Changes in Training Characteristics and Functions for Swimmers during a "DuoBa-KunMing" Altitude Training

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Keywords: Altitude Training, Swimming, DuoBa, KunMing, Training Characteristic, Function.

Abstract: It's rare to see studies on altitude training (AT) carries out continuously in 2 altitudes. This study followed a 10 weeks swimming training program that included 2 weeks training in DuoBa (2366M) and another 2 weeks in KunMing (1890M). The training characteristics and swimmers' functional changes were studied in seven swimmers during the training program, just before swimmers participated in the Chinese 12th National Games. Blood samples, heart rates and weights were collected and analyzed for physiological index. Conclusion: (1) The training before plateau was mainly about moderate -high intensity aerobic training. In Duoba, low-moderate and moderate intensity aerobic training was priority. In KunMing, high intensity aerobic and anaerobic training was increased. After the plateau, recovery and conditioning adjustment are the main part. (2) This AT has non-significant effect on athletes' HR level; the body weight has significant decreased after 3 weeks in plateau and recovered to the common level after a week return to the plain. The athletes' hemoglobin and blood testosterone increase significantly in plateau. (3) The great results of all seven swimmers in the National Game shows that this pattern of AT is an effective way for improving swimmers' performance.

1 INTRODUCTION

Altitude training can bring athletes simulation of hypoxia and training load, which was regarded as an effective training way to improve performance. The purpose of altitude training before a major competition is to promote athletes' peak performance. The decrease of training intensity after altitude training will improve performance significantly (Roberts et al., 1992). Normally altitude training is performed in a period of time in one location with high sea levels. In this study, a different pattern was adopted which separated the altitude training in 2 different locations with different altitudes. It was aimed to find a more effective way of altitude training for elite swimmers before an important competition.

2 METHOD

7 elite swimmers from Beijing Sport University (BSU) were studied. All of them have participated in the swimming competition of Chinese 12th National Game, which represented the most important events with highest performance levels in China. Among the subjects, there were 2 freestylers, 2 flyers, 2 backstrokers and 1 breaststroker. All of them had experienced altitude training before.

Table 1: Basic information of the subjects (n=7).

Sex	Age (y)	Height (cm)	Weight (kg)	Training time (y)
Male	21.57±2.44	183.57±5.03	78.89±6.72	8.29±4.31

The altitude training took place in four different locations (Table 2) for 10 weeks. Blood samples were collected and analyzed for blood testosterone (T), blood urea nitrogen (BUN), hemoglobin (HB) on 7:00-7:30 every Monday during the period and after the meet. BHR and weight were recorded every morning. Eppendorf-6124 semi automatic biochemical analyzer and blood urea kit produced by BIO SINO were used.

Wen, Y., Ge, Y., Zhang, M. and Peng, Y..
Changes in Training Characteristics and Functions for Swimmers during a "DuoBa-KunMing" Altitude Training.
In *Proceedings of the 3rd International Congress on Sport Sciences Research and Technology Support (icSPORTS 2015)*, pages 121-125
ISBN: 978-989-758-159-5

Table 2: 4 phases of the altitude training.

Phase	Purpose	Location	Altitude (M)	Period (W)
1	Preparation	Beijing	44	3
2	Extra high altitude	Duoba	2366	2
3	Moderate high altitude	Kunming	1890	2
4	Tapering	Harbin	128	3

3 RESULTS AND ANALYSIS

3.1 Training Characteristics

Sports' training is an important part of competitive sports activities, which is the special organized sports activities, aiming at improving the athletes' competitive ability and sports performance (Tian et al., 2000). Volume and intensity are two factors that the coaches need to mainly focus on, especially when the altitude changed. Volume for swimmers is usually shown as miles.

3.1.1 Changes in Miles

Training load is a method using the physical exercise as basic means to make the training stimulation work on athletes' body (Wu et al., 2001). The changes of miles during the altitude training aere showed in figure 1.

