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Effect of 3 Weeks of Balneotherapy on Immunological Parameters, Trace Metal Elements and Mood States in Pilots

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Abstract. [Purpose] The aim of this study was to investigate the effects of balneotherapy on immunological parameters, trace metal elements and mood states in pilots. [Subjects] Thirty-six healthy male pilots were enrolled into this study. [Methods] All subjects received therapy for 3 weeks. They took entire-body immersion baths in thermomineral water for 30 min a day for 3 weeks. Blood samples were taken 1 day before and after the balneotherapy treatment. Blood concentrations of trace metal elements were measured using a BH5100 atomic absorption spectrometer. Blood serum concentrations of immunoglobulins and complements were measured with an automatic biochemical analyzer. The Profile of Mood States test was conducted to determine changes in mood states. [Results] After 3 weeks of balneotherapy, the concentrations of immunoglobulin A and complement component 4 increased significantly and the blood concentration of lead significantly decreased. The mood scores of tension-anxiety, anger-hostility, fatigue-inertia and confusion-bewilderment decreased. The mood score of vigor-activity significantly rose. [Conclusion] The findings indicate that balneotherapy over a 3-week period may exert a beneficial influence on the immune system and play an assistive role in improving the mood states of pilots.
Key words: Balneotherapy, Immune function, Mood

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INTRODUCTION

The use of balneotherapy for treating illnesses goes back to ancient times[1, 2]. In recent centuries, the use of hot springs and water in other forms was popularized by early practitioners of what later would become naturopathy. Out of these practices, a formal system of medicine known as hydropathy developed. Today, mud packs, saunas, and steam baths are often included along with water baths under the general name of balneotherapy[3]. Certain types of water are often particularly prized by practitioners of balneotherapy. These include sulfur springs and the concentrated salty water of drying lakebeds, such as the Dead Sea in Israel. Interestingly, hot springs high in the radioactive substance radon are also said by some proponents to possess particular healing properties[4–6]. However, scientific reports, especially sound studies of the effectiveness of this kind of treatment on pilots' health, are rare.

Balneotherapy is popular for the treatment of various diseases in China. It has been discovered that the earliest record of spring water being used for therapy in China is the Wentang Stele written by Wang Bao in the 7th century B.C. Wang reported a spring which contained sulfur that could treat disease[7]. In the 16th century, Li classified hot springs into sulfur springs, arsenic springs, cinnabar springs, aluminite springs and described their individual indications[7]. Since the middle of 20th century, many mineral spring sanatoriums and rehabilitation centers have been established in China. It was reported in the 1st National Geothermal Conference that there were more than 2600 mineral springs in China[7]. Lintong mineral spring is one of the most famous mineral springs in China. The Lintong spring water is a moderately hyperthermic (38–40 °C) mineral water. It contains a lot of mineral elements[8, 9]. The main salts in Lintong mineral water are sulfate, chloride and bicarbonate. The water contains many cations, such as potassium, sodium, calcium (Ca) and magnesium (Mg), among which sodium has the highest concentration. The main anions in Lintong mineral water are chloride, bicarbonate (HCO_3^-), carbonate (CO_3^{2-}) and sulfate (SO_4^{2-}), among which sulfate has the highest content. The mineral water also contains many other chemical constituents, such as fluoride, bromide, and iodide, and iron (Fe), lithium, strontium, manganese, silicon, barium, zinc (Zn), copper (Cu), among which fluoride has the highest content. There is also radon gas and a small amount of radium in the spring water.

The development of mineral springs has been promoted

Table 1. Chemical composition analysis of Lintong mineral spring water

Anions (mg/L)				Cations (mg/L)				TOTAL mineral	Radon	pH
Cl^-	HCO_3^-	SO_4^{2-}	F^-	Ca^{++}	Mg^{++}	Na^+	K^+	(mg/L)	(Bq/L)	
193.2	384.5	277.2	3.5	33.9	14.2	326.5	3.4	1251.2	15.1	7.7

in China over the last 20 years. However, due to the pressure of population and the financial costs involved in the popularization of balneotherapy, the benefits of mineral springs are limited to people who can afford the costs or have the specific welfare entitlements to enjoy the use of balneotherapy. Pilots are exposed to vibratory environments and ergonomically unfavorable working conditions, which can cause a sub-optimal health state and various diseases. To avoid the occurrence of these conditions and promote the health of pilots, a series of measures can be employed such as regular physical examinations and natural remedies. As an important part of natural remedies, balneotherapy has been widely utilized for the health promotion of pilots in China. Although pilots take a shower almost every day, they have a welfare entitlement to take balneotherapy in sanatoriums for 4 weeks every year. However, the effectiveness of balneotherapy is only partially understood. Publications on the effect of mineral water on the changes of immunological parameters, trace metal elements and mood states in pilots are scarce. Therefore, the aim of the present study was to clarify the effects of balneotherapy in health promotion for pilots.

