



Original Article

Effect of a 21-day balneotherapy program on blood cell counts, ponogen levels, and blood biochemical indexes in servicemen in sub-health condition

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Abstract. [Purpose] The aim of our study was to explore the changes in the blood of servicemen in sub-health conditions during a 21-day balneotherapy program. [Subjects and Methods] For this study, 129 servicemen in sub-health condition were recruited. The subjects were randomly divided into either the balneotherapy group (70) or the control group (59). Subjects in the balneotherapy group received whole-body immersion bath therapy in thermo-mineral water (30 min daily) for 21 days. Their blood samples were examined 1 day before and after balneotherapy. The parameters studied included mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), white blood cell (WBC), lactic acid (LAC), alanine aminotransferase (ALT), glucose (GLU), and triglycerides (TG) levels. [Results] After 21 days of balneotherapy, MCH levels and MCHC increased significantly and WBC counts increased significantly. LAC levels decreased significantly. ALT, GLU, and TG levels decreased significantly. In the control group, there were no statistical differences before and after tap water baths following the same procedure. [Conclusion] A 21-day balneotherapy program significantly improved blood cell counts and blood biochemical indexes and reduced ponogen levels in servicemen in sub-health condition.

Key words: Balneotherapy, Blood cells, Blood biochemical indexes

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INTRODUCTION

Sub-health, also known as the gray state or a disorder of the body and mind, belongs to the category of “treating pre-disease”. It is described as a borderline state between health and disease, which can be categorized into three kinds: somatic, mental, and socially adaptive sub-health¹⁾. The most common symptoms of sub-health are fatigue (78.7%), poor quality of sleep (73.4%), amnesia (59.9%), fatigue that cannot be relieved even after rest (59.1%), and dry throat (59.0%)²⁾. Muscle fatigue is a condition that is particularly worrisome for individuals who practice sports. Some energy molecules may transform into acidic substances during physical activity, causing the pH of body fluids to decline. These acidic substances are called ponogens and include lactic acid, pyruvic acid, and total carbon dioxide (CO₂). Fatigue elevates ponogen levels and impairs cardiovascular function, as well as hematologic, renal, gastrointestinal, and central nervous system functions, via

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biochemical and metabolic modifications to the body. Ponogens also affect the psyche of a subject³). As a result, people may feel tired, weak, and dysphoric and have slow responses and weakened adaptabilities. Furthermore, people severely lose interest in work and life, leading to the development of a variety of physio-psychological problems and disorders³).

Balneotherapy, which is a spa therapy, involves inhalation, massages through moving water, mud baths, relaxation, or stimulation⁴). Mineral ions contained in springs, such as chloride ion (Cl^-), sodium ion (Na^+), bicarbonate (HCO_3^-), cupric ion (Cu^{2+}), fluoride ion (F^-), and sulfate ion (SO_4^{2-}), can make complete exchanges within the body, stimulating nerve endings in the skin, expanding peripheral vascular, accelerating blood flow and metabolism, and promoting the excretion of lactic acid. Besides these effects, balneotherapy has been observed to induce an increase in insulin-like growth factor-1 (IGF-1), which stimulates cartilage metabolism, and in transforming growth factor- β (TGF- β), which acts as a very potent immunomodulating and anti-inflammatory cytokine⁵). The muscle and bone load can also be reduced by mineral water; decreased muscle tone can effectively eliminate muscle and body fatigue and joint movement disorders caused by joint diseases, such as neuralgia paralysis⁶). Hot stimuli may also influence muscle tone and pain intensity, helping to reduce muscle spasms and increase the pain threshold. Thus, the symptoms of sub-health such as muscle aches and fatigue can be relieved⁷). Because of the benefits that balneotherapy brings, SPA therapy is widely used in the treatment of a large range of chronic diseases, such as ankylosing spondylitis (AS)⁸), lower back pain⁹), rheumatologic disorders (rheumatoid arthritis, osteoarthritis, and psoriatic arthritis¹⁰), psoriasis and atopic dermatitis¹¹), and cardiovascular rehabilitation¹²). Luca et al.¹³) have reported a breakthrough that a combination of SPA therapy and rehabilitation may cause a clear, long-term clinical improvement in AS patients being treated with tumor necrosis factor inhibitors. Balneotherapy can improve the feelings and mood of subjects through 5-hydroxytryptamine (5-HT) platelet transporter modifications in ozonized water baths¹⁴). Another 21-day balneotherapy program for the treatment of overweight or obesity has also been shown to be significantly effective¹⁵). It has also been shown to exert positive effects on the oxidant/antioxidant system, resulting in a reduced release of reactive oxygen species (ROS) and reactive nitrogen species (RNS)¹⁶). The Lintong Sanatorium is rich in natural healing resources, especially mineral springs. It contains many kinds of chemical constituents, such as radon, potassium, sodium, calcium, and magnesium¹⁷). The Lintong springs have medical value; the chemicals, temperature, and mechanical stimulation provided by the Lintong springs may treat a variety of diseases¹⁷). Over 10,000 pilots have received recuperation (including mineral spring baths, climatotherapy, and landscape convalescence) at Lintong Sanatorium, and most of them were satisfied with the results of the treatments for chronic diseases or sub-optimal health conditions¹⁸).

