Influence of Bathing in A White Sulfur and Sodium Bicarbonate Hot Spring on Pulmonary Function in Normal Subjects

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Abstract

The short period effect of hot spring on pulmonary function of normal subjects is unclear. We attempt to investigate the pulmonary function changes during bathing in white sulfur springs (WSS), sodium bicarbonate hot spring (SBH) or tap water (TW). Fifty healthy people were enrolled and tested in 3 different types of water of WSS, SBH and TW for 20 minutes. Spirometry was used to evaluate the pulmonary function at the 0, 5, 10 15 and 20 minutes after the start of each bath. Among these three groups, the % predict value of forced expiratory capacity (FVC%), forced expiratory volume in the first second (FEV_1%) and forced expiratory flow from 25% to 75% of the vital capacity ($FEF_{25-75\%}$) were not significantly different during WSS, SBH and TW at the 0, 5, 10, 15 and 20 minutes after the start of bathing. In WSS group, a significant increased FEV_1% was found during WSS bathing at 10 minutes (89.43 ± 11.50) of bathing compared to baseline (87.33 ±11.87) (p =0.023). FVC% at 10min (79.6 ± 12.4; p=0.04) and at 20 min (80.0 ± 13.1; p=0.03) were significant higher than baseline at 0 min (77.7 ± 12.3). There was a significant increased %$FEF_{25-75\%}$ at 10 min (109.7 ± 20.4; p=0.040) and 20 min (110.9 ± 23.2; p=0.037) compared with baseline (106.3 ±20.8) in SBH, and at 20 minutes

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(108.0 ± 22.7; p=0.014) compared with baseline (105.2 ± 21.9) in TW. These indicted that hot water aerosol inhalation to improve $FEF_{25-75\%}$ reflected more patency in the small airway. $FEF_{25-75\%}$ was not improved in WSS reflected aerosol of hot spring with H_2S might to harmful for aerosol of hot spring with H_2S. However, bath in hot spring improved FEV_1 and FVC which reflected improved the respiratory effort. We concluded under good ventilation environment, white sulfur springs bathing in short period was not harmful but even beneficial to the pulmonary function. (J Intern Med Taiwan 2007; 18: 97-103)

Key Words : **Hydrogen sulfide, White sulfur spring, Hot spring bathing, Pulmonary function test**

Introduction

There was no report about the effects of hot spring bathing or bathing in sulfur springs on pulmonary function, but spa therapy improves the condition of small airways disorder in patients with SDIA (steroid-dependent intractable asthma) [1,2]. Beitou, well-known for its hotels and sulfur baths, is situated on the side of the Daiton volcanic mountain group in northern Taiwan[3]. There are 3 major types of sulfur springs in Beitou area: green sulfur spring (GSS), white sulfur spring (WSS) and ferrous sulfur spring (FSS). The water of WSS is acidic (pH:3-4) with an of $SO4^{-2}$ content of around 1000ppm. The temperature ranges from 50 ℃ to 97 ℃ and color of the spring is turbid white with the smell of rotten eggs at WSS[4]. Bathing in WSS has been thought to bring symptomatic relief from chronic skin diseases, arthritis or neuralgia[5]. But episodes of acute H_2S poisoning have been reported in the U.S.A., Spanish and Beitou area[6-8]. Prevention of accidents and toxic effects of H_2S by bathers and WSS personnel has become a health issue. This study investigated the effects of WSS bathing on the pulmonary function of healthy adults.

Methods

Subjects

This study included 50 healthy subjects. Subjects were excluded if they had any of the following conditions: smoker, pregnant, disabled, hypertension, heart diseases, lung diseases, diabetes mellitus or body mass index (BMI) > 30 Kg/m^2 . All of the subjects underwent spirometric testing during bathing procedures in 3 different places: Armed Forced Beitou Hospital (TW) in the Beitou District of Taipei, Hwangshiliing hot spring restaurant (WSS) in Beitou district of Taipei, and Spring Spa hot spring hotel (SBH) in Wulie of Taipei County from January 2001 to December 2001. Each subject was tested in the sequent locations of TW, WSS and SBH with the elapsed time 2 days between test baths. Physical conditions including chest tightness, shortness of breath or dizziness were also closely observed, and testing was stopped immediately if any safety concerns were noted.

