Letter to the Editor

Research on Rapid Initial Adaption to the Environment of a Plateau*

WANG Bin Hua[1], CAO Zheng Tao[2], WU Feng[2], YANG Jun[2], LIU Yuan Yuan[1], and YU Meng Sun[2,#]

We designed two types of pre-adaption plans for this study. One was a pre-adaption training with progressive intermittent hypoxia, with a constant lower pressure oxygen tank used in the plain before arriving at the plateau (PG). The other was by progressively increasing the time of exposure to hypoxia with oxygen supplied in stages after radical plateau (RG). By testing the blood oxygen saturation (SpO_2), heart rate (HR), and quality of sleep after arriving at the 3800 m high plateau, results showed that the pre-acclimatization and radical groups performed better than the control group (CG). Both strategies were equivalent in terms of effects and principles in providing more flexible choices for acclimatization.

Oxygen deficiency is the main environmental factor in plateaus that influences human health[1-2]. Humans who travel quickly from lower to high altitudes have a greatly increased probability of developing individual plateau symptoms, and reduced performance capacity and cognitive ability. The risk of occurrence of plateau symptom is greater at higher altitudes and at faster speeds of travel[3-4].

The low oxygen-containing environment in the plateaus affects not only the mental state of people during the daytime, but also the quality of sleep during nights. When a person is sleeping, the body is in a state of protective inhibition in order to prevent excessive consumption of nerve cells and further functional failure, and repairs fatigued nerve cells. Different degrees of hypoxic stimuli lead to the occurrence of certain sleep disorders, and these are the human body's comprehensive stress response to hypoxic stimulus[5-6].

Related studies have shown that the body has a great ability to acclimatize to the environment of the plateau, and by acting appropriately within certain limits it can effectively aid individuals and groups in the acclimation process, and promote acclimatization to the plateau. Acclimatization methods mainly include fitness exercises, hypoxic pre-adaption, use of plateau oxygen enriched rooms, drugs, hypoxia acclimatization factors, nutrition, and eating plateau oxygen resistant food[7]. Among these, an especially effective method is to use low oxygen tank plain hypoxic pre-adaption training in an environment with low oxygen levels[8]. Currently there is no unified standard for hypoxic exposure, and no clear guiding theory.

The statistical analysis of results indicate that the SpO_2 in the first 10 days after arriving at the plateau in the pre-adaption group was significantly higher than in the control group (F=1.17-30.40, P<0.05), except on the ninth day. The SpO_2 in the first 10 days after arriving at the plateau in the pre-radical group was significantly higher than in the control group (F=0.69-134.49, P<0.05), except on the seventh, ninth, and tenth days. Further, there was no difference between the pre-adaption and radical groups, except on the third day (Table 1).

The statistical analysis of the results indicates that there is no significant difference in the HR in the first 10 days after arriving at the plateau between the pre-adaption, radical, and control groups (Table 2).

The statistical analysis reveals that there is no significant difference in deep sleep time during the first 10 days between the pre-adaption and radical groups. The deep sleep time was more on the third day in the pre-adaption than in the control group. The deep sleep time on the first, second, seventh, and eighth days was more in the radical than in the control group (Table 3).

This paper explored two active rapid radical plateau adaptation strategies. These were plain hypoxic pre-acclimatization training using a constant

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1. School of Control Science and Engineering, Shandong University, Jinan 250061, Shandong, China; 2. Academician Center, Aviation Medicine Institute, Beijing 100142, China

