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Influences of Four Weeks Intermittent Hypoxic Training on Aerobic Ability of High-Level Race Walking Athletes

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Objective Altitude training is an important training method for endurance athletes to improve aerobic capacity. Endurance athletes take advantage of the dual stimulation of hypoxia in the altitude environment and hypoxic during training to improve their exercise capacity and physiological function. However, due to the high stimulation of altitude training, the difficulty of recovery and other characteristics, and with the appearance of hypoxic installation, a series of new training methods have been developed.

The advantage of IHT is that it can be combined with routine training, and the training altitude and training plan can be adjusted according to the actual situation. Studies in recent years have shown that IHT has some advantages in achieving better athletic performance: (1) IHT can prevent athletes from having sleep disorders and dehydration, which are typical symptoms of prolonged exposure to high altitude environments; (2) The recovery after IHT training is performed under normoxic conditions, which can prevent the athletes from the harmful effects of prolonged hypoxia, and shorten the recovery time after training; and (3) the time spent apart from training under hypoxic conditions may be used for normal training activity.

The study intended to develop a appropriate four-week IHT plan, which would be integrated into the training of five high-level race walking athletes in the winter training and with the plain training period, full attention to the combination of special training，hoping to achieve better training effect. At the same time, through the test of aerobic capacity-related indicators, explored the influences of four-weeks IHT on specific ability of high-level race walking athletes. This study will be of great significance to guide the race walking training in the future.

Methods Five high-level male race walking athletes(20.6±2.5 y,175±7.7 cm,57.4±9.1 kg) provided informed consent to participate in this study. They would be conducted to four weeks of routine training and four weeks of IHT training. IHT was performed for four weeks, three times a week, about three hours each, in a hypoxic laboratory at an altitude of 2500 m and an oxygen concentration of about 15.3%. Each week, athletes would
do aerobic walk training (10 km~15 km,85%AT), intermittent walking training (2 km*5~2 km*6,90-100%AT) and special endurance walking training (16 km~20 km,80%AT). The training programs for routine training and hypoxic training were all consistent. Blood test and treadmill incremental load test were performed before and after the two trainings. In the blood test, the functional indexes such as RBC, Hb, Hct, CK and BU were recorded. In the incremental load test of treadmill, the initial speed was 9 km/h, added 1 km/h every 3 minutes, and HR, BLA, VO_2were recorded indicators of aerobic capacity. During the routine and hypoxic training, the athletes wore heart rate monitors and oxygen saturation meters throughout the course of training and recorded the heart rates and oxygen saturations before and after training.

Statistical analyses were undertaken using the SPSS software (Version 20). All test results were presented as mean ± SD, and the mean of relevant indicators before and after hypoxic training were analyzed using the paired sample T-test, as $p < 0.05$, with significant difference, as $p < 0.01$, with significant significance differences.

Results There was no significant difference in blood lactate and maximal oxygen uptake in post-routine training compared with pre-routine training, and heart rate was significantly different

(p<0.01); post-IHT compared to pre-IHT, there was a significant difference in the heart rate and oxygen uptake (P<0.05), but the difference in blood lactate was not significant (P>0.05). Before and after the two trainings, there were no significant differences in blood parameters such as CK, BU, RBC, Hb, and Ferri (P>0.05). After routine training, the maximum speed increased from 13.2±0.64km/h to 13.4±0.55km/h, and the maximum heart rate of anaerobic threshold decreased from 194.7±10.17 beats/min to 188.6±12.18 beats/min. During the intermittent hypoxia training, the oxygen saturation in the quiet state and after training gradually increased. Among them, the maximum heart rate of anaerobic threshold decreased from 188.6±12.18 beats/min to 182.8±8.35 beats/min, and the maximum walking speed increased from 13.4±0.55 km/h to 13.8±1.1 km/h. After intermittent hypoxia training, HRAT and $\%HR_{max}$increased, while HR_{max}decreased. The increase in HRAT and $\%HR_{max}$indicated that the proportion of aerobic energy supply had increased in incremental loads. The decrease in HR_{max}indicated that the athletes' heart and lung function had improved after training.
$VO_{2max}$is one of the major determinants of endurance exercise capacity. It reflects the ability of the body to ingest, transport and utilize oxygen. It is a good index for evaluating cardiopulmonary function and aerobic endurance of athletes. The anaerobic threshold（AT）refers to the body in the process of incremental loads, means the critical point from the aerobic energy supply to anaerobic energy supply. Evaluation of the body's aerobic capacity is not only dependent on VO_{2max}, but also closely related to AT. VO_{2max}mainly reflects the cardiopulmonary function and skeletal muscle metabolism, while AT can reflect the utilization of $VO_{2max}$when lactic acid begins to accumulate, which can reflect the utilization of oxygen by skeletal muscle. Zhang compared the anaerobic threshold ventilation and heart rate anaerobic threshold, pointed out that the test condition of the ventilation anaerobic threshold is demanding, it is difficult to achieve in general, and use of heart rate monitoring training is simple and easy to operate. Ham's Study also pointed out that lactic acid anaerobic threshold requires blood, ventilation anaerobic threshold requires expensive equipment and manpower, and heart rate anaerobic threshold to estimate anaerobic threshold is more appropriate. The point at which heart rate begins to increase non-linearly is usually called the anaerobic threshold heart rate (HR_{AT}). In this experiment, the results of HR_{AT}, anaerobic thresholds / maximum heart rate (% HR_{max}) were analyzed. After hypoxic training, HR_{AT}% HR_{max}increased, while HR_{max}decreased. Increases in HRAT and % HR_{max}, indicated that there is an increase in the proportion of aerobic energy supplied during incremental loads. The drop in HR_{max}indicated that athletes improved cardiorespiratory fitness after training.
After four weeks of routine and hypoxic training, RBC, Hb, Hct decreased. Wilber mentioned in his article, there was no relevant research that RBC production-related transferrin receptor, RBC volume, Hct quality had increased. Park conducted a meta-analysis of eight sports of elite athletes and found that hypoxic training for more than three weeks, three times per week, and one hour each can improve blood oxygen delivery and aerobic capacity, reflected in RBC, Hb and other related indicators. Levine' related studies have shown that hypoxic training exercise performance improvement is not the role of hematological mechanisms, but the skeletal muscle mitochondria, capillary fiber ratio, the changes in fiber cross-sectional area. The reason for this may be related to the duration of hypoxic exposure in the experimental protocol and the training intensity stimulating RBC production had not been reached or the body was still in an adaptive state. Increasing the duration of hypoxic exposure may result in an increase in RBC levels. In addition, because of individual differences, each athlete has his/her own range of the best parameters of blood cells, even if the relevant indicators are not high, but can complete the corresponding training plans. Besides of individual differences, it is also possible to reduce blood cell parameters during periods of intensive training due to excessive body exhaustion, as long as proper adjustment is made before the competition, a athlete can still be in the best condition.
Conclusions After 4 weeks of IHT, the heart rate anaerobic threshold of high-level race walking athletes has been increased, indicating that aerobic energy ratio has been increased and aerobic capacity has been improved.
After 4 weeks of IHT, the RBC, Hb and other hematological indicators of high-level walking athletes do not improve.