Protocol

Ventilatory capacity was measured in all 50 subjects using a portable flow-volume spirometer (Spirodoc, MIR Co., Rome, Italy). All subjects were tested 3 times during bathing for 20 minutes in all three different water bath types of TW, WSS and SBH. We first prepared and controlled the water temperature at around 37-39 ℃ in the bathtub, and asked the subject to lie in the bathtub in the supine position with head and neck above the water. After keying in their general data including age, gender, height and weight on the spirometer, we asked them put the new mouthpiece connected with spirometer well into the mouth after took a slow and deep inspiration. They then immediately blew with rapid strength of expiration into the spirometer over a 6 second period. The expiratory maneuver must be made with maximum effort and at the maximum possible velocity. All of the air in lungs must be expired to ensure a correct spirometry result.The measurement is stopped automatically a few seconds after the last variation in flow, ie when flow is zero. The mean predicted FVC%, FEV_1% and $FEF_{25-75\%}$ values calculated automatically by spirometer at each setting time were used in the analysis.

Evaluation the H_2S concentration in air

The concentrations of H_2S in the air at the TW, WSS and SBH were determined by measuring the amount of sulfur dioxide (SO_2) converted from H_2S. The concentration of sulfur dioxide was measured by the ultraviolet detection method using an API model 100A monitor (N.Y,U.S.).

Statistical analysis

Age and measurement data were expressed as the mean ± standard error of the mean. Repeated-Measures ANOVA and Wilcoxon rank-sum test were used to analyze the differences among data from the 3 types of baths. Two-tailed paired t test was used to compare the mean predicted FVC%, FEV_1% and $FEF_{25-75\%}$ values at 5,10 and 20 minutes with baseline values at 0 minutes for each type of bath. Data were analyzed using SAS software version 8.2 for windows. A p value<0.05 was considered statistically significant.

Results

A total of 50 healthy subjects were enrolled in this study, including 23 men (age range, 19-40 years; 26.9 ± 5.3 years) and 27 women(age range, 21-41 ; 30.9 ± 6.3 years) . All subjects completed the hot spring bathing experiments without noting discomfort.

The pulmonary function tests were performed in these subjects at 3 different locations. The concentration of H_2S in air around bathtub in these three locations was as follows: Hwangshiliing hot spring restaurant (WSS) : 274-283ppb, Spring Spa Hot spring Hotel (SBH):<2ppb (lower than the detectable limit), and Armed Forced Bei-tou Hospital (TW) : 7.8-12.5ppb (background air data in hospital).

Among these three groups, the % predict value of forced vital capacity (FVC%), forced expiratory volume in the first second (FEV_1%) and forced expiratory flow from 25% to 75% of the vital capacity ($FEF_{25-75\%}$) were not significantly different during WSS, SBH and TW at the 0, 5, 10, 15 and 20 minutes after the start of bathing (Table 1,2 and 3). In WSS group, a significant difference in FEV_1% was found during WSS bathing at 10 minutes (89.43 ± 11.50) of bathing compared to baseline(87.33 ± 11.87)(p =0.023) (Table 1). FVC% at 10min (79.6 ± 12.4; p =0.04) and at 20 min (80.0 ± 13.1; p =0.03) were significant higher than baseline at 0 min (77.7 ± 12.3) (Table 3). In SBH or TW groups, there was a significant increased %$FEF_{25-75\%}$ at 10 min (109.7 ± 20.4; p=0.040) and 20 min (110.9 ± 23.2; p=0.037) compared with baseline (106.3 ± 20.8) in SBH, and at 20 minutes (108.0 ± 22.7; p=0.014) compared with baseline (105.2 ± 21.9) in TW (Table 2).

Discussion

Spa therapy was found to improve the values of ventilation parameters[1,2] and exercise in a pool filled with hot spring water, on the other hand, may be useful in treating chronic obstructive pulmonary disease. Kurabayashi H et al demonstrated that 22 patients (70.9 ± 9.1 years of age) with stable chronic obstructive pulmonary disease (12 cases of bronchial asthma and 10 cases of pulmonary emphysema) treated with a two-month exercise program performed in a pool filled with hot spring water, the ratio of FEV_1% was significantly increased after the exercise program ($p < 0.05$), whereas the ratio of forced vital capacity to predicted normal value (FVC%) did not change. The changes in respiratory function was considered attributable to respiratory muscle training and small airway clearance[9]. In our study, we found that a significantly increased value of FEV_1% at 10 minutes, increased value of FVC% at 10 and 20 minutes, and

