# Effect of Warmed Whirlpool on Symptoms of Exercise-Induced Muscle Damage
# 熱水療對運動後肌肉損傷的影響

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## Abstract

Exercise-induced muscle damage, also called DOMS, is soft tissue injury after strenuous exercise. There are many ways of treatments on DOMS. Hydrotherapy is one of the effective treatments for DOMS. The mechanism of hydrotherapy on DOMS is unclear. Therefore, the purpose of the study was to assess the effects of warmed whirlpool immersion on the symptoms of DOMS following strenuous eccentric exercise. After performing a bout of damage-inducing eccentric exercise of the elbow flexors on a Biodex, 22 females were randomly assignment into a control group, CG (n=11) and hydrotherapy group, HG (n=11). HG immersed their exercised arm in warmed water (41°c) for 10 min immediately after eccentric exercise and then every 12 h for 15 min, seven sessions. Plasma creatine kinase (CK), relaxed elbow angle (REA), muscle soreness index (MSI) and swelling were measured immediately before eccentric exercise and 3 day afterward, respectively. Analysis of variance revealed significant ($p < .05$) main effects on time for all variables, with increases in MSI, CK, upper arm circumference (URC) and decreases in REA. There were significant interactions ($p < 0.01$) between group and time for REA and CK. REA was greater and CK was lower for the HG than the CG on day 2 and day 3 following the eccentric exercise. We concluded that heated whirlpool immersion might reduce muscle stiffness, CK and increase REA.

## 摘 要

運動引起的肌肉損傷，也稱為運動後延遲性的肌肉酸痛，簡稱為DOMS，為一種劇烈運動後的軟組織損傷。處理DOMS的方法很多，但熱水療的方法卻是處理DOMS非常有效的方法。熱水療對DOMS的效果並不清楚。因此，本文主要在探討熱水療對運動後產生肌肉酸痛的影響，受試者經實施屈肘離心運動後，22位受試者隨機抽樣分配成熱療組及控制組。熱水療組於離心屈肘運動後，將運動肘浸泡在水溫維持在41℃的熱水中10分鐘後，分別於運動前、運動後立即、運動後24小時、運動後48小時、運動後72小時，分別測量肘關節活動範圍、血漿肌酸激有活性、腫脹及肌肉酸痛指數。經分析發現在運動後各期間的DOMS、血漿肌酸激有活性及腫脹隨時間增加而增加；肘關節活動範圍及血漿肌酸激有活性在組別及時間上有交互作用，且其交互作用是運動後的48小時及72小時熱水療組肘關節活動範圍較大，而血漿肌酸激有活性較低，顯示熱水療於離心性運動後關節活動範圍增加、減少肌酸激有活性與降低肌肉酸痛指數。

## Introduction

Exercise-induced muscle damage, delayed onset muscle soreness (DOMS), consisted of a dull aching pain, stiffness, tenderness, and a prolonged loss of muscle strength that commonly occurred after strenuous eccentric muscle action. The DOMS was tended to develop within the first 24 h post-exercise, peak between 24 and 72 h, and then subside after 5-7 days (Armstrong, 1990; Cleak & Eston,1992; Nosaka & Clarkson, 1995). Muscle damage included disruption of the sarcolemma, fragmentation of the sarcoplasmic reticulum, lesions of the plasma membrane, cytoskeletal damage, and swollen mitochondria (Armstrong, 1990; Friden & Leiber, 1992; Stauber, 1989).

Additional symptoms of exercise-induced muscle damage included swelling and a decrease in the range of motion. Studies on the arm had observed an increase in volume (Talag, 1973), circumference measurements (Cleak & Eston, 1992; Friden et al., 1988; Nosaka & Clarkson, 1997), and a decrease in active and passive range of elbow flexion and extension (Clarkson & Newham, 1994). Meanwhile, when the arm was hanging in a relaxed position, the elbow angle was significant reduction (Clarkson & Newham, 1994; Cleak & Eston, 1992; Nosaka & Clarkson, 1997).

