Intervention Effect Study on Recovery Effect of Cold Bath after Resistance Training

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Abstract. In sports practice, cold water baths are increasingly used by athletes and practitioners to relieve post-exercise fatigue and accelerate the recovery of physiological functions and athletic ability. Various cold bathing schemes with different water temperature and time combinations used in previous studies can all produce a certain recovery effect, but it is still difficult to determine the appropriate cold bathing scheme that is conducive to short-term recovery. Its relatively good recovery effect is sought under the condition that the time combination is controlled. The purpose of this paper is to investigate the effect of an intervention on the recovery effect of cold water baths after resistance training. The research in this paper will use literature method, experimental method and mathematical statistics method to sort out the existing literature data, and carry out experimental research on the basis of the existing research results. Physiological function and the recovery effect of the ability to exercise again in a short period of time, explore its mechanism, and provide a reference for the practical application of cold water bathing. Experiments have shown that different cold bath programs have different intervention effects after resistance training, which can increase the recovery effect by about 10% and shorten the recovery time.

Keywords : Cold Bath, Resistance Training, Intervention Effect, Recovery after Training

1. Introduction

For all kinds of sports participants, physical function needs to be adequately recovered after heavy-duty exercise. If fatigue accumulates for a long time without effective recovery, it will not only cause adverse effects on body function, but also increase the risk of sports injury. Therefore, efficient means of alleviating fatigue is particularly important. Improving the efficiency of recovery in a limited time is one of the necessary ways to avoid sports injuries, and it is also a common problem faced by all sports participants. Today, there are endless ways to relieve fatigue, and there are various means, but each method has its advantages and disadvantages. According to the characteristics of different sports, athletes of each sport and even each individual should have different recovery methods. Only by finding the best recovery method can the best recovery effect be achieved [1-2] .

In the research on the intervention effect of cold bath on the recovery effect of resistance training , many scholars have studied it and achieved good results, for example : Moghadam BH et al found that compared with the control group (-16.5%), TWI (30min in water at 29°C) helps maintain peak leg muscle power (-4.1%) after 24h downhill running [3]. Japilus S investigated the effect of 45-60min high-intensity swimming interval training 10h after high-intensity interval running on the recovery of running performance in triathletes [4].

The research in this paper will use literature method, experimental method and mathematical statistics method to sort out the existing literature data, and carry out experimental research on the basis of the existing research results. Physiological function and the recovery effect of the ability to exercise again in a short period of time, explore its mechanism, and provide a reference for the practical application of cold water bathing.

2. Research on the Intervention Effect of Cold Water Bath on the Recovery Effect after Resistance Training

2.1 The Effect of Cold Water Bath on Physiological System Function

(1) The effect of cold bath on blood flow

Studies have shown that cold baths can constrict blood vessels in the skin of the legs by 40-50% compared to PAS, resulting in reduced blood flow to the skin of the legs. Blood vessels will passively shrink after being stimulated by cold. The skin, as the organ most directly exposed to cold water, has the most obvious vasoconstriction. Constricting blood vessels will cause blood to flow back

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into the heart to maintain body temperature at the core of the body [5-6] .

Hypothermia induces peripheral blood reflux, stimulates changes in fluid regulation and water balance, and has significant physiological effects on the increase in thoracic blood volume. Acute cold air exposure reduces plasma volume by 7-15% and increases plasma osmolality and sodium concentration. Cold baths can reduce plasma volume by 15-20%, and this hemoconcentration is mainly due to the increased urination caused by hypothermia, and can increase fluid losses by almost twofold. Peripheral vasoconstriction induced by hypothermia increases peripheral vascular resistance and blood pressure, and alters capillary fluid and ion exchange between the intravascular and interstitial spaces. Therefore, hypovolemia during cold stress may be due to the combined effects of increased urine output, concomitant decreased renal reabsorption (occurring at hypothermia), and fluid relocation to the interstitium.