Table 1.The predicted FEV_1% vales bathing for 20 min in 3 different water

FEV_1%*	WSS	SBH	TW	p-value ǀ
	Mean ± SD	Mean ± SD	Mean ± SD	
0 min	87.33 ± 11.87	84.17 ± 15.58	84.78 ± 12.54	0.460
5 min	87.66 ± 11.12	83.83 ± 13.87	84.65 ± 13.53	0.298
10 min	89.43 ± 11.50	84.60 ± 14.21	84.81 ± 12.79	0.109
15 min	88.10 ± 12.40	83.69 ± 13.65	85.17 ± 13.14	0.231
20 min	88.33 ± 12.49	85.06 ± 14.51	85.20 ± 13.28	0.391
p-value ‡	0.151	0.584	0.949	
0 VS 5 min p-value ǀ	0.650	0.732	0.876	
0 VS 10 min p-value ǀ	0.023	0.715	0.968	
0 VS 15 min p-value ǀ	0.404	0.708	0.708	
0 VS 20 min p-value ǀ	0.288	0.648	0.595	

*Data are mean ± standard error of the mean; ǀ One-way ANOVA; ‡ Random effects model
§ Repeated-Measures ANOVA; ǀ Paired t test

Table 2.The predicted $FEF_{25-75\%}$ values bathing for 20 min in 3 different water

PEF2575 (%)*	WSS	SBH	TW	p-value ǀ
	Mean ± SD	Mean ± SD	Mean ± SD	
0 min	112.44 ± 21.39	106.28 ± 20.77	105.16 ± 21.90	0.189
5 min	111.54 ± 21.52	108.18 ± 21.93	107.68 ± 20.21	0.614
10 min	113.50 ± 23.00	109.72 ± 20.38	107.50 ± 21.23	0.374
15 min	112.14 ± 23.50	108.44 ± 22.26	106.00 ± 21.11	0.385
20 min	112.08 ± 23.68	110.94 ± 23.20	107.98 ± 22.66	0.660
p-value ‡	0.648	0.170	0.076	
0 VS 5 min p-value ǀ	0.386	0.283	0.111	
0 VS 10 min p-value ǀ	0.418	0.040	0.144	
0 VS 15 min p-value ǀ	0.830	0.327	0.592	
0 VS 20 min p-value ǀ	0.786	0.037	0.014	

*Data are mean ± standard error of the mean; ǀ One-way ANOVA; ‡ Random effects model
§ Repeated-Measures ANOVA; ǀ Paired t test

Table 3.The predicted FVC% vales bathing for 20 min in 3 different water

Time(Min)	WSS	SBH	TW
0	77.7 ± 12.3	77.2 ± 11.8	75.9 ± 11.9
5	78.8 ± 10.9	76.2 ± 12.6	74.7 ± 13.2
10	79.6 ± 12.4*	76.5 ± 13.0	75.2 ± 12.6
15	79.7 ± 12.9	76.4 ± 12.2	76.3 ± 12.9
20	80.0 ± 13.1 ǀ	76.9 ± 12.1	76.3 ± 13.6

Date was presented as mean ± SD; *: In WSS group, compared with the value of FVC in 0 min significant increased in 10 (p= 0.037*) and 20 min (p =0.025 ǀ) respectively.

no significant change of FEV_1/FVC were noted compared with baseline values in WSS. Because of no improvement of %$FEF_{25-75\%}$ and FEV_1/FVC in WSS, an increased value of FEV_1 was due to increased value of FVC which reflect and increased respiratory effect. It seemed WSS bathing might have some good effect on pulmonary function which might due to improve the expiratory effort. However no significant difference of FVC% and FEV_1% were found in TW and SBH group. These findings indicated WSS better improved respiratory muscle strength than TW and SBH.

Pulmonary function testing (PFT) provides objective lung function assessments such as screening pubic health/epidemiological evaluations and also yields reproducible, quantitative results, and allowing longitudinal monitoring[10]. Predicted values for a given subject can be obtained using subject's age and height in the appropriate regression equation. $FEF_{25-75\%}$ is the mean expiratory flow rate in the middle half of the FVC maneuver and a more sensitive measurement of early airflow obstruction, particularly in small airways[11]. On the other hand, the pulmonary function is affected by normal subjects' position. Vilke GM, et al explained that healthy men with BMI < 30 Kg/m^2, changing from the sitting to supine position results in statistically significant decline in the spirometry values ： FVC was 102% ± 4% while sitting, 95% ± 4% while supine. FEV_1 was 104% ± 3% while sitting, 96% ± 3% while supine [12]. All of the spirometry values of subjects in supine position with head and neck above the water also showed relatively lower respiratory pattern in this study. This study found the mean predicted $FEF_{25-75\%}$ indicated significant dilation effects in small airways at 10 minutes and 20 minutes after bathing in SBH compared with baseline, and 20 minutes in TW, but no significant change occurred while bathing in the WSS These findings suggest aerosol inhalation of SBH and TW is beneficial to small air way which might result from hot aerosol inhalation to improve the dilatation of airway or clearance of mucus. However, there was no effect of WSS on the small airways of healthy people after exposure to low concentrations of H_2S in WSS. This different effect of WSS might be due to combination effect from bronchodilatation effect of hot water aerosol and bronchoconstriction effect H_2S substance on small airway.