Fifty percent of the body submersion under warm water more than 20 min could significantly increase blood flow to the heated area and raise core temperature as much as 2℃ (Kirk & Kersley, 1968). Local muscular circulation increased due to water agitation and the heat transmitted to the injured area. Muscular circulation was changed by a reduction in congestion, spasm, and pain. Pain was reduced as a result in releasing endorphin from the free nerve endings. This was known as the gate theory of pain control (Clarkson & Newham, 1994; Friden & Leiber, 1992). Heat was also believed to lessen swelling and inflammation by increasing cellular metabolism, lowering PH level, increasing capillary permeability and releasing vasodilators such as histamine and serotonin. Heat could decrease tissue ischemia by means of vasodilatation. The resultant increase in blood flow will increase oxygen and nutrients to cells near the damaged area (Prentice, 2002).

The effects of heat and cold therapy, in conjunction with stretching exercise on DOMS symptoms was published by Prentice (1982), who observed a combination of cold treatment and stretching on DOMS and found it was the most effective method. Another applied technique mostly in research settings because of its ability to control the temperature while it was immersion in heated water. However, as far as we were aware, this form of hydrotherapy had not been used in human studies due to tissue swelling on muscle damage resulting from exercise. The aim of this study was to assess the effects of heated whirlpool on symptoms of DOMS after a strenuous bout of eccentric exercise.

## Materials and Methods

Twenty-two female student volunteers (aged 14.10±0.70 years; height:168.20±6.30cm; weight: 59.30±6.90 kg) at the junior high school of Chung-ching, Taipei, signed the informed consent prior to the study. After a bout of eccentric exercise on the elbow flexors of the dominant arm, the participants were randomly assigned into a hydrotherapy treatment group (HG) or a control group (CG). The symptoms of DOMS were compared to baseline values over a period of 3 days.

### The Bout of Damage-inducing Exercise

The bout of eccentric exercise consisted of four sets of ten maximal contractions (eccentric and concentric) by Biodex. This was similar to other muscle damage-inducing protocols (Gulick et al., 1996; Nosaka & Clarkson, 1995).

### Hydrotherapy

The HG submerged their exercised arm (ensuring that the origins and insertion of the biceps were fully submerged) into a whirlpool of water for 20 min (Prentice, 2002). The water was maintained at the recommended temperature of 41±1°c (by adding ice cubes, cold or hot water, previously practiced in a pilot study) to elicit a increase in intramuscular temperature of about 5-10°c (Prentice, 2002). This treatment was applied immediately post-exercise and every 12 h thereafter for a duration of 3 days.

### Measurements of DOMS

The criterion of evaluation on DOMS included the plasma CK activity, elbow flexors, REA, local muscle tenderness and UAC. The data were recorded immediately after exercising, and then every 24h till 3 days.

### Plasma CK activity

Plasma CK activity was measured from a fingertip blood sample. A warm fingertip was cleaned with a sterile alcohol swab and allowed to dry. Capillary puncture was token 30μl whole blood from the fingertip and analyzed it by using a spectrometric absorption (Kodak Ektachem DT-SC, America).

### REA

The exercised arm was fully flexed and then activity extended into a relaxed position. The angle was recorded using a transparent goniometry, an indirect method of measuring muscle stiffness and soft tissue shortening that had been used previously (Cleak & Eston, 1992; Nosaka & Clarkson, 1997).

### MSI

Muscle soreness index (MSI) was measured by algometry (Imada, Japan) at sitting position (Chen, 2000). The subject was ratted the visual analog scale when they felt the sensation change from discomfort to pain after 5kg probe pressure into the same mid-belly site of biceps (Prentice, 2002). Accurate placement of the probe was assured by a pen mark at the mid-belly site. The mean of three trials was recorded as the soreness index.

