903	2963	2988	2919	2972	2996
	p<0.01	p<0.01	NS	p<0.01	p<0.01	p<0.05
20-min CMP	2907	2958	2971	2901	2964	3004
	p<0.01	p<0.01	NS	p<0.01	p<0.01	p<0.05
20-min sitting	2903	2963	2991	2919	2972	3001
	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01	p<0.05

WT: whirlpool therapy; CMP : calf muscle pump; Sitt: sitting
NS: non-significant

vigor of the CMP might not have been optimal so as to 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 and causing pressure on its posterior aspect during WT and so inhibiting venous and lymph return to the thigh.

The limb volume increased, on average, by 1.8 %, whereas, in McCullock et al's WT at 40 ℃, it was by 3.7 %[8], which was more than double the amount shown from the authors' experiment with an increased water temperature of 2 ℃. This finding possibly demonstrates a lowered sensitivity of Japanese people's vasomotor response to warm water compared to the American's. This may be regarded as a culturally-derived conditioned reflex.

Swelling generally continues to increase for a further 10-minute period following WT. Thus, these findings demonstrate that CMP during WT does not seem to have a direct effect on the volume of the lower leg, although the authors hypothesised other-

wise before the experiment. The fact that swelling could not be prevented even in normal individuals during WT while, at the same time, performing the CMP should sound a warning for such a treatment to clients with circulatory disorders of their lower leg. There was, however, a tendency for the limb volume to be less for the conditions when using the CMP than when only sitting was carried out for the post-treatment conditions, together with 10 minutes of CMP and the resting position in sitting, but there was no significant difference between the two. In contrast to these conditions, the tendency was opposite in effect for both of the post-treatment conditions with 20 minutes of CMP and resting in sitting. But again, there was no significant difference between the two treatment conditions. Further, the limb volume showed no significant increase in three out of four post-treatment conditions with CMP in contrast to only one out of four post-treatment conditions with sitting only. Therefore, post-WT combined with CMP may be effective in decreasing swelling. When the four different post-WT conditions for both treatment conditions were compared, there was no significant difference in limb volume. Therefore, the CMP during WT followed by sitting may be effective in keeping swelling to a minimum.

CONCLUSIONS

Based on all the results of this study, it can be concluded that: 1) The CMP during WT does not prevent swelling of the lower limb; 2) Japanese and American people's vasomotor response to warm water is possibly different; 3) Swelling continues to increase for the first 10-minute period following treatment, but WT combined with CMP lowers the rate of this post-treatment swelling; 4) Sitting is the preferred resting position compared to standing for the post-WT period; and 5) CMP for 10 minutes following WT reduces swelling. Therefore, CMP during whirlpool therapy and 10 minutes of CMP in sitting after treatment may be recommended to reduce post-WT 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. Because WT is often applied to clients with circulatory disorders or decompensation of the circulatory system, attention should be paid to the possible danger of it.

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渦流浴中の下腿三頭筋の筋ポンプ作動と渦流浴終了後の休憩姿勢の下腿容積に対する影響

荻原新八郎，立野　勝彦，灰田　信英，濱出　茂治
洲崎　俊男，浅井　　仁，山崎　俊明，三秋　泰一

要　　旨

渦流浴，ふくらはぎの筋ポンプ作動および休憩姿勢と下腿以下の容積との関係を検討した。渦流浴の実施中に筋ポンプを作動しても下腿以下の容積は大きくなり，それは休憩の最初の10分間増大し続けたが，渦流浴終了後のそれは，筋ポンプを作動させない場合に比べて小さかった。渦流浴終了後の休憩姿勢については，立位よりも椅座位の場合の下腿の容積が小さかった。また渦流浴終了後に椅座位で10分間筋ポンプを作動させると，20分間のそれに比べて下腿の容積は小さかった。ゆえに渦流浴の実施中に筋ポンプ作動，そして終了直後に椅座位で10分間の筋ポンプ作動が推奨される。