

# The Effect of Cold-Water Immersion on Fatigue, Stress, and Autonomic Nervous System Activity of Body Fatigue Recipient

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**Abstract.** This is a quasi-experiment study aimed to develop an effective intervention method for fatigue by analyzing the effect on fatigue degree, stress index, and autonomic activity. Cold-water immersion, targeting the legs, was applied in university students with body fatigue induced by treadmill exercise. By roll of dice, 20 healthy students recruited from August 3 to 28, 2015, were assigned to either the experimental or the control group. Students with an odd number were assigned to the experimental group and received cold-water immersion, and those with an even number were assigned to the control group and did not receive cold-water immersion but had static rest. The study results indicated that the experimental group showed a significant positive differences in psychological fatigue ( $F= 6.79, p=.019$ ), stress index ( $F= 9.70, p=.006$ ), and autonomic nervous system activity ( $F= 8.03, p=.011$ ).

**Keywords:** Foot Bath, Cold-water Immersion, Fatigue, Stress, Autonomic nervous system activity

## 1 Necessity

Exercise should be regularly conducted, but many people discontinue exercise because the process is hard and exhausting. An advanced research study reported that more than 50% of people who start to exercise fail after 6 months, so intervention to reduce the feeling of fatigue is important [1]. Fatigue is a phenomenon everyone experiences and is caused by continuous and repetitive mental and physical works.

Thus, it is defined as tiredness, loss of vitality, and decline in the ability to conduct work or leisure activity [2]. In spite of the many research studies already conducted, the exact cause of fatigue has not been determined but may include mental disease, drug side effects, infection, chronic fatigue syndrome, and idiopathic chronic syndrome. It is reported to be related to autonomic nervous system activity [3].

Cold-water immersion immediately minimizes bleeding or edema by contracting blood vessels and reduces inflammation by reducing the intracellular metabolic rate. Thus, cold-water immersion has a positive effect in terms of relief from muscle

fatigue. In addition, it is safer than other interventions, has great effect with a small outlier, and is a simple medical treatment [4].

The American Academy of Orthopaedic Surgeons(AAOS) divided the pathophysiologic effects of cold-water immersion into hypothermia, decreased metabolism, easing of inflammation, circular effect, easing of pain and muscle cramps, and aggravated charley horse [5]. Serban reported that cold-water immersion is a fatigue recovery method that promotes reduction in the excitation of the central nervous system and removal of metabolites, unlike the fatigue recovery method using massage to promote circulation of capillary arteries and to relieve the tonus of muscle, or electrical stimulation and supersonic wave treatment [6].

Most advanced research studies were about cold-water immersion, and interventions for pain relief [7] and easing of arthritis [8] are insufficient. Therefore, this study aimed to offer basic material for development of nursing interventions that can be applied for body fatigue by providing better understanding of the effect of cold-water immersion on fatigue level, stress, and autonomic activity.

## **2 Study Methods**

### **2.1 Study Subjects**

The study subjects were selected among volunteers at S University in Seoul, South Korea. The inclusion criteria included non-use of a psychoactive drug, absence of any cardiac disorders such as angina, and orthopedic or neurological diseases.

The subjects who agreed were assigned to either groups by throwing a dice at random. Those who got an odd number were assigned to the experimental group and received cold-water immersion for 5 minutes, and those who got an even number were assigned to the control group and did not receive cold-water immersion but underwent a static rest.

### **2.2 Progress of the Study**

This study was conducted from August 3 to 28, 2015. After induction of fatigue by exercise on a treadmill for 10 minutes, the fatigue level, autonomic nervous system activity, and stress index were measured. The subjects in the experimental group underwent cold-water immersion for 5 minutes while comfortably sitting in a chair. The control group did not undergo cold-water immersion but took a static rest for 5 minutes. After the rest period, fatigue level, autonomic nervous system activity, stress index, and vital signs were measured again.

### **2.3 Induction of Fatigue**

Muscle fatigue is divided into different levels. In this study, the subjects exercised at level 3 body fatigue, which is equivalent to a “backbreaking job” according to the job step energy-consuming rate, by using a treadmill). The speed of the treadmill was set at 140.0 m/min (8.4 km/h) for men and 133.3 m/min (8 km/h) for women, with 3% of tilt for 10 minutes.

