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Original Research Article

The Influence of Half-Body Bath on Muscle Fatigue and Electrical Conductance of Meridian - A Study of Elite Baseball Players

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ABSTRACT

This study is to observe the influence of half-body bath on muscle fatigue of baseball players. In addition to the detection of general physiological and fatigue parameters, this study also applies Ryodoraku method to observe the influence of half-body bath on meridian balance. The subjects involved are 18 elite baseball players. It is defined that in a half-body bath, the body is soaked from the foot to the umbilicus, and the water temperature is controlled at 38~40℃. The water bath is taken 3 times a week, 15~20 minutes each time for 6 consecutive weeks. Half-body bath can lower diastolic pressure and raise heart rate and tympanic temperature but has no significant effect on systolic pressure. Hand-grip force, back-life force, and flexibility are significantly improved after half-body bath. Moreover, for those who experience abnormal or unbalanced meridian energy after high-intensity training, half-body bath tends to facilitate the recovery of meridian energy to the normal state. It can be concluded that half-body bath indeed has positive health benefits for baseball player's muscle fatigue and meridian imbalance induced by high-intensity training.

Keywords: Hot water immersion, Meridian energy, Ryodoraku, Athletes

INTRODUCTION

"Water is therapeutic" has always been approved and well-accepted by the general public. When human body is immersed in water, hydrostatic force may facilitate the flowing of venous blood back to the heart and lungs. [1, 2] According to the Frank-Starling law, increase of venous return can enhance the contraction of the heart, which further increases stroke volume. The increase has positive effects on the activities of the heart. It can also enhance the hemodynamic function of patients with cardiovascular disease and further improve their quality of life. [3] The thermal effect of water can help reduce fatigue and tender points. [4, 5] Therefore, four major functions of hydrotherapy can be induced: 1) To improve local blood return, reduce edema and facilitate the expulsion of inflammatory substances; [6] 2) To reduce blood viscosity and circulation resistance; [7] 3) To lower muscle tension and elevate the

pain threshold and tolerance; [4, 8] and 4) To increase the secretion of β-endorphin. [9]

In this study, Ryodoraku instrument is used to detect the electrical conductance of meridian. Ryodoraku method has been developed by Nakatani since 1947. [10] It is conceived that internal physiological conditions will be reflected upon the variation of electric resistance on specific points of human skins (i.e., acupuncture or energy points). By measuring the variation of the electric current, the bioenergy level and distribution can be evaluated. It has been pointed out that fatigue will lower skin conductance, which reflects the variation of body energy. [11] If meridian energy distribution remains unbalanced for a long period of time, disorder of the autonomic nervous system may occur. [12] Serious imbalance can result in a series of neuroendocrine disorders, such as overtraining syndrome. [13] Therefore, this study uses Ryodoraku to evaluate bioenergy abnormality and autonomic imbalance resulted from fatigue by high-intensity training.

Sport players usually use the overload principle to enhance their physical performance, but this training method may easily cause fatigue. Proper recovery leads to super-compensation and improvement of sport performance. But if fatigue keeps building up without proper recovery, overtraining may easily occur in the long run. [14] This problem not only affects a sport player's performance but also causes disorder of the autonomic nervous system, [15] which may be very detrimental to a sport player's health conditions. From the accumulation of fatigue to the appearance of symptoms, the process is progressive and not easily perceived. Therefore, this problem should be emphasized and prevented. The purpose of this study is to examine the benefits of half-body bath for the recovery of elite baseball players from fatigue after regular trainings.

