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Effects of Altitude Training and Sea-Level Training Programs on the Physiological and Performance of Elite Chinese Male Marathon Runners

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Abstract

Background and Aims: Examining the differences between sea-level training programs and altitude offers important new perspectives on how environmental influences affect physiological adaptations and athletic performance. By being aware of these variations, coaches and athletes can tailor training plans to the unique conditions of altitude, which may improve performance in terms of endurance, oxygen use, and general athletic ability. Thus, this study aimed to investigate the effects of altitude training on physiological adaptation and performance in Chinese elite male marathon runners compared to plains training. By comparing the results of altitude training with those of sea-level training, this study sought to determine whether altitude training has a significant advantage in terms of physiological adaptation and performance enhancement for the Chinese elite male marathoner. In addition, exploring the variability of altitude training responses will help to inform an in-depth understanding of training strategies affecting elite marathoners and help to optimize performance enhancement methods in endurance sports.

Methodology: Thirty-two Chinese elite male marathon runners will be recruited and subjected to a randomized controlled trial (RCT) in which they will be assigned to either a high altitude or plains training group. SPSS was used to perform independent samples t-tests and paired samples t-tests on the data of technical indicators. Both groups will receive structured and standardized training for a predetermined period, with the altitude of the high-altitude training set at 2366 m for 8 weeks.

Results: (1) In the experimental group, the differences in red blood cells (RBC), maximal heart rate (HRmax), maximal oxygen uptake (VO_2max), and full marathon performance before the altitude experiment compared to after the altitude experiment were significant (P=0.001); the differences in maximal anaerobic power and hemoglobin (HB) before the experiment were substantial (P<0.005); and the differences in maximal heart rate (HRmax) between the 28 days of the experiment and the post-experiment were substantial. (HRmax) difference was substantial (P=0.001). (2) The red blood cells (RBC), hemoglobin (HB), and maximal oxygen uptake (VO_2max) of the experimental group were significantly higher than those of the control group compared with the control group (P < 0.005)

Conclusion: The results of the study showed that eight weeks of altitude training at an altitude of 2,366 meters above sea level could improve the athletes' performance in the marathon and aerobic capacity, and could be used in the training of marathon runners.
Keywords: Altitude Training; Marathon; Performance

Introduction:

With the continuous development of society and the constant innovation of training methods and approaches in competitive sports, sports records are continuously being broken, and competition has become extremely fierce. Coaches and sports researchers have begun to seek a new training concept and methods to improve and consolidate athletes' competitive level. As a special training method, "altitude training" refers to organizing athletes to engage in specialized sports training regularly in areas with suitable altitudes in a purposeful and planned manner (Vargas, 2014). Its essence lies in leveraging the reactive and adaptive changes that occur in the human body in hypoxic environments to enhance the body's ability to transport and utilize oxygen, thereby significantly enhancing the effects of aerobic endurance training and rapidly improving aerobic capacity (Chapman, 2015), making it one of the important endurance training methods in the marathon event. Altitude training has long been a topic of interest for athletes and researchers because of its potential to enhance physiological adaptation and improve athletic performance (Mujika et al, 2019). Physiological changes induced by exposure to high altitudes include increased production of red blood cells, improved oxygen utilization, and enhanced buffering capacity, all of which contribute to improved endurance performance (Ramchandani, 2024).

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In marathon racing, aerobic capacity and endurance are key to success, making altitude training a promising avenue for improving marathon runners' performance (Sperlich et al, 2016).

Altitude training has gained popularity among elite athletes as a means to enhance their performance through physiological adaptations. However, its effectiveness compared to traditional sea-level training programs remains a subject of ongoing research. This study aims to investigate the effects of altitude training on the physiological and performance outcomes of elite Chinese male marathon runners and compare them with a plains training program.

Objectives

To compare the outcomes of an altitude training program with a plains training program for elite Chinese male marathon runners.

Literature Review

Programs for training and sea-level training are essential for improving runners' physiological adaptations and performance. Training at low altitudes, or sea level training, enables athletes to build muscle strength, endurance, and aerobic capacity under ideal oxygen-rich circumstances (Chapman et al., 1998). On the other hand, athletes who train at altitude experience lower oxygen levels, which triggers physiological changes like higher red blood cell production and better oxygen utilization efficiency (Millet et al., 2010). Running programs that combine altitude and sea level training can help athletes adapt their bodies more effectively to changing environmental conditions and improve their overall performance.

Physiological adaptations and performance outcomes of runners can be significantly influenced by training regimens customized to their individual needs and goals. Running enthusiasts can systematically increase their fitness, strength, and endurance while lowering their risk of overtraining and injury by following structured training regimens that include periodized training cycles, focused workouts, and recovery periods (Saw et al., 2016). Furthermore, runners can optimize their training adaptations and maximize their potential for improvement with customized training plans that take into account variables like age, fitness level, injury history, and performance goals (Helgerud et al., 2007). Running programs with a clear design can help runners improve their physiological capabilities and performance at sea level as well as at altitude.

Including strength and conditioning exercises in training regimens can also improve runners' physiological adaptations and performance. Enhancing muscle strength, power, and running economy through resistance training, plyometric exercises, and core stability workouts leads to improved performance and reduced risk of injury (Beattie et al., 2017). Exercises for mobility and flexibility also aid in maintaining the ideal range of motion for joints, lowering the chance of injuries like sprains and strains of the ligaments (Behm & Chaouachi, 2011). Running programs can enhance a runner's overall physical preparedness, resilience, and performance capabilities at sea level and in altitude environments by including comprehensive strength and conditioning components.

Conceptual Framework

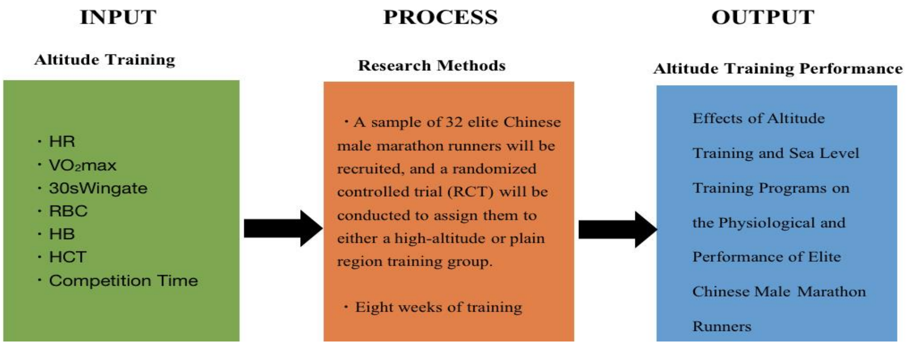

Figure 1 Conceptual Framework

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Methodology

Population and Sample: A sample of 32 elite Chinese male marathon runners with consistent training backgrounds and competitive experience will be recruited for this study. They will be randomly divided into two groups, one undergoing high-altitude training and the other training in a plain region. Both groups will follow structured and standardized training programs.

Table 1 Basic information of experimental subjects

		Experimental group (n=16)	Control group (n=16)	P
Age (YEAR) M±SD		20.44±1.50	20.75±1.70	0.992
Height (CM) M±SD		172±3.26	172.4±2.82	0.442
Weight (KG) M±SD		63.4±3.62	62.37±4.11	0.458
Years of exercise (YEAR) M±SD		4.31±1.30	4.63±1.26	0.914
Campaign level	National-level fitness champion	4	4	-
	Athletes at the national level one	12	12	-

Test indicators and tools

Selection