As a special occupation, servicemen carry the responsibilities of guarding territory, such as acting during earthquakes, making them more inclined to suffer from sub-health condition due to a lack of relaxation and continuing work under stress. Although publications on the effect of balneotherapy on relieving fatigue are scarce, in our early studies, we found that balneotherapy could improve pilots' cardiopulmonary function and physical capacity¹⁸). Thus, we are interested in the effects of balneotherapy on servicemen in sub-health condition. The purpose of the present study was to explore the changes in blood cell counts, ponogen levels indicating fatigue, and blood biochemical indexes in servicemen in sub-health condition during a 21-day balneotherapy program.

SUBJECTS AND METHODS

This study was performed at Lintong Sanatorium in Lanzhou Military Region. Multimedia diagnostic instrument (MDI) sub-health assessment was conducted to select subjects who were in sub-health state using the MDI-9702 multi-function ultra-high power microscope. This system is produced by the Nanjing Kangshifu Science and Technology Company in cooperation with Olympus Company and is based on the theory of oxidation. It aseptically collects blood from the end of the little finger and then generates blood pills for morphological observation at the cellular level. At the same time, different hormones and enzymes were analyzed in the system. Finally, it reports the health condition of the body. According to the MDI health state standard developed by the World Health Organization, health state is above 85 assessment points, disease state is below 70 points, and sub-health state is between 70 and 85 points¹⁹).

First, the MDI sub-health assessment was used to screen 662 male servicemen; only those who scored 70–85 were considered to be sub-healthy. Second, those who had alcohol or tobacco addictions or a history of diabetes mellitus, hypertension, heart failure, valvular heart disease, cardiomyopathies, atrial fibrillation, coronary artery disease, asthma, chronic obstructive lung disease, psychiatric diseases, rheumatological or neurological conditions, and upper limb or spine pathologies were excluded. Finally, 129 servicemen were selected; 70 of them (mean age: 40.0 ± 1.3 years; body weight: 69.3 ± 13.8 kg; height: 173.2 ± 3.8 cm) were enrolled in group A (mineral water group) and the other 59 servicemen (mean age: 41.0 ± 2.6 years; body weight: 69.0 ± 12.9 kg; height: 174.2 ± 1.5 cm) were enrolled in group B (control group). The subjects were fully informed about the purpose of this study and the associated procedures, and they individually agreed to participate in the therapy program. The study protocol was approved in advance by all the committees of the Fourth Military Medical University Human Research Ethics Committee. Informed consents were received from all the participants in the experiment.

All subjects spent 21 days at Lintong Sanatorium, and their daily lives were planned similarly. The subjects in group A were administered balneotherapy (30 min daily) with whole-body immersion in thermomineral water ($35\text{--}37^\circ\text{C}$ from day 1 to day 7, $38\text{--}40^\circ\text{C}$ from day 8 to day 21). Group B received tap water baths with the same procedure. The details of the analysis of the thermomineral water used in the balneotherapy are listed in Table 1¹⁷).