MATERIALS AND METHODS

Subjects and intervention

Eighteen male athletes recruited from baseball team A members of Chia-Nan University of Pharmacy & Science were between the ages of 18 and 21. None had a history of cardiovascular or skin diseases. Each subject gave written informed consent for this experiment according to the protocol approved by the Ethical Committee of I-Shou University. These players regularly receive at least 3 hours/day of training from Monday to Friday afternoons. The experiment is carried out 30 minutes after their training. In half-body bath, the water level is about the umbilicus (stomach level), and the temperature is between 38~40℃. Each bath time lasts 15~20 minutes, and the bath should be taken at least 3 times a week for 6 consecutive weeks. This study aims to compare the physiological changes of the subjects before and after the bath or in different weeks of the experiment. In this experiment, no control group is arranged, because of the following reasons: 1) elite athletes were often justifiably reluctant to participate in controlled studies when we divided them into sham (placebo) group. 2) The coach does not expect the training to be affected by their participation in this experiment. The exercise intensity and training amount of each player may vary by the tasks assigned, so consistency in these aspects cannot be dominated. 3) Setting up a control group of non-athlete males was not feasible because of the difficulty in identifying a suitable group.

Measuring procedures

Basic physiological parameters (blood pressure, heart rate, tympanic temperature) are measured 10 minutes before and within 10 minutes after bath; fatigue parameter (hand-grip force, back-lift

force, flexibility) and meridian parameters are measured 15 minutes before and within 30 minutes after bath. Parameters to be measured are numerous and cannot be entirely collected in each bathing process, so physiological, fatigue, and meridian parameters are respectively measured at the 1st (Monday), 2nd (Wednesday), and 3rd (Friday) experiment every week. Body composition parameters (body mass index, body weight, muscle weight, body fat weight, and total body water) are measured in other time arranged for. Body Composition Analysis (InBoby 3.0, Biospace, Seoul, Korea.) is used to measure these parameters in the 1st, 3rd, and 6th week for the analysis of water bath's long-term effects.

Physiological meanings of fatigue and meridian parameters

The measurement methods for fatigue parameters and meanings are respectively explained as follows: 1) hand-grip dynamometer (JAMAR hydraulic hand dynamometer model J00105, Lafayette Instrument Company, Indiana.) is used to measure the strength of forearm flexors, and the measure represents fatigue loading of local muscles; [16] 2) back-lift strength (Back and leg dynamometer package model 32527A, Lafayette Instrument Company, Indiana.) represents the load on all the body muscles; [17] 3) using sit-and-reach method (Sit and reach flexibility tester, model 01285, Lafayette Instrument Company, Indiana.) to measure flexibility can reflect both central and reflex adjustments to the fatigue-induced contractile failure. [18] All the above measurements are executed by the same physical therapist.

Meridian Energy Analysis Device 4 (ME-PRO, MedPex Enterprises, Taipei, Taiwan.) was used to measure the variations of skin conductance. By measuring (regional) skin resistance, the function of peripheral (regional) autonomic innervation can be evaluated directly. [19] Measurements are made at 24 energy points that lie along the 12 principal meridians. Six points are located on each wrist and six are located on each foot. Analyzing the balance of skin conductance on the test points of each limb to evaluate health conditions is a common method adopted by traditional Chinese medicine doctor. [20] In addition, autonomic nervous system is very easily affected by emotions, ambient temperature, and activities. Therefore, Ryodoraku measurements should be made prudently: 1) the subjects are not allowed to drink any coffee and tea or take any drug; 2) no food can be served within 3 hours before bath, but an adequate amount of water is allowed; 3) before and after bath, the subjects should repose in a quiet environment with stable humidity (50~60%) and temperature (25~26 ^{0}C) to calm down and maintain a steady mood; 5) before reposing, the subjects are required to wipe out the sweats or body moisture with a dry towel.

Statistic analysis

The statistics are presented in mean ± standard deviation. For the collected statistics, student's paired *t*-test will be used to test the variations of parameters before and after bath, and one-way ANOVA would be applied to test the variations in the different weeks of the experiment. All data were analyzed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL) for Windows, version 13 and significance was set at $p < 0.05$.

RESULTS

The average age of the subjects is 19.1±1.0 yrs (n=18); average height is 177.2±4.5 cm; average body weight is 78.3±8.5 kg; average body mass index (BMI) is 25.1±3.2 kg/m^2.