Table 1. Statistical Analysis of SpO_2

Time (d)	PG	RG	CG	PG *vs.* CG		RG *vs.* CG		PG *vs.* RG	
				F	*P*	*F*	*P*	*F*	*P*
1	92.3±4.34	95.0±1.41	79.8±2.21	26.22	0.002*	134.49	0.000*	1.45	0.274
2	91.3±3.68	94.5±0.57	82.5±2.08	17.09	0.006*	123.42	0.000*	3.31	0.132
3	89.3±0.95	87.3±0.95	84.0±2.16	19.75	0.004*	7.56	0.030*	8.73	0.025*
4	90.5±1.91	92.5±0.57	84.5±3.87	7.71	0.032*	16.69	0.000*	4.00	0.092
5	92.3±2.06	92.0±1.15	85.0±1.63	30.40	0.01*	49.00	0.000*	0.05	0.839
6	91.0±2.70	93.0±1.15	86.0±0.81	12.50	0.012*	98.00	0.000*	1.85	0.223
7	91.3±1.70	88.3±1.70	87.5±0.57	17.31	0.006*	0.69	0.430	6.17	0.048
8	90.8±2.06	92.8±0.50	86.3±1.70	11.30	0.015*	53.36	0.000*	3.56	0.108
9	89.0±2.44	88.5±1.73	87.0±1.82	1.71	0.238	1.42	0.270	0.11	0.750
10	89.0±1.41	87.3±1.50	85.3±1.50	13.24	0.011*	3.55	0.10	2.88	0.140
F	2.75	138.24	18.59						
P	0.020*	0.001*	0.020*						

Note. *was significant difference of *P* was 0.05.

Table 2. Statistical Analysis of HR

Time (d)	PG	RG	CG	PG *vs.* CG		RG *vs.*CG		PG *vs.* RG	
				F	*P*	*F*	*P*	*F*	*P*
1	64.3±8.50	65.5±10.14	84.5±4.04	18.52	0.005*	12.10	0.013*	0.04	0.856
2	69.00±5.59	67.5±8.73	77.0±6.97	3.20	0.124	2.88	0.140	0.08	0.782
3	72.3±5.05	67.8±8.61	74.5±2.28	0.65	0.452	2.28	0.180	0.81	0.402
4	69.8±6.23	63.5±9.11	72.5±1.73	0.72	0.448	3.76	0.100	1.28	0.301
5	70.8±4.85	65.0±6.78	71.0±5.47	0.01	0.948	1.89	0.210	1.90	0.217
6	69.3±8.53	63.3±5.90	70.3±10.53	0.02	0.880	1.34	0.290	1.34	0.292
7	72.5±6.35	71.5±7.32	69.5±6.24	0.45	0.526	0.17	0.690	0.04	0.843
8	67.5±2.64	61.5±5.97	70.3±4.57	1.08	0.338	5.41	0.050	3.38	0.116
9	71.8±9.67	71.3±12.52	70.0±1.63	0.13	0.733	0.03	0.850	0.04	0.952
10	68.8±7.08	71.8±10.24	66.8±3.86	0.25	0.638	0.83	0.390	0.23	0.647
F	0.76	4.14	17.61						
P	0.657	0.135	0.025*						

Note. *was significant difference of *P* was 0.05.

Table 3. Statistical Analysis of Deep Sleep Time

Time (d)	PG	RG	CG	PG *vs.* CG		RG *vs.* CP		PG *vs.* RG	
				F	*P*	*F*	*P*	*F*	*P*
1	47.3±16.29	50.8±1.89	28.0±15.55	2.92	0.138	8.43	0.027*	0.18	0.685
2	45.3±11.95	64.3±14.10	27.0±16.87	3.12	0.128	11.48	0.015*	4.22	0.086
3	52.8±3.94	49.5±18.06	30.3±3.40	74.54	0.00*	4.39	0.081	0.12	0.737
4	52.8±11.44	56.8±10.14	36.3±16.85	2.62	0.156	4.34	0.082	0.27	0.620
5	54.5±7.55	62.0±5.22	50.5±17.07	0.18	0.683	1.66	0.245	2.67	0.154
6	63.3±5.91	61.0±8.12	54.5±12.71	2.48	0.167	0.74	0.422	1.01	0.352
7	57.7±6.70	61.3±2.98	46.0±11.19	3.24	0.122	6.93	0.039*	0.91	0.377
8	65.9±20.51	66.5±11.28	44.4±11.00	3.43	0.114	7.86	0.031*	0.00	0.965
9	40.3±34.75	60.8±10.99	44.00±23.26	0.03	0.864	1.95	0.241	1.27	0.304
10	52.50±7.72	43.3±23.14	46.3±12.20	0.75	0.420	0.05	0.826	0.58	0.477
F	1.70	1.55	2.34						
P	0.127	0.172	0.035*						

Note. *was significant difference of *P* was 0.05.

pressure lower oxygen tank, and stepwise radical hypoxic exposure training in the early stage (10 days) after arriving ont the plateau. Both strategies involved gradual adaptation to the environment of the plateau and were suited to natural human physiological processes. When compared with Juli Jones' radical 4300 m equal height intermittent hypoxia training plan, irritation or injury caused by the process of severe adaptation is avoided[9]. In the present study, when compared with the control group the blood oxygen saturation, heart rate, and deep sleep time of the two study groups were better. These revealed that both solutions could help passive adaptation to the plateau environment, have obvious advantages, could significantly improve the subjects' ability to adapt to the low oxygen environment, and help them adapt to the plateau environment quickly.