SUBJECTS AND METHODS

Thirty-six healthy male pilots participated in this study at the Lintong Sanatorium of Lanzhou Military Region in 2010. The subjects had a mean (range) age of 31±5 yr, body weight of 69±7 kg and height of 169±4 cm. All subjects were in good condition, were without alcohol or tobacco addiction, and had no history of diabetes mellitus, asthma or psychiatric diseases. None of the subjects had upper limb or spine pathologies, or rheumatological or neurological conditions. The subjects were fully informed of the purpose of this study and contents, and individually agreed to participate in the therapy program. This study was approved by the Fourth Military Medical University Human Research Ethics Committee, and informed consent was obtained from all of the participants prior to the experiment.

All subjects spent 21 days in the Lintong Sanatorium. During this period, they lived in the sanatorium and received daily bath therapy (once a day, 30 min) in the thermal mineral spring water (35–37 °C from Day 1 to Day 7, 38–40 °C from Day 8 to Day 21). All subjects took half-body bathing with the level of water around the middle thorax and entire-body immersion with the level of water up to shoulders, alternatively. The water used in balneotherapy was thermomineral water and the details of the water analysis of Lintong mineral spring are listed in Table 1.

Blood samples were taken 1 day before and after the balneotherapy treatment. Sampling was done 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 for future study. Blood concentrations of trace metal elements, including Cu, Zn, Ca, Mg, Fe, lead (Pb) and cadmium (Cd), were measured using a BH5100 atomic absorption spectrometer (Bohui, China). Blood serum concentrations of immunoglobulins (IgG, IgA, IgM and IgE), complement components (C3 and C4) and C1 inhibitor (C1INH) were measured as immunological parameters with an automatic biochemical analyzer (Toshiba, Japan).

The Profile of Mood States (POMS) standard testing was used to assess the mood states of the pilots before and after the balneotherapy program. POMS can assess transient and fluctuating moods and enduring affective states[10]. POMS is a 65-item self-report form that is rated by subjects on a 5-point scale[11]. It measures six identifiable affective states: tension-anxiety (T), depression-dejection (D), anger-hostility (A), vigor-activity (V), fatigue-inertia (F) and confusion-bewilderment (C).The scores of POMS were collected by questionnaire.

The data are presented as mean values±SD. For the evaluation of statistical differences, the paired two-sample t-test was used. Significance was accepted at p values of less than 0.05.

RESULTS

The concentrations of IgA and C4 complement increased significantly (6.6%, 9.5%, respectively, $p<0.05$) after 3 weeks of balneotherapy treatment (Table 2). IgG and IgM showed trends of increase, while IgE and C3 complement showed decreasing tendencies without statistical significance. The concentration of C1INH didn't change after 3 weeks of balneotherapy treatment.

The blood concentration of Pb decreased significantly by 53.2% ($p<0.01$) after 3 weeks of balneotherapy treatment (Table 3). Cu, Zn, Ca, Mg and Fe showed trends of increase, while Cd showed a decreasing tendency.

After 3 weeks of balneotherapy treatment, the passive mood scores of T, A, F and C decreased significantly ($p<0.05$), whereas the active mood scores of V elevated significantly ($p<0.05$, Table 4). The mood state of depression-dejection showed a decreasing trend after treatment of balneotherapy.

DISCUSSION

In this study, 3 weeks of balneotherapy improved immune function by increasing the concentrations of IgA and C4 complement, reduced the potential adverse effects of trace

Table 2. Changes of immunological parameters in pilots after balneotherapy treatment

Parameter	Pre- balneotherapy	Post- balneotherapy
IgG (g/L)	12.48 ± 1.87	12.59 ± 2.11
IgA (g/L)	2.73 ± 0.92	2.91 ± 0.94*
IgM (g/L)	1.15 ± 0.43	1.16 ± 0.46
IgE (IU/ml)	107.54 ± 115.49	105.24 ± 110.23
C3 (g/L)	1.03 ± 0.26	1.02 ± 0.16
C4 (g/L)	0.21 ± 0.04	0.23 ± 0.05*
C1INH (g/L)	0.31 ± 0.02	0.31 ± 0.03

($\bar{x}$ ± s, n=36) *p<0.05 as compared with pre-balneotherapy

Table 3. Changes of blood trace metal element concentrations in pilots after balneotherapy treatment

Parameter	Pre- balneotherapy	Post- balneotherapy
Cu (μmol/L)	13.14 ± 1.97	14.84 ± 2.09
Zn (μmol/L)	110.33 ± 14.01	117.78 ± 15.99
Ca (mmol/L)	1.77 ± 0.16	1.79 ± 0.36
Mg (mmol/L)	1.59 ± 0.11	1.64 ± 0.17
Fe (mmol/L)	9.67 ± 0.75	9.78 ± 0.78
Pb (μmol/L)	0.37 ± 0.14	0.17 ± 0.10**
Cd (mmol/L)	31.49 ± 7.21	27.31 ± 14.06