The influence of half-body bath on cardiovascular responses and muscle fatigue status

The subjects' diastolic pressure significantly decreased after bath ($p < 0.001$), but their systolic pressure did not vary significantly. Heart rate and tympanic temperature also significantly increased ($p < 0.001$), as shown in Table 1.

Table 1. The immediate effects of half-body bath on physiological and muscle fatigue parameters (n=18)

		Before bath	After bath
Physiological parameters	Systolic pressure (mmHg)	128.9±11.1	131.5±14.6
	Diastolic pressure (mmHg)	80.6±7.2	75.0±10.1†
	Heart rate (beats/min)	72.6±11.2	87.7±15.7†
	Tympanic temperature (℃)	36.2±0.3	36.9±0.5†
Fatigue parameters	Hand-grip force (kg)	49.6±7.8	50.8±8.4*
	Back-lift force (kg)	150.5±30.9	161.0±31.9†
	Flexibility (cm)	36.3±5.6	37.5±4.8†

Values are expressed as means ± standard deviation.
* $p < 0.05$; † $p < 0.001$, indicating the statistic difference between before and after bath.

In a comparison of fatigue parameters measured before and after bath, it was discovered that the subjects' hand-grip force increased after bath ($p < 0.05$), and their back-lift force and flexibility also significantly increased ($p < 0.001$).

To observer whether the effects of the regular bath process on hand-grip force, back-lift force, and flexibility can be maintained for a long term, we divided the 6-week regular bath process into three periods (1st week, 3rd week, 6th week), to analyze the parameters before bath in each period (Table 2). No significant difference in hand-grip force and back-lift force was observed among the three periods. However, flexibility was significantly improved in the 6th week from 34.5±6.4cm in the 1st week to 37.3±4.1cm ($p < 0.05$) and from 35.6±3.8 in the 3rd week to 37.3±4.1 ($p < 0.05$). This improvement revealed that the 6-week half-body bath process can indeed progressively enhance and maintain body flexibility.

Table 2. The 6-week effects of the half-body bath process on muscle strength and flexibility (n=18)

	The 1st week	The 3rd week	The 6th week
Hand-grip force (kg)	47.4±7.7	46.0±8.0	50.1±9.3
Back-lift force (kg)	135.9±29.4	138.2±22.0	160.8±34.6
Flexibility (cm)	34.5±6.4	35.6±3.8	37.3±4.1*,†

Values are expressed as means ± standard deviation.
Non-significant difference between the 3rd week and the 1st week
*The statistic difference between the 6th week and the 3rd week ($p<0.05$)
†The statistic difference between the 6th week and the 1st week ($p<0.05$)

The immediate effects of half-body bath on conductance and balance of meridians

The mean of the conductance of meridians is the bioenergy, and the normal value ranges from 28~59μA. Subjects with an excessively high value (from 80.4±19.0 to 59.3±17.6μA, n=8, $p < 0.005$) or an excessively low value (from 20.3±7.0 to 34.4±18.0μA, n=3, $p < 0.05$) could have their bioenergy restored to the nearly normal value after water bath. Subjects with a normal bioenergy were not affected (n=7) (Table 3).

A healthy person's meridian system should be in a balanced state. The normal balance ratio (upper/lower, left/right and Yin/Yang meridians) ranges between 0.8 and 1.1. It was discovered that hyper- or hypo-active subjects could have their upper/lower ratio return to a nearly normal level after bathing (from 1.28±0.12 to 0.95±0.15, n=3, $p < 0.005$; from 0.69±0.12

to 0.76±0.14, n=9, $p < 0.05$), but normal subjects (n=6) were not significantly affected. The subjects with a hyper-active left or right meridian system could have their balance ratio return to a nearly normal value after half-body bath (from 1.17±0.06 to 1.05±0.12, n=5, $p < 0.005$; from 0.72 to 0.80, n=1), but those with a normal left/right balance ratio (n=12) were not significantly affected. When Yin meridians had excessive strong functions, half-body bath could help restore the ratio to the normal level (from 1.37±0.29 to 1.04±0.14, n=8, $p < 0.005$). However, subjects with balanced Yin/Yang meridians (n=9) or stronger Yang meridians (n=1) were not significantly affected (Table 3).