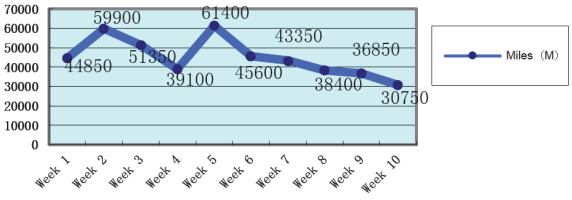

Figure 1: Changes of miles.

Miles increased during the 1st 2 weeks, which was a traditional way for altitude training. Then decreased to make subjects keeping good mental and physical condition. Miles decreased in the 3rd week and increased in the following 2 weeks. Miles decreased in a great amount in the 6th and 7th weeks, while intensity improved significantly, so that swimmers' ability could be developed at the most rage. Miles continuously decreased in the last 3 weeks, so that swimmers' physical function could be gradually recovered and peak performance released in the competition.

3.1.2 Intensity

6 degrees intensity sorts were used to establish load levels, including aerobic low (EN1), lactate threshold (EN2), VO2max (EN3), lactic acid tolerance (SP1), lactic acid production (SP2) and power (SP3). Changes of miles and intensity were showed in Table 3.

Table 3: Changes of miles and intensity.

Week	miles (M)	EN1 (%)	EN2 (%)	EN3 (%)	SP1 (%)	SP2 (%)	SP3 (%)
1	44850	75.92	11.15	3.12	3.79	0.22	5.8
2	59900	51.59	29.72	10.68	5.51	0	2.5
3	51350	55.02	26.87	4.87	7.59	1.46	4.19
4	39100	75.58	20.46	0	0	0	3.96
5	61400	51.87	39.58	6.19	0	0	2.36
6	45600	61.4	11.19	20.61	1.97	0.55	4.28
7	43350	67.53	16.49	9.92	1.62	0	4.44
8	38400	60.42	24.22	9.1	0	3.13	3.13
9	36850	66.55	16.83	7.87	5.83	0.95	1.97
10	30750	69.51	20.49	2.44	2.6	2.6	2.36

In Week 2 and 3, percentage of EN2, EN3 and SP1 were larger than in Week 1, which means the training arrangement is preparing for the hypoxia environment of the plateau.

In Week 4 and 5, aerobic intensity training were the majority part and SP3 training had been added into the training session at the same time, so that swimmers' aerobic capability could be improved as long as speed ability maintained. In Week 6, EN3, SP1 and SP2 were highest among the four phases. In Week 7, the amount of aerobic training was increasing and the intensity was decreasing, the fatigue could be relieved so that swimmers could prepare for the pre-competition training phase.

Week 8 emphasize on EN2, week 9 focus on SP2. The main purpose of post-altitude training is to recover and adjust, so swimmers could participate in the competitions in their best competitive conditioning. During this phase, training for pace and speed need to be held with decreasing miles.

3.2 Physiological Index

Physiological index is an important index to evaluate swimmers' physical condition. The research followed swimmers' BHR and weight to monitor their physical condition and study the changes' pattern.

3.2.1 BHR

The heart rate in the morning while people wake up and lie quietly is called as BHR. When the training volume is suitable, BHR should be stable; without any other factors that could affect BHR, if the fluctuation increase for a period of time, the reason could be physical fatigue caused by over-trained (Wang et al., 2002).

Table 4: Changes in BHR (n=7).

Phase 1	Phase2	Phase3	Phase4
53.36 ± 3.09	55.10 ± 2.30	56.88 ± 3.97	52.60 ± 2.70

Resting heart rate can directly reflect the condition of cardiovascular. BHR in the altitude training can reflect swimmers' physical conditioning (Ga and Liu, 2004). Table 4 shows that BHR in DuoBa is higher than that in plain, which showed plateau's hypoxia environment caused the speed of body metabolism to increase ($P>0.05$). In general, the subjects' BHR did change in different phases but without significant difference ($P>0.05$), which means this pattern of altitude training didn't affect BHR significantly.