(2) Influence of cold bath on body temperature

When the human body is in a thermoneutral environment, the body regulates body temperature by controlling changes in heat flux and skin vascular tone. When the external ambient temperature decreases, the vasomotor tension of the skin increases (vasoconstriction), and the autonomic response to metabolic energy conversion (thermogenesis) increases. Thermal energy is transferred in the body through several pathways, and during a cold bath , convective heat loss predominates. Body temperature is regulated by a balance between heat accumulation and consumption. Due to the difficulty of performing the necessary experiments in humans, much data must be obtained from animal models. Although these models cannot accurately reflect all the characteristics of human physiology, they also provide a reasonable reference to a certain extent.

Even under normal circumstances, hypothermia produces the most pronounced constriction of blood vessels and reduces heat loss by increasing tissue insulation, reducing heat conduction and peripheral blood flow, and minimizing blood flow from exposure to cold environments. Therefore, this lowers the body surface temperature further, forcing it to get closer to the water temperature during immersion in cold water. The reduction in peripheral blood flow delays cooling of deeper peripheral tissues and establishes a pathway for heat loss. This, combined with the increased heat production that accompanies cooling of the skin, explains why paradoxical increases in core body temperature can be observed early in cold exposure. The duration of elevated core body temperature is directly related to an individual's subcutaneous fat thickness and muscle mass [7-8] .

(3) Influence of cold bath on inflammation, DOMS and EIMD

Cold therapy is a well-established form of acute trauma treatment. Cold baths are commonly used as a treatment for exercise-induced muscle injuries, and the therapeutic effect is generally recognized. Cold baths improve EIMD through several mechanisms including local cooling, hydrostatic pressure, and blood flow redistribution. Studies have suggested that cold baths can promote recovery by reducing muscle edema. Owing to the increased mechanical pressure of the local capillaries, edema hinders the oxygen transfer to the muscle, resulting in an increase in the transport distance between capillaries and muscle fibers, resulting in compromised oxygen exchange efficiency. Cold baths reduce edema by causing vasoconstriction by cold stimulation and hydrostatic pressure, reducing peripheral blood flow and promoting peripheral fluid clearance . Vasoconstriction and hydrostatic pressure effects increase central venous pressure and promote the movement of fluid from the intracellular and extravascular interstitium to the intravascular to increase central blood volume and central blood volume. By promoting the clearance of dead tissue cells and metabolites, the fluid flow from outside to inside the blood vessels is enhanced, thereby promoting recovery from EIMD.

Indeed, the movement of fluids from extravascular to intravascular causes an osmotic gradient inside and outside the cell, which promotes the transfer of cellular debris and necrotic tissue from the local muscle to the central circulation. The decrease in muscle temperature caused by cold stimulation further reduces muscle metabolism, thereby reducing damage due to hypoxic cell death and inflammation.

But the efficacy of cold baths in promoting recovery from EIMD is also controversial. The exercise patterns used to induce EIMD may have an impact on the effectiveness of cold baths in promoting recovery. Cold baths typically do not improve key markers of EIMD , such as infiltration of muscle proteins into the bloodstream, MVC recovery, or reduction of DOMS and swelling. These studies suggest that a cold bath is not effective for EIMD caused by sustained single-joint eccentric exercise, but may be more effective for EIMD caused by intermittent, endurance-based team sports. Even though cold water baths can promote the recovery of MVC after exercise, they cannot fully reflect the recovery of EIMD [9-10] .

2.2 Cold Tolerance

Because prolonged physical activity affects muscle mass and metabolic activity, resistance exercise may also increase the body's ability to tolerate cold. In a cold environment, short-term exercise to generate heat is the most beneficial to the human body. Good resistance provides the body with the ability to maintain high-intensity exercise for a long time, which is very important for maintaining thermal homeostasis in the body.