Table 3. The immediate effects of half-body bath on the balance of meridian systems (n=18)

		Before bath	After bath
Mean (bioenergy, μA)	＞59 (n=8)	80.4±19.0	59.3±17.6†
	28~59 (n=7)	44.8±10.5	44.4±15.3
	＜28 (n=3)	20.3±7.0	34.4±18.0*
upper/lower ratio	＞1.15 (n=3)	1.28±0.12	0.95±0.15†
	0.8~1.1 (n=6)	0.99±0.07	0.94±0.14
	＜0.88 (n=9)	0.69±0.12	0.76±0.14*
left/right ratio	＞1.1 (n=5)	1.17±0.06	1.05±0.12†
	0.8~1.1 (n=12)	0.99±0.07	0.99±0.08
	＜0.8 (n=1)	0.72	0.80
Yin/Yang ratio	＞1.1 (n=8)	1.37±0.29	1.04±0.14†
	0.8~1.1 (n=9)	0.97±0.08	0.94±0.12
	＜0.8 (n=1)	0.72	0.76
max/min ratio	＞1.5 (n=14)	2.76±1.50	1.85±0.65†
	1.0~1.5 (n=4)	1.34±0.10	1.49±0.31

Values are expressed as means ± standard deviation.
* $p < 0.05$; † $p < 0.005$, indicating the statistic difference between before and after bath.

We analyzed the ratio of max to min values detected on the 24 energy points to evaluate the balance of autonomic nervous functions. The normal ratio ranges between 1.0 and 1.5. It was discovered that imbalance of autonomic nervous functions could be significantly improved through half-body bath (from 2.76±1.50 to 1.85±0.65, n=14, $p < 0.005$), but normal subjects (n=4) were not significantly affected (Table 3).

The 6-week effects of half-body bath on the meridian systems and body composition

In an analysis of the number of subjects whose meridian systems recovered to normal state after 6 weeks of regular water bath, it was discovered that the number of subjects whose max/min ratio returned to the normal value gradually increased from the 1st week (n=3) and the 3rd week (n=5) to the 6th week (n=6). In other aspects, no significant increase in the number of subjects was observed (Table 5). The analysis of experimental data showed that the hypo-active subjects with their upper/lower ratio significantly decreased in the 3rd week but returned to nearly the initial level in the 6th week. Variations of other items were not statistically significant (Table 4).

The records of the variations of the subjects' body composition showed that their muscle weight and total body water did not significantly vary during the 6 weeks (Table 5). BMI, body weight, body fat weight, and body fat ratio started to significantly increase in the third week. However, in the sixth week, except body weight, other parameters, including BMI,

body fat weight, and body fat ratio did not significantly increase.

Table 4. The 6-week effects of the half-body bath process on meridian balance (n=18)

		The 1st week	The 3rd week	The 6th week
Mean (μA)	＞59	82.8±22.1 (8)	81.5±19.0 (8)	77.3±17.4 (10)
	28~59	45.2±10.8 (7)	44.1±12.9 (7)	44.4±11.6 (4)
	＜28	23.8±2.8 (3)	24.5±2.8 (3)	14.5±7.9 (4)
upper/lower	＞1.15	1.37±0.17 (3)	1.23±0.08 (5)	1.28±0.08 (2)
	0.88~1.15	0.96±0.09 (4)	0.99±0.08 (7)	0.98±0.07 (5)
	＜0.88	0.73±0.08 (11)	0.57±0.16*(6)	0.70±0.12†(11)
left/right	＞1.1	1.15±0.04 (4)	1.17±0.04 (8)	1.12±0.03 (2)
	0.8~1.1	1.00±0.06 (14)	0.98±0.07 (10)	0.98±0.07 (15)
	＜0.8	NA (0)	NA (0)	0.72 (1)
Yin/Yang	＞1.1	1.33±0.19 (8)	1.40±0.32 (7)	1.34±0.35 (10)
	0.8~1.1	0.97±0.10 (8)	0.97±0.09 (11)	0.97±0.06 (7)
	＜0.8	0.68±0.16 (2)	NA (0)	0.78 (1)
max/min	＞1.5	2.34±0.71 (15)	2.96±1.60 (13)	3.19±2.17 (12)
	1.0~1.5	1.37±0.09 (3)	1.32±0.07 (5)	1.34±1.12 (6)