3.2.2 Weight

Long term altitude training may cause lean body weight and fat decrease significantly, and the range of the decrease was closely related to the altitude. One study showed that after living in the 4300 meters plateau for 8 days, weight would drop by 3%; and after living in the 5300-8000 meters plateau for three months, body weight decreased by 15%. (Wang et al., 2002). Weight loss will directly affect sports performance and may result in strength decrease. Thus it is very necessary to control weight in altitude training.

Table 5: Changes in body weight (n=7).

Phase1 (kg)	Phase2 (kg)	Phase3 (kg)	Phase4 (kg)
78.89 ± 6.72	78.76 ± 6.91	77.94 ± 6.83	78.70 ±6.87

Table 5 showed that body weight of the subjects did not lose significantly ($P > 0.05$) after 2 weeks in mountain. However, weight lost in the 3rd week in mountain ($P < 0.05$). Weight began to recover in sea level training following the mountain. Throughout the whole period, body weight significantly decreased only after 3 weeks trained in the plateau and the weight restored after 1 week left from the plateau, which mean subjects capacity did not decrease because of weight loss.

3.3 Hemogram Index

3.3.1 T

T is a male hormone in the body, which has a strong assimilation effect. (Zhang et al., 2010).

Table 6: Changes of T level (n=7).

Before Altitude Training-3 (mmol/L)	Altitude Training-2 (mmol/L)	Altitude Training-3 (mmol/L)	After Altitude Training-1 (mmol/L)	After Competition (mmol/L)
525.14± 106.66	576.43± 104.06	663.76± 133.61	630.2 ±132.58	641± 122.54

After training on the plateau for 2 weeks, the T levels were significantly higher than that of the plain ($P<0.05$), and after 3 weeks, T levels increased continuously comparing with that 2 weeks ($P<0.05$). Karvonen et al., (1990) studied that T falled after 15 days training in the 1860 meters height for 5 national level male sprinters. Another research showed that 6 swimmers T decreased after training in the height of 1890 meters ($P<0.01$) (Qian et al., 1993). Zhao et al. (1997) showed that after altitude training, T level national rowing team's significantly decreased (Zhao et al., 1997). The research of Feng et al., (2000) showed that during the 4 weeks altitude training (1917 meters), T level of 6 elite male middle and long distance runners decreased (Feng et al., 2000). All the research results above are opposite to the result in this study. The specific reason could be related to the training intensity, or the result shows that the pattern of 2 weeks training in 2366 meters height and 2 weeks training in 1890 meters height is better for holding and improving the level of T during athletes training in altitude.

When coming back to the plain from the plateau, the seven swimmers' T level still holds in a relatively high level. Their T level were apparently higher than that before the altitude training, even after the competition ($P<0.05$).

3.3.2 Bun

BUN is usually used as the index to value protein decomposition (Zhang et al, 2010). The changes of swimmers BUN showed in Table 7.

Table 7: Changes in BUN (n=7).

Before Altitude Training-3 (mmol/L)	Altitude Training-2 (mmol/L)	Altitude Training-3 (mmol/L)	After Altitude Training-1 (mmol/L)	After the competition (mmol/L)
5.43 ± 1.95	7.34 ± 1.87	5.86 ± 0.50	6.75 ± 0.84	3.99 ± 0.60

After training in altitude for 2 weeks, BUN increased significantly ($P < 0.05$), means training load in Duoba was huge, decomposition metabolism of body and protein catabolism increased, body reaction is significantly higher than that in plain. Because BUN is an important indicator of the evaluation of sports load and fatigue degree, the results could suggest that when trained in Duoba, swimmers are more likely to feel fatigue. BUN decreased significantly when swimmers moved to the relatively low altitude, Kunming, which was consistent with the decrease of the training load in this phase.