Resistance training can lead to exercise-induced fatigue, and acute exercise-induced fatigue may lead to thermoregulation dysfunction. The combination of chronic exercise-induced fatigue, decreased sleep, and decreased appetite reduces cold tolerance due to weight loss (reduced tissue insulation) and decreased thermogenic reactivity. However, acute fatigue by itself had little effect on shivering or hypothermia.

2.3 Precautions for Cold Bath

Humans, while generally living in warm and comfortable environments, are endowed with heat tolerance through our behavioral and autonomic thermoregulatory responses, supported by a complex system of receptors, central integrators, afferent and efferent pathways, and effector organs. and cold environment capability. Thermoregulatory responses vary from person to person and are influenced by factors such as age, gender, body composition, exercise and fitness status. Although resistance to cold bath resistance has obvious benefits for recovery and regeneration, potential negative effects, such as non-icy cold damage, seem to be generally not considered. Cold stress can have a rapid and dramatic effect on the body's thermoregulatory system, and the sudden drop in skin temperature caused by cold bath resistance can cause an extremely dangerous " cold shock " reaction. With prolonged cold exposure, excessive cooling of muscles, nerves, and deep tissue can impair the function of the body and thermal effectors, leading to hypothermia and even death.

Reactions elicited by cold exposure and hazards associated with cold exposure are determined by the severity and duration of the cold stimulus . When cutaneous cold receptors trigger strong cardiovascular and respiratory responses, these are most pronounced in the early stages of resistive cold bath resistance , including wheezing responses, uncontrolled hyperventilation, hypertension, and tachycardia. These initial responses to cold soaks constitute " cold shock , " a precursor to drowning and heart problems that can lead to the majority of hypothermia-related deaths[11-12].-

2.4 Algorithm Selection

and class variable $Y=\{Y_1, Y_2, \cdots, Y_m\}$ of each sample data $X=\{X_1, X_2, \cdots, X_d\}$, D can be divided into Y m categories. Considering X and Y as random variables, it is called $P(X|Y)$ the posterior probability of Y, and P(Y) is the prior probability of Y. According to Bayes' theorem, the posterior probability can be determined by the prior probability P(Y), The class conditional probability $P(X|Y)$, and the evidence P(X) represent:

$$P(Y|X)=\frac{P(X|Y)P(Y)}{P(X)} \quad (1)$$

for the class conditional probability in formula (1) $P(X|Y)$: naive Bayes classifier and Bayesian belief network, this paper uses the naive Bayes classifier to calculate the class conditional probability $P(X|Y)$ [11-12] .

$$P(X|Y \approx y)=\prod_{i=j}^{d} P(X_i|Y \approx y) \quad (2)$$

3. Intervention Effect Research Design Experiment on the Recovery Effect of Cold Water Bath after Resistance Training

3.1 Experimental Hypothesis

Research results have shown that when a cold bath (CWI) is performed after exercise, there will be physiological responses such as peripheral vasoconstriction, blood return, systemic blood redistribution, and decrease in core body temperature and body surface temperature. In this paper, three CWI program intervention groups (water temperature 15°C, duration 15min; water temperature 10°C, duration 10min; water temperature 10°C, duration 15min) were compared with the passive recovery group, and the recovery effects were compared among the three CWI program groups. For comparison, the following experimental hypotheses are proposed.

After a one-time endurance exercise:

(1) In the intervention group receiving cold water bath, the heart rate, stroke volume, cardiac output, blood perfusion index, core body temperature and body surface temperature decreased, and the rate of decrease was faster than that of the control group, and the lower the water temperature of the intervention program, the rate of decrease sooner.

(2) In the intervention group receiving cold water baths, the duration of the second exercise was longer than that of the control group, which was basically close to the duration of the first exercise, and the lower the water temperature of the intervention program and the longer the soaking time, the longer the second exercise.