($\bar{x}$ ± s, n=36) **p<0.01 as compared with pre-balneotherapy

Table 4. Changes of mood states in pilots after balneotherapy treatment

Parameter	Pre-balneotherapy	Post-balneotherapy
T (tension-anxiety)	4. 75 ± 1.43	2.17 ± 1.02*
D (depression-dejection)	0.50 ± 0.16	0.36 ± 0.14
A (anger-hostility)	2.09 ± 1.37	0.88 ± 0.30*
V (vigor-activity)	15.87 ± 3.96	21.71 ± 4.17*
F (fatigue-inertia)	3.46 ± 1.17	1.12 ± 1.32*
C (confusion-bewilderment)	3.36 ± 2.60	1.17 ± 1.51*

($\bar{x}$ ± s, n=36) * p<0.05 as compared with pre-balneotherapy

metal elements by decreasing the concentration of Pb, and improved mood and reduced anxiety of the pilots.

Most data addressing the beneficial effect of balneotherapy have suggested that balneotherapy itself is able to improve the immune function of animals and humans. Moreover, immunomodulating effects as well as immunostimulatory effects of moderate hyperthermia have been categorically proven to be effective in many experiments[12–14]. Most interestingly, although moderate hyperthermia stimulates different functions of the immune system, intensive hyperthermia shows a significant immunosuppressive effect[14]. Our current result was in line with the results of the studies cited above. The temperature of spring water used in this balneotherapy program ranged from 35 °C to 40 °C. It may have produced moderate hyperthermia in the pilots during the balneotherapy. IgA is a protective antibody that plays a critical role in the immune system. The decrease of IgA in the human body can cause a clinically significant immunodeficiency[15]. Similarly, C4 complement is a vital protein involved in the complement system that takes part in the in vivo clearance of antigen-antibody immune complexes[16]. Therefore, the improvement of the concentration of IgA and C4 complement indicates an enhancement of the pilots' immune function after the balneotherapy treatment. It should be noted, however, that the exact mechanism of the alterations in the immune function observed in this study remains unknown. Recent studies have suggested that radon in mineral water may play an important role in the relief of diseases[17, 18]. However, it has also been reported that a low radon concentration failed to demonstrate a significant effect on the functioning of the endocrine system[19]. In this study, the level of radon in the thermomineral water was too low to have caused any substantial effects.

Cd and Pb are widely distributed heavy metals which can induce a broad range of physiological, biochemical, and behavioral dysfunctions in laboratory animals and humans[20–22]. This includes age-specific variations in absorption, retention, and tissue distribution of Pb. However, there are no reported data about changes induced in these processes by balneotherapy. The results of the present investigation show that 3 weeks of balneotherapy induced a significant decrease in Pb and a slight reduction in Cd in the pilots. Pb contamination is a serious problem in in-flight environments, and Pb can easily enter the human body through respiration, digestion, or skin permeation. Thus, exposure to low levels of Pb may have reduced the risk of accumulation of Pb during the experimental period. In addition, the thermal effects of balneotherapy might have promoted dilation of blood vessels, increasing speed of blood flow and metabolic rate, thereby discharging Pb and Cd from the human body. The exact mechanism of the Pb concentration change caused by balneotherapy needs further investigation.

Pilots are often forced to deviate from their normal work/sleep schedules because of flight operations that involve irregular work hours, night flights, early starts or transmeridian flights. With the improvement of aircraft performance and the complexity of flying missions, the crewing members' psychological loads are increased and their biological rhythms are disrupted, lead to decrements in their mood states as a function of fatigue[23, 24]. Adverse mood state is related to the depression and suppression of specific immunities[25]. A sub-optimal health state could imperil flight safety unless appropriate adverse-mood state

countermeasures are implemented. The results of the present study clearly demonstrate that several passive mood states, including Tension-Anxiety, Anger-Hostility, Fatigue-Inertia and Confusion-Bewilderment, showed significant improvement; the state of Vigor-Activity also showed a significant improvement after balneotherapy. Our findings are in accord with previous reports[26, 27]. Balneotherapy with mineral water has been shown to provide several physiological and psychological benefits, such as improvement of relaxation[28] and sleeping disorder[28], relief of chronic pain[29], and to deliver an immunostimulatory effect to the immune function[12–14]. These benefits may play important roles in the improvement of mood states after treatment with balneotherapy.

In conclusion, balneotherapy may exert a beneficial influence on the immune system and play an assistive role in the improvement of mood states of pilots. Bathing in mineral water induced discharge of the potentially hazardous Pb from the pilots' bodies. Further investigations of the mechanism by which balneotherapy affects the immune function and psychological states are needed.

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