Table 1. Mineral analysis of Lintong mineral spring water

pH	TOTAL mineral (mg·L ⁻¹)	Anions (mg·L ⁻¹)				Cations (mg·L ⁻¹)			
		Cl ⁻	HCO ⁻	SO ₄ ²⁻	F ⁻	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺
7.7	1,251.2	193.2	384.5	277.2	3.5	33.9	14.2	326.5	3.4

Table 2. Change in parameters of blood cells in servicemen after water treatment (Mean ± SD)

Group		RBC	HGB	HCT	MCH	MCHC	WBC	PLT
		(10 ¹² ·L ⁻¹)	(g ·L ⁻¹)	(%)	(pg)	(g ·L ⁻¹)	(10 ⁹ ·L ⁻¹)	(10 ⁹ ·L ⁻¹)
Group A (n=70)	Before	4.5 ± 0.3	141.2 ± 11.6	0.42 ± 0.1	31.1 ± 1.2	339.2 ± 9.2	5.2 ± 1.1	198.2 ± 54.1
	After	4.3 ± 0.4	149.2 ± 10.9	0.40 ± 0.1	33.3 ± 1.3*	346.4 ± 6.9*	5.9 ± 1.1**	211.8 ± 46.2
Group B (n=59)	Before	4.3 ± 0.4	144.3 ± 9.3	0.41 ± 0.1	31.3 ± 1.9	339.1 ± 11.9	5.9 ± 1.3	201.1 ± 47.3
	After	4.2 ± 0.4	150.1 ± 10.1	0.39 ± 0.1	32.3 ± 1.7	341.9 ± 19.2	5.9 ± 1.9	190.1 ± 51.2

*p<0.05, **p<0.01 as compared with before treatment. RBC: red blood cell; HGB: hemoglobin; HCT: hematocrit; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; WBC: white blood cell; PLT, blood platelet

Blood samples were taken 1 day before and after the study. Samples were collected at 8:00 in the morning by venipuncture using stainless steel needles and vacutainer heparinized 7-ml tubes for blood and no-additive 7-ml tubes for serum. The serum tubes were centrifuged, and both blood and serum were stored at -20 °C for 3 weeks until the end of the experiment. Red blood cell (RBC), white blood cell (WBC), blood platelet (PLT) counts; hemoglobin (HGB), hematocrit (HCT), mean corpuscular hemoglobin (MCH) levels; and mean corpuscular hemoglobin concentration (MCHC) were measured using an automatic hematology analyzer (Sysmex KX-21N, Japan).

Lactic acid (LAC), total CO₂ (TCO₂), total cholesterol (TC), triglyceride (TG), renal blood urea nitrogen (BUN), alanine aminotransferase (ALT), and glucose (GLU) levels were measured using an automatic biochemical analyzer (Toshiba, Japan).

Data were presented as mean values ± standard deviation (SD). Statistical analysis was performed using SPSS version 17.0 software for Windows (SPSS Inc., Chicago, IL, USA). For the evaluation of statistical differences, the paired two-sample t-test was used. Significance was accepted for p values less than 0.05.

RESULTS

In group A, the 21-day balneotherapy treatment had significant effects on parameters of blood cells, ponogen levels, and blood biochemical indexes. MCH levels and MCHC increased significantly (p<0.05), whereas RBC counts and HCT levels reduced insignificantly. The PLT count did not change, and the WBC count increased significantly (p<0.01) after 21 days of balneotherapy (Table 2). LAC levels significantly decreased after balneotherapy treatment (p<0.05), whereas TCO₂ levels showed an increase, with no significance (Table 3). ALT, GLU, and TG levels decreased significantly (p<0.05) after 21 days of balneotherapy, with no apparent changes in TC and BUN levels (Table 4). In contrast, no statistical differences were found in the parameters of blood cells, ponogen levels, and blood biochemical indexes in group B.

DISCUSSION

When a person is in sub-health condition, some parameters in the blood, such as pressure, viscosity, lipids, glucose, hormones (especially cortisol), plasma fibrinogen, glycosylated hemoglobin (which shows increasing tendency)²⁰, and peripheral microcirculation, fluctuate and the antioxidant and immune system become imbalanced^{21, 22}, distinctly showing rheological behavior disorders²³. Our results regarding blood cell parameters exhibited that balneotherapy affected MCH levels, MCHC, and WBC counts, which is consistent with the results of Wang's study²⁴. After a single warm water bath, some parameters, such as serum TC levels, RBC counts, and HGB and HCT levels, had significantly increased²⁵. The increase in MCH levels and MCHC may be because balneotherapy can cause blood to redistribute in various organs and vessels via vasodilation caused by nervous system excitement. With the amelioration of blood circulation, the oxygen supply and the capability of RBCs to carry oxygen are enhanced. Therefore, the average amount of HGB contained in each RBC and liter of blood increases, which is beneficial for reducing ischemia and hypoxia to ameliorate the physical symptoms.