(3) In the intervention group receiving the cold water bath, the sympathetic nerve excitation was inhibited, the parasympathetic nerve excitation was increased, and the lower the water temperature and the longer the soaking time, the more obvious the effect was.

After a one-time speed exercise:

(1) In the intervention group receiving cold water bath, the heart rate, stroke volume, cardiac output and blood perfusion index decreased, and the rate of decrease was faster than that of the control group, and the lower the water temperature of the intervention program, the faster the rate of decrease.

(2) Core body temperature and body surface temperature decreased, and the lower the water temperature of the intervention program, the faster the rate of decrease, but due to the short exercise time and the comfortable room temperature environment, the temperature gradient was relatively low, so the difference compared with the control group may not be significant.

(3) Compared with the control group, the maximum power and average power of the second exercise decreased significantly compared with the first exercise, and the lower the water temperature of the intervention program and the longer the soaking time, the maximum power and average power of the second exercise. smaller.

(4) In the intervention group receiving cold water bath, the excitability of sympathetic nerves was inhibited and the excitability of parasympathetic nerves was increased,

and the lower the water temperature and the longer the soaking time, the more obvious the effect was.

3.2 Experimental Process

This paper then carries out an endurance exercise program or a speed exercise program, and collects relevant indicators immediately after the exercise. 1 hour recovery after exercise, including PAS/CWI(15°C, 15min)/CWI(10°C, 10min)+PAS(5min)/CWI(10°C, 15min), Omegawave physical function test(15min) and PAS(30min)) 3 parts. During the recovery process, relevant indicators were collected at the 5th, 10th, 15th, and 60th minutes, respectively.

4. Experimental Analysis of Intervention Effect Research on the Recovery Effect of Cold Bath After Resistance Training

4.1 Heart Rate Test

This article invites four subjects to perform the cold bath test. Four subjects performed resistance training of the same item and the same duration at the same time, and their heart rates were recorded at the end of the training, so that the subjects were in passive recovery, and 3 different CWI programs (C1, C2, C3), 3 CWI The protocols were C1 (15°C, 15min), C2 (10°C, 10min) and C3 (10°C, 15min), respectively. According to the principle that the lower the water temperature, the shorter the soaking time is, the higher the water temperature can make up for by prolonging the soaking time. Considering the adaptability of the subjects to CWI, the experiments were arranged as PAS, C1, C2, and C3 according to the water temperature and duration in the order of increasing stimulation intensity. The heart rate of the subjects at 5, 10, 15, and 60 minutes was recorded, and the data are shown in Table 1.

Table 1. Heart rate after resistance training in different cold water baths

	0	5	10	15	60
PAS	177.00	111.28	102.57	96.57	87.00
C1	179.42	97.81	94.42	88.14	75.42
C2	177.28	99.14	94.13	92.85	81.42
C3	171.57	97.71	92.57	85.85	83.66

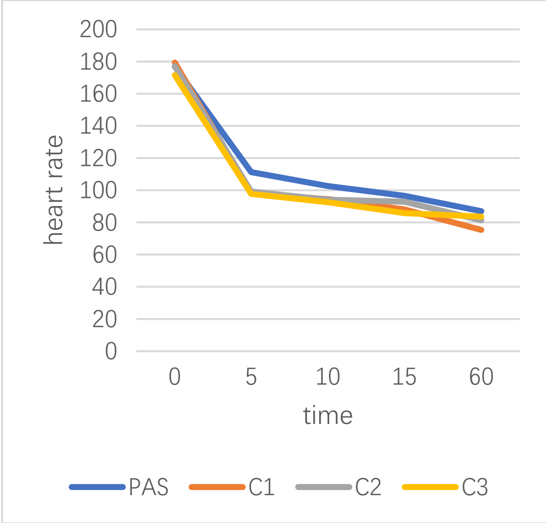

Figure 1.Heart rate after resistance training in different cold water baths

It can be seen from Figure 1 that during the whole experimental process, the four groups of heart rate change curves tend to be consistent. Immediately after the two exercises, the heart rate of the four groups was not significantly different. Only in the recovery phase, the heart rate of the three intervention groups was slightly lower than that of the control group. From the comparison of the heart rate decline rate, the results showed that the heart rate decline rate of the C1, C2, and C3 groups at the 5th, 10th, 15th, and 60th minutes of the recovery phase was higher than that of the control group, but the decline rate of the C1 group was higher than that of the C2 and C3 groups. This result partially supports the experimental hypothesis.