### Swelling

An anthropometric tape measure was used to determine the upper arm circumference at the mid-belly of the biceps. The mean of three trials was recorded as the swelling score.

### Data Analysis

Two-way ANOVA mixed design was used to test the difference between two groups. CK activity was converted to natural log values to satisfy the assumptions of homogeneity of variance necessary for the analysis. The homogeneity of covariance was tested by the Mauchly sphericity test. If it were significant difference as in the case of the CK activity, the Greenhouse-Geisser epsilon was then used to adjust the degrees of freedom to increase the critical value of the F-ratio. Turkey post-hoc comparisons were applied to determine between-the mean differences if the analysis of variance revealed a significant main effect for time or interaction of group and action time.

## Results

The results for both the HG and CG are shown in Table 1.

### REA

The CG had a significantly lower REA than the HG ($p<.01$). There was a significantly interaction between the group and action time ($p<.01$) (Fig. 1). A significant decreases in REA for HG was higher than those of CG to difference periods of change post exercise test.

**Table 1. The CK, REA, Muscle Soreness Index, and Arm Circumference between Two Groups.**

| Variable | Baseline | Post-test | 24 h | 48 h | 72 h |
|---|---|---|---|---|---|
| **CK (mg/dl)** | | | | | |
| Hydrotherapy | 130.9 ± 26.7 | 220.6 ± 22.7 | 174.4 ± 37.2* | 155.8 ± 42.4* | 165.5 ± 59.1* |
| Control | 133.2 ± 20.6 | 218.5 ± 22.4 | 288.8 ± 29.6 | 369.0 ± 91.9 | 560.9 ± 127.4 |
| **REA** | | | | | |
| Hydrotherapy | 175.3 ± 3.4 | 165.2 ± 3.6 | 161.7 ± 3.0* | 173.1 ± 4.6* | 175.2 ± 4.0* |
| Control | 176.0 ± 4.2 | 156.5 ± 5.8 | 135.4 ± 4.7 | 126.0 ± 4.7 | 137.5 ± 11.6 |
| **MSI** | | | | | |
| Hydrotherapy | 1.2 ± 0.15 | 4.5 ± 0.2 | 5.6 ± 0.3* | 2.3 ± 0.4* | 1.5 ± 0.2* |
| Control | 1.2 ± 1.45 | 4.7 ± 0.2 | 8.5 ± 0.7 | 7.4 ± 0.3 | 5.5 ± 0.2 |
| **UAC (cm)** | | | | | |
| Hydrotherapy | 25.0 ± 2.6 | 25.4 ± 2.6 | 25.5 ± 2.6 | 25.5 ± 2.6 | 25.3 ± 2.6 |
| Control | 25.1 ± 2.6 | 25.5 ± 2.8 | 25.5 ± 2.8 | 25.5 ± 2.7 | 25.3 ± 2.5 |

Abbreviation: CK= creatine kinase activity, *: $P< .05$.

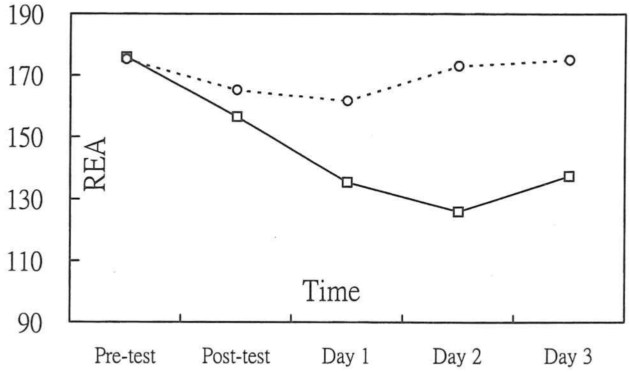


**Figure 1. REA of the HG(O) and the CG ( ) immediately before and 3 day after strenuous eccentric exercise of the elbow flexors (mean±SD). The REA for the CG were lower than both the baseline values and the HG on day 3 (p<.01).**