As seen in this trial, the parameters of ALT, GLU, and TG levels decreased after balneotherapy, with no remarkable

Table 3. Changes of LAC and TCO₂ in servicemen after water treatment (Mean ± SD, mmol·L⁻¹)

Group		LAC	TCO ₂
Group A (n=70)	Before	1.3 ± 0.3	24.4 ± 1.3
	After	1.2 ± 0.3*	25.1 ± 1.6
Group B (n=59)	Before	1.3 ± 0.3	25.2 ± 1.1
	After	1.2 ± 0.2	25.8 ± 1.5

*p<0.05 as compared with before treatment. LAC: Lactic acid; TCO₂: total carbon dioxide

Table 4. Changes in blood biochemical indexes in servicemen after water treatment (Mean \pm SD, mmol·L⁻¹)

Group		ALT	GLU	TG	TC	BUN
Group A (n=70)	Before	24.7 \pm 16.7	5.4 \pm 0.4	1.9 \pm 0.9	4.6 \pm 1.0	7.0 \pm 1.1
	After	23.8 \pm 20.1*	4.2 \pm 0.3*	1.5 \pm 0.7*	4.6 \pm 0.8	5.8 \pm 1.3
Group B (n=59)	Before	30.2 \pm 5.7	4.9 \pm 0.5	1.6 \pm 0.7	4.1 \pm 0.5	5.3 \pm 0.7
	after	28.7 \pm 8.3	4.3 \pm 0.5	1.5 \pm 0.4	4.2 \pm 0.5	4.9 \pm 0.6

*p<0.05 as compared with before treatment. ALT: alanine aminotransferase; GLU: glucose; TG: triglyceride; TC: total cholesterol; BUN, renal blood urea nitrogen

changes in TC and BUN levels. Consistent with the results mentioned above, the largest decreases were seen in blood viscosity, relative viscosity, and TG levels in a group undergoing remedial exercise combined with iodine brine therapy²⁶). Mihály et al.²⁷) also observed that after 3 months of balneotherapy, serum cholesterol and TG levels continued decreasing in patients. In other words, balneotherapy helps remove lipids from plasma, which is favorable for preventing hyperlipidemia, and plays a positive role in maintaining the steady state of the cardiovascular system.

In the study of the pronounced ameliorative effect of balneotherapy, it is difficult to analyze the function of every mineral in spring waters. In fact, the effect is the result of a combination of factors, among which the mechanical, thermal, and chemical effects are most dominant. By absorption of mineral substances through the skin, nerve endings are stimulated, and peripheral vasodilatation is induced, resulting in an increase in cutaneous blood flow and improved microcirculation. As a result, the body's metabolism is accelerated, organization and cellular respiration are promoted, acidic waste is eliminated, and ponogen levels are decreased. Peripheral vasodilatation could also be the result of increased parasympathetic and decreased sympathetic activity. These actions could mainly be the effect of peripheral acidosis on the function of several calcium channels, leading to an increase in the amount of calcium sequestered into the norepinephrine-sensitive intracellular calcium store¹⁶). Also, radon (Rn) in the Lintong springs can be absorbed through the skin to form an "active Rn film", penetrating through the mucosa or the respiratory tract for non-pharmacological therapy. Yamaoka emphasized the positive effect of radon-containing medicinal baths on the activity of superoxide dismutase and stated that catalase mineral water may exert a beneficial influence on the antioxidant system²⁸).

In summary, we have investigated the possible benefits of balneotherapy on servicemen in sub-health condition. We found that a 21-day balneotherapy program effectively induced changes in blood cells, ponogen levels, and blood biochemical indexes, indicating beneficial effects on the health of servicemen during their stay at the Lintong Sanatorium. The findings of this study provide a basis for further investigation on the use of balneotherapy as a natural remedy for servicemen in sub-health condition. The appropriate duration of balneotherapy and the most effective regimen of different thermal loads involved in this balneotherapy method needs to be investigated in the future.

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