4.2 Core Body Temperature Test

In this paper, four subjects were allowed to perform resistance training with the same item and the same duration at the same time, and their core body temperature was recorded at the end of the training. The subjects were in passive recovery and 3 different CWI programs (C1, C2, C3). , 3 CWI schemes are C1 (15°C, 15min), C2 (10°C, 10min) and C3 (10°C, 15min). The core body temperature of the subjects at 5, 10, 15, and 60 minutes was recorded. The data are shown in Table 2.

Table 2. Recovery of core temperature after resistance training in different cold baths

	0	5	10	15	60
PAS	36.04	35.77	35.90	35.95	36.15
C1	35.85	36.18	36.12	35.93	35.88
C2	35.91	36.21	36.10	36.13	35.82
C3	35.95	36.30	36.17	36.04	35.80

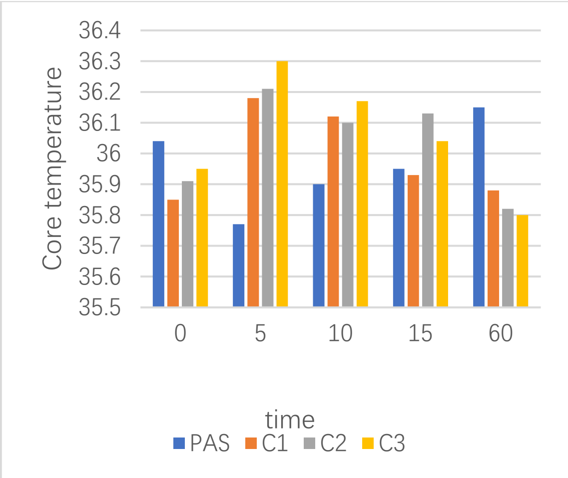

Figure 2. Recovery of core temperature after resistance training in different cold baths

From Figure 2, it can be seen that the core body temperature of the subjects in the quiet state was 35.61±0.57°C, 35.74±0.42°C, 35.68±0.37°C and 35.91±0.19°C, respectively, and there was no significant difference between them. During the whole recovery process, There were no significant differences among the 4 groups.

5. Conclusions

This study draws the following conclusions: Cold showers with different time and temperature combinations have different effects on reducing post-exercise fatigue. Especially for different workouts, a cold shower program should be chosen. After a resistance exercise, a warmer, longer cold shower can be beneficial for training. The low temperature, short-term cold bath is more conducive to the recovery of the nervous system and the function of the nervous system after exercise. The corresponding temperature and averaging time must be selected according to different needs. Cold water has an inhibitory effect on the second exercise of higher intensity in the short term, and the lower the temperature, the more obvious the inhibitory effect. This article is about different cold bath regimens and exercise regimens, and although enough preparation has been done, there are still many regrets. First, the selection of indicators and indicator collection time points is not yet perfect. It is suggested to make improvements in future research, and to simplify indicators, so as to obtain more accurate and meaningful results. Secondly, the exercise program can be more diversified and more closely integrated with the sports specialization, so that the research results can be more targeted. Third, the experimental period is short. This article focuses on the effects of recovery within a short period of time after exercise, and whether exercise capacity is restored or improved within a short period of time after recovery. However, due to the lack of continuous follow-up, we have no way of knowing whether this effect takes longer to manifest, and future studies may consider long-term follow-up studies to explore the long-term effect of cold bathing.

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