3.3.3 HB

HB is often used for measuring the concentration of HB during the training so to value swimmers' nutritional status and physical function (Zhang et al., 2010). HB directly affects the body's ability of obtaining oxygen and aerobic metabolism (Gao and Liu, 2004).

Table 8: Changes in HB (n=7).

Before Altitude Training-3(g/L)	Altitude Training-2(g/L)	Altitude Training-3(g/L)	After Altitude Training-1(g/L)	After the competition(g/L)
149.14 ± 10.35	161.16 ±6.89	164.09 ± 7.85	163.57 ± 6.35	153.57 ± 8.52

HB significantly improved ($P<0.05$) after training in altitude for 2 weeks, and after 3 weeks training in altitude, HB increased more($P<0.05$) compared with that in 2 weeks; this result is similar to researchers' results like Zhao and Xue (2011), Qian and Wang (2004), which means swimmers had a good adaptation to the plateau environment, the aerobic endurance was developed. But in this aspect, the results of this study are not consistent with some of the researches. Some researchers believe that during the early phase of altitude training, HB will improve significantly, but decline later (Liu and Liu, 2006; Fan, 2008; and Wei, 2007). The different opinion indicates that there is still controversy about the changes of HB in the later phase of altitude training. In this study, subjects moved to a relatively low altitude from the third week, caused HB increased significantly later ($P<0.05$).

Ma et al., (2013) suggested that 2 weeks after the four-week altitude training in 1900 meters, HB of seven cyclists was 0.8% lower (Ma et al., 2013). Even in 5 weeks after altitude training, HB was still higher than that before.

3.4 Performance

Subjects competed in the National Swimming Championship in May 2013. The purpose of this altitude training was preparing for the 12th National Game that held in September 4, 2013. It is meaningful to compare the results of the two games, because the interval between the two games is only three months and the main training method is this altitude training.

Table 9: Comparison of major events' time in 2 games (n=7).

Championships' Time (seconds)	National Games' Time (seconds)	D-value(%)
55.99±4.32	55.70±3.98	0.005

*D-value：reduction value.

Although the times didn't improve hugely, this training mode has its positive significance. Altitude training is like a double-edged sword, applying before competition is risky. One research suggests that (Feng, 2009) altitude training is related with many problems which needs to be further studied. Currently coaches still use the traditional mode (Li et al., 2009; Brooks et al., 1991). There are lots of failed cases of altitude training before. However, subjects competition results improved, which indicated a success. Furthermore, subjects in this study are in high competitive level and had experienced altitude training, the results suggested that this pattern of altitude training is helpful for improving advanced swimmers' competition performance in a short time.

But it's only experimented once and all different situations could happen in training, so the significance of this altitude training need to be further researched and analysis for proving.

4 CONCLUSION

(1) The training characteristics of this pattern of

altitude training were: the training before plateau was in relatively huge volume and intensity, which consisted mainly of moderate -high intensity aerobic training; In Duoba, low-moderate and moderate intensity aerobic training was priority; In KunMing, high intensity aerobic and anaerobic training increased; After the plateau, recovery and conditioning adjustment were the main part—volume decreased but pace and speed were hold.

(2) This pattern of altitude training brings no significance influence for swimmers’ BHR; body weight decreased significantly after training in altitude for three weeks and recovered to the plain level after one week left plateau. T and HB were raised significantly in mountain.

(3) The performance of the subjects in the National Game shows that this pattern of altitude training is effective.

REFERENCES

Brooks, G., Butterfield, G., Wolfe, R., Groves, B, Mazzeo, R., Sutton, R., Wolfel, E. &

Reeves, J. (1991), Decreased reliance on lactate during exercise after acclimatization to 4300 m. *J Appl Physiol*. Vol.71. Maryland ： The American Physiological Soc.1991.p 333-341

Roberts, D. &Smith, D. (1992), Training at moderate altitude: iron status of elite male swimmers. *J Lab Clin Med*. Vol.120. Mosby：Mobsby, Inc. 1992. p 389 -391.