### **2.4 Measuring Instrument**

#### **2.4.1 Subjective Measurement of Fatigue Level**

After exercise and intervention, the subjects in both the experimental and control groups were assessed by using the VAS on a 10-cm horizontal plane. The left starting grade of the scale is 0, with an operant definition of “slight condition without fatigue.” The right end of the scale is 10, defined as “intolerably tired condition.”

#### **2.4.2 Measurement of Stress Based on Autonomic Nervous System Activity**

In this study, measurement of autonomic nervous system activity was based on the electrical activities of the sympathetic and parasympathetic nerves of the heart, which affect the sinoatrial node. Electrocardiographic (ECG) signals were analyzed by using a non-invasive HRV measuring instrument (SA6000, Medcore, Korea).

### **2.5 Cold-water Immersion**

After inducing artificial fatigue, the feet of the subjects in the experimental group were soaked in a plastic basin filled with cold water for 5 minutes. The water temperature was measured by using an infrared thermometer (M700, Benetech, China). After setting at 15°C, the temperature was maintained by putting ice cubes in the water bath.

### **2.6 Data Analysis**

For the statistical analyses, IBM SPSS Ver. 21 was used. Analysis, of comparison before and after of the examination between the experimental and control groups, was made by analysis of covariance after controlling the preliminary grade.

### 3 Results

#### 3.1 Effects of Cold-water Immersion on Autonomic Nervous System Activity and Stress index

In the analysis of autonomic nervous system activity after cold-water immersion, the stress index ( $F= 9.70, p = .006$ ) of the experimental group decreased in comparison with that of the control group. Autonomic nervous system activity ( $F= 8.03, p = .011$ ) of the experimental group increased significantly (Table 1).

**Table 1.** Comparison of stress index and autonomic nervous system activity after exercise

group	Experiment group	Control group	F	p
	Mean( $\pm$ SD)	Mean( $\pm$ SD)		
Stress index	132.61 (137.51)	284.95 (145.14)	9.70	.006
Autonomic nervous system activity	77.30 (14.26)	62.50 (6.87)	8.03	.011

#### 3.2 Effects of Cold-water Immersion on Fatigue Level

Regarding fatigue level, psychological fatigue ( $F= 6.78, p = .019$ ) of the experimental group decreased significantly in comparison with those of the control group (Table 2).

**Table 2.** Comparison of fatigue after exercise

group	Experiment group	Control group	F	p
	Mean( $\pm$ SD)	Mean( $\pm$ SD)		
Psychological Fatigue	3.19 (0.84)	5.38 (1.91)	6.78	.019

### 4 Discussion

In this study, when cold-water immersion was applied after inducing fatigue by using a scientific method and the same exercise intensity on a treadmill, the fatigue level,

stress, and autonomic nervous system activity of the experimental group showed significantly greater positive changes than those of the control group.

In a study of Deokbun Lee [9] about the effect of cold-water immersion on lactic acid concentration, lactic acid concentration of the control group decreased by 49.3%, but that of the experimental group decreased by 67.6%. Decreased lactic acid concentration means decreased fatigue. This result supports the finding that the fatigue level of the experimental group decreased more significantly than that of the control group in this study. Fatigue level was more significantly reduced after cold-water immersion because cold water contracts expanded blood vessel, thereby stabilizing blood circulation and oxygen supply to muscles, disassembling lactic acid.

The autonomic nervous system maintains body homeostasis through antagonism of the sympathetic and parasympathetic nerves. This is why defense mechanism is in maintaining homeostasis. Under a stressful condition, catecholamine is secreted by invigorating the sympathetic nerve according to the defense mechanism, and blood pressure and heartbeat increase. These increase the oxygen supply in the musculoskeletal system. However, if invigoration of the sympathetic nerve continues, the autonomic nervous system becomes unstable, decreasing the possibility of recovery of elasticity, which then becomes a new cause of stress, initializing the vicious circle [10]. This study suggests that cold-water immersion relieves excitation of the central nervous system and then stabilizes the autonomic nervous system activity, thereby decreasing the stress index.

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