Values are expressed as means ± standard deviation (n)
*The statistic difference between the 3rd week and the 1st week ($p<0.05$)
†The statistic difference between the 6th week and the 3rd week ($p<0.05$)
Non-statistic difference between the 6th week and the 1st week
NA＝not available.

Table 5. The 6-week effects of the half-body bath process on body composition (n=18)

	The 1st week	The 3rd week	The 6th week
BMI (kg/m^2)	25.1±3.2	25.7±3.5*	25.8±3.5‡
Body weight (kg)	78.3±8.5	79.8±8.8 *	80.5±8.9†,‡
Muscle weight (kg)	61.2±3.8	61.2±3.9	61.5±4.0
Body fat weight (kg)	13.7±5.6	15.2±5.9 *	15.6±6.3‡
Body fat ratio (%)	17.1±5.6	18.5±5.8 *	18.9±6.3‡
Total body water (L)	44.9±2.8	44.9±2.9	45.1±3.0

Values are expressed as means ± standard deviation.
BMI＝body mass index.
*The statistic difference between the 3rd week and the 1st week ($p<0.05$)
†The statistic difference between the 6th week and the 3rd week ($p<0.05$)
‡The statistic difference between the 6th week and the 1st week ($p<0.05$)

DISCUSSION

The immediate influence of half-body bath on cardiovascular system

It was discovered that 38~40℃ half-body bath could help decrease diastolic pressure, increase heart rate and tympanic temperature. Reduction of blood pressure could be induced by the thermal effect of water, as heat dilates blood vessels and leads to the reduction of diastolic pressure. This effect consequently causes the reduction of blood pressure and increases the heart rate for compensation. The objective of using the thermal effect of water in this study was to accelerate the expulsion of fatigue substances accumulated in baseball players' muscle systems after routine training. Their body functions can rapidly recover. Our finding is inconsistent with the findings of previous studies, [21, 22] mainly due to different objectives of water bath. They discovered that for healthy persons, heart rate is always slower when they are soaked in the water (35℃) than on the ground. According to Pascal's principle, when an object is placed in fluid, the pressure on the object is positive related to the depth of the fluid. Thus, when human body is immersed in water, hydrostatic pressure was largest on the lower limbs, followed by abdomen. This feature can avoid the concentration of venous blood in the lower limbs. According to Frank-Starling law, increase of venous return can enhance the contraction of the

heart, which further induces reflexive bradycardia. [23] The main difference between their study and ours lies in water temperature. They excluded water's thermal effects on enhancement of metabolism, blood circulation, flexibility of muscles and tendons, and the reduction of spasm and fatigue. Their focus was different from that of this study. Therefore, the effect on heart rate would be different.

Bath water temperature is an important factor affecting physiological responses. A previous research performed an experiment on subjects taking a 15-minute bath in 42℃ water. At last, the subjects' heart rate and systolic pressure increased, diastolic pressure decreased, and sublingual temperature reached as high as 39℃. [24] This effect caused adverse burden on the body and did not bring any benefit to fatigue recovery. Therefore, the bath water was controlled at 38~40℃ in our experiment for the optimal fatigue recovery effect.