Karvonen, J., Peltola, E., Saarela, J. & Nieminen, M. Changes in running speed, blood lactic acid concentration and hormone balance during sprint training performed at an altitude of 1860 metres. *J Sports Med and Physical Fitness*. Vol.30. Torino ： Edizioni Minerva Medica.1990.p 122-126.

Fan, X.(2008), Effects of Altitude Training on Middle-and-Long Distance Runners' Oxygen-Carrying Ability of Blood. *Journal of Beijing Sports University*. Vol. 31. Beijing: Beijing Sports University Press.2008.p 1223-1224.

Feng, L. (2000), The practice and research of altitude training. *Chinese Physical Coach*. Vol. 4. Shanghai: Chinese Physical Coach Press.2009.p16-17.

Feng, S., Hong, P., Zong, P., Guo, J., Li, F., Li, Y., Zhang, J., Zhu, K., Ren, Y. & Yang, B. (2000), Effects of Altitude Training on Serum Hormone of Male Middle and Long Distance Runner. *China Sport Science*. Vol.20. Beijing: China Sport Science Press.2000. p 49-52.

Gao, X. & Liu, P. (2004), The Method of Monitoring Athletes' Physical Condition during Altitude Training. *Journal of Beijing Sports University.* Vol. 27. Beijing: Beijing Sports University Press.2004.p 44-46.

Li, X., Hu Y., Tian, Z. &Li, W. (2004), Influences of Living High-Training Low on Athletes' Body Composition. *Journal of Shenyang Institute of Physical Education*, Vol. 23.Shenyang: Shenyang Sports College Press.2004.p 424-425.

Liu, J. & Liu D. (2006), Research on body enginery of excellent marathon athletes during the altitude training. *Journal of Beijing Sports University.* Vol. 29. Beijing: Beijing Sports University Press.2006.p 1061-1062.

Ma, G., Li, Z., Liang, X. & Ni, D. (2013), Effect of Four Weeks’ 1990m Altitude Training on Anaerobic Capacity of Male Track-Sprinted Cyclists. *Chinese Sports Science and Technology*. Vol. 49. Beijing: Chinese Sports Science and Technology Press.2013.p 60-66.

Qian, F. & Wang, C. (2004), The Effects of Altitude Training to Blood Components and Performance of Swimming Athlete. *Sports and Science*. Vol.25. Jiangsu: Sports and Science Study Apartment.2004.p 69-71.

Qian, F., Lu, Q. & Zeng, F. (1993), Effects of Altitude Training on Swimmers’ Blood Testosterone, Hydrocortisone and Gonadotropin. *Sports Science Research*. Vol. 1. Gansu: Sports Science Research.1993.p 33-36.

Tian, M. (2000), Sports Training. 2nd ed. Beijing: Beijing Sports University Press.2000.p185-188.

Zhang, A. (2010), Sports Biochemistry. 1st ed. Beijing: Beijing Sports University Press.2010.p95-102.

Zhao, J., Wang, Q., Liu, A. & Yuan S.(1997),Effects of Altitude Training on Elite Rowing Athletes’ Serum Testosterone， Blood Testosterone and Hydrocortisone. *Chinese Journal of Sports Medicine*, Vol. 16.Beijing: Chinese Journal of Sports Medicine Press.1997.p 137-139.

Zhao, S. & Xue, W.(2011), Effects of Altitude Training on Swimming Athletes. *Journal of Wuhan Institute of Physical Education*, Vol. 45.Wuhan:Wuhan Sports College Press. 2011. p 78-82.

Wei, W. (2007), Analysis of Altitude Training in Physical Ability of Male Rowing Athlete. *Journal of Beijing Sports University*. Vol.30. Beijing: Beijing Sports University Press. 2007. p 1656 -1657.

Wang, R. (2002), Sports Physiology. Beijing: People’s Sports Press, 2002.

Wu, H. (2001), Sports Training. Beijing: People’s Sports Press, 2001.