H_2S is an irritant and an asphyxiant gas. At a concentration of 50 ppm, H_2S acts as an irritant on mucous membranes of the respiratory tract. Prolonged exposure to moderate concentration (250ppm) may cause pulmonary edema[13,14] .Reaction of H_2S with vital metalloenzymes, such as cytochrome oxidase, is the likely toxic mechanism of H_2S[15]. A threshold limit value of 10 ppm as an 8-hour time-weighted average and a short-term exposure limit of 15 ppm was recommended by the American Conference of Governmental Industrial Hygienists[16]. Oral inhalation of 10 ppm H_2S for 15 minutes does not significantly alter pulmonary function in healthy men and women[17], and healthy men and women can safely perform at a moderate intensity work in environments contaminated with 5 ppm H_2S[18]. A preliminary study done in Rotorua, New Zeland, a major recreational center, showed that no chronic health impairment could be identified after long-term exposure to 0.005 to 1.9 ppm[19]. The results of this study showed that healthy people did not suffer decreases in pulmonary function from the concentration H_2S of 274-283ppb (0.274-0.283 ppm) in the area around the bathtub at the WSS. In conclusion, our study showed hot water aerosol inhalation to improve $FEF_{25-75\%}$ which reflected more patency in the small airway. $FEF_{25-75\%}$ was not improved in WSS which reflected aerosol of hot spring with H_2S might be harmful for aerosol of hot spring with H_2S. However, both in hot spring improved FEV1 and FVC which reflected improved the respiratory effort. Therefore we suggest under good ventilation environment, white sulfur springs bathing was not harmful but even beneficial to pulmonary functions.

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泡北投白磺泉及烏來碳酸氫鈉泉對於健康人肺功能之影響

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摘 要

溫泉短期在肺功能的效果上並不清楚。本研究的目的在於瞭解健康正常人在泡白磺泉，碳酸氫鈉泉或是自來水短期溫泉暴露的過程中肺功能的變化。50位健康正常人分別於白磺泉，碳酸氫鈉泉及自來水等3種不同的泉質中測試肺功能20分鐘。我們利用肺功能機來評估在泡3種不同泉質的過程中，其肺功能分別於0, 5, 10, 15 及 20 分鐘5個階段時的狀況。在泡白磺泉，碳酸氫鈉泉及自來水等3種不同泉質的肺功能測試中，第0, 5, 10, 15 及 20 分鐘等不同階段之用力肺活量，第1秒用力呼氣容積及最大呼氣中期流速的值，在3種泉質之間並無顯著的差異。泡白磺泉中，在第10分鐘(89.43 ± 11.50) 比剛開始泡 (87.33 ± 11.87) 之第1秒用力呼氣容積的值來的高 (p =0.023)。用力肺活量的值，在第10分鐘 (79.6 ± 12.4; p=0.04) 及 20 分鐘時 (80.0 ± 13.1; p=0.03) 是比剛開始泡 (77.7 ± 12.3) 顯著的高。最大呼氣中期流速所測試的結果中，在泡碳酸氫鈉泉時，第10分鐘 (109.7 ± 20.4; p=0.040) 及 20 分鐘 (110.9 ± 23.2; p=0.037) 所測的值分別比剛開始泡時 (106.3 ± 20.8) 有顯著的增加，而且在泡自來水20分鐘 (108.0 ± 22.7; p=0.014) 時的最大呼氣中期流速是比剛開始泡 (105.2 ± 21.9) 有較高的數值。熱水氣吸入可改善最大呼氣中期流速，但在含有硫化氫空氣吸入可能有害而抵消了溫泉中熱水氣的改善作用，泡白磺泉可增加肺活量的值與第1秒用力呼氣容積的值，因此良好的通風環境下，短期泡白磺泉對於正常人的肺功能而言並沒有害處甚至是有幫助的。