The effects of half-body bath on recovery from muscle fatigue

It was discovered that the benefits of half-body bath were primarily reflected upon hand-grip force, back-lift force, and flexibility. To verify that the improvement of muscle strength was not resulted from resistance training, we extended our observation to 6 weeks to compare the muscle weight (Table 3), hand-grip force, and back-life force (Table 2) in the periods of the 1st week and 6th week. It was discovered that muscle weight did not significantly vary and hand-grip and back-lift force did not significantly increase, either. This validates that the immediate improvement of muscle strength was induced by the recovery of muscle functions after bath.

Moreover, the findings showed that the regular bath process led to long-term improvement of flexibility in the 6th week. Many studies have pointed out that in addition to fatigue reduction, improvement of flexibility is also one of the important factors that can enhance sport player's performance. [25, 26] Along with flexibility, range of motion can also be increased. The occurrence of sport injuries can thus be reduced. [25]

The immediate effects of half-body bath on meridian systems

It was discovered that after regular training: 1) 61% of the subjects (11/18) had abnormal bioenergy level. Hyper-active levels (>59μA, n=8) were probably attributed to higher sympathetic nervous activity after workout; hypo-active levels (<28μA, n=3) were probably related to fatigue caused by overtraining. 2) 67% of the subjects (12/18) were in the state of imbalance between upper/lower meridians. This was probably related to central fatigue created after regular training. 3) 33% of the subjects (6/18) were in the state of left/right meridian imbalance, and most of them had higher electrodermal activities on the left side of body skins. This was probably because that 94% of them (17/18) are right hand dominant. After a large amount of sport training, fatigue would easily occur to their dominant side (the pitching side). As pyramidal tract is involved in the regulation of electrodermal activities, [27] and somatic motor cortex initiates descending signals to autonomic centers at bulbar and spinal levels, [28] it is reasonable and feasible to measure neuromuscular activity with the variation of skin conductance. 4). Yin meridians (heart, heart constrictor, liver, spleen, lung, and kidney) are viscera that store body energy, and Yang meridians (large intestines, small intestines, triple heater, gall bladder, stomach, and bladder) are metabolic viscera in charge of ingestion, digestion, secretion, and evacuation. Exercise can activate energy system and inhibit the digestive system, so the subjects

with more active Yin meridians before bath (8/18) outnumbered those with more active Yang meridians before bath (1/18). Besides, the regulating effect of half-body bath on hyper-active energy system was more significant. 5) After regular training, 78% of the subjects (14/18) had autonomic nervous disorders. The effects of half-body bath on regulating conductance and balance of meridians were significant and could help the above-mentioned over- or under-values return to the normal range.

The 6-week effects of the half-body bath process on meridian systems and body composition

The 6-week half-body bath process did not significantly increase the number of subjects whose abnormal meridian energy (upper/lower, left/right, Yin/Yang) could return to normal states. Moreover, no significant difference was found in the parameters between the 1st week and 6th week. This finding revealed that the effects of half-body bath on the long-term improvement of meridian imbalance were not significant. Nevertheless, all the subjects were in-service baseball players, and they still had to receive a great deal of training during the experiment. Therefore, fatigue-induced meridian imbalance was repeatedly stimulated. Moreover, the training items were frequently adjusted by the coach depending on the assignment for sport players, so the result of our long-term observation would be affected.

The 6-week water bath process did not affect muscle weight and total water of the body composition. The subjects' increase of body weight and body fat weight was speculated to be contributed by the arrangement of the water bath, which affected the subjects' self-training; or by the relaxation of fatigue and stress, which enhanced their appetites. Moreover, the coach did not allow us to dominate their weekly training. The above-mentioned factors were either not fully controlled or verified, so the increase of body weight and fat weight observed could only explain that half-body bath has no effect on fat control.

CONCLUSION

It was empirically proven that the regular half-body bath process has significant effects on the recovery of muscle fatigue and improvement of flexibility for baseball players. It also has the function of rectifying fatigue-induced variation or imbalance of meridian systems.

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