In terms of effect, hypoxic pre-adaption training and stepwise radical plateau hypoxic exposure were equivalent in promoting adaption to the plateau environment. At the same time, they also increase the flexibility choice for the preconditioning method. With respect to the principle, the equal exposure levels led to the equivalence of the two schemes. Hypoxic exposure by the stepwise method on the plateau, used by the radical group controlled the hypoxic exposure time required to achieve similar effects to changes in altitude. This was done by using exposure time to achieve similar effects to altitude. By gradually increasing the hypoxic exposure time to accelerate the hypoxic exposure value, the exposure value was close to that of the corresponding time in the pre-adaptation plan. In addition, in order to allow the radical group to adapt more quickly to the environment, an oxygen tank was used while they slept at night. This also improved sleep quality.

According to the theory of self-organization system environment adaptability, the pre-adaption, radical, and control groups began at different starting points, with different speeds or time constants to achieve adaptation, and finally adapted to the plateau environment. According to the analysis and comparison of all aspect indices of the three groups, the starting point of adaptation to the plateau was higher in the pre-adaption group, which achieved the initial state of adaptation on the first day. The starting points of the radical and control groups were the same, but due to the rate of environmental changes that matched the time constant of the self-organism organizing system in the radical group, providing oxygen during sleep at nights was beneficial. Oxygen was conducive to sleep at night and good at boosting the self-organ stress capacity. Therefore, the adaption was fast and the process was smooth. The initial state of adaptation was achieved on the fourth day. As the control group did not have any interventions, and relied entirely on the body's self-organizing system to passively adapt to the environment, adaptation was slower, the process was relatively intense, and the subjects did not achieve initial acclimatization status until the seventh day[10].

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#Correspondence should be addressed to YU Meng Sun, Tel: 86-10-66927048, E-mail: 7539wbhwbh@163.com

Biorgraphical note of the first author: WANG Bin Hua, 1983, PhD, majouring in physiological signal processing and data mining.

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REFERENCES

1. Inder S Anand, Tianyi Wu. Syndromes of subacute mountain sickness. High Alt Med Biol, 2004; 5, 156-70.
2. SR Muza, BA Beidleman, CS Fulco. Altitude preexposure recommendations for inducing acclimatization. High Alt Med Biol, 2010; 11, 87-92.
3. Hackett PH, Roach RC. High-altitude illness, New Engl J Med, 2001; 345, 107-14.
4. Flück M. Functional, structural and molecular plasticity of mammalian skeletal muscle in response to exercise stimulation. J Exp Biol, 2006; 209, 2239-48.
5. Weil JV. Sleep at high altitude, High Alt Med Biol, 2004; 5, 180-9.
6. TE Kupper, V Schoffl. Preacclimatization in hypoxic chambers for high altitude sojourns. Sleep Breath, 2010; 14, 187-91.
7. CS Fulco, SR Muza, B Beidleman, et al. Exercise performance of sea-level residents at 4300 m after 6 days at 2200 m. Aviat Space Environ Med, 2009; 80, 955-61.
8. Thomas EAH Küpper, Volker Schöffl. Preacclimatization in hypoxic chambers for high altitude sojourns. Sleep Breath, 2010; 14, 187-91
9. Juli E Jones, Stephen R Muza, Charles S Fulco, et al. Intermittent Hypoxic exposure does not improve sleep at 4300 m. High Alt Med Biol, 2008; 9, 281-7.
10. Yu Mengsun. Human-performance engineering at high altitude. Advances in High Altitude Medicine and Hypoxic Physiology in China. (A Sponsored Supplement to Science), 2012; 12, 7-8.