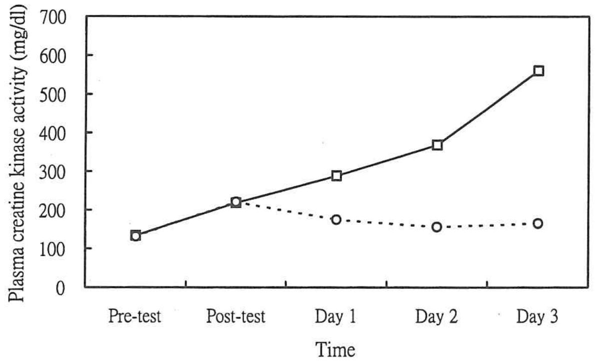


**Figure 2. Natural log values for plasma CK activity for the HG (O) and the CG ( ) immediately before and 3 days after strenuous eccentric exercise of the elbow flexors (mean±SD). The CK activity of the CG were higher than baseline values and the values for the HG by day 3 (p<.01).**

## Swelling: UAC

No difference was found on the swelling score between two groups. However, CG had tendency of swelling at arm circumference. There was an interaction between the group and action time. Figure 1 was shown an interaction on relaxed armed angle ($p< .05$) between two groups. Only CG was lower than HG on day 3 after Turkey post-hoc t comparisons.

## CK activity

There was a significant main effect for action time between two groups. Turkey post-hoc comparisons were shown the CK activity significantly higher than pre-test ($p<.01$) on day 3. There was also a significant interaction between group and action time (Fig. 2).

## MSI

There was a significant main effect for time on muscle tenderness ($p<.01$). Tenderness values were significantly higher than baseline values on day 1 and remained above baseline values on day 2 and day 3. There was an interaction between group and action time muscle soreness.

## Discussion

The DOMS result in the study was quite similar with previous studies (Cleak & Eston, 1992; Friden et al., 1988; Howell et al., 1993; Newham er al., 1983; Newham & Jones, 1985; Nosaka & Clarkson, 1997; Yackzan et al., 1984). One of the possibilities is because of the soft tissue injury, which might induce muscle soreness that leads muscle swelling. If it were true, the REA for the CG on day 3 was decreased greatly is true. Warm hydrotherapy, in turns, might increase muscular extension and the connective tissue became shortened after strenuous eccentric exercise.

The overall decreased in REA for the CG on day 3 was similar to the finding by Cleak and Eston (1992). Some investigators had concluded the muscle shortening due to an abnormal calcium ions increased in muscle cell (Armstrong, 1984; Clarkson & Tremblay, 1988; Ebbeling & Clarkson, 1989; Newham et al., 1985). Increase or loss calcium ions might detrimental membrane potential caused lose muscle contraction function after damage exercise. The other reason of DOMS was probably caused by an inflammatory reaction that was mentioned by many researchers (Assmussen, 1956; Stauber, 1989). No one would use the warmed water as a treatment on DOMS recently due to it might detrimental muscle tissue. The warmed water as a therapy because it had been found to reduce pain , increase blood flow and enhance the healing process by speeding cellular metabolism and flushing out cellular infiltrates (Kirk & Kersley, 1968; Prentice, 2002). Not many researchers utilized the warmed water to treat the exercise-induced muscle damage due to this treatment might cause the muscle injuries. The present study showed that REA, CK, and MSI were better than the baseline measurements. Some researchers, such as Francis & Hoobler (1987); Friden et al. (1988); Talag (1973) felt it might increase muscle blood flow, which decreased limb motion, increased pressure on nerve endings that were responsible for pain perception.

In conclusion, the warmed hydrotherapy tended to reduce the DOMS, CK activity, and REA after strenuous eccentric exercise. However, this result might be different due to subjects, age, gender, or warmed water immersed time, etc. Further researches needed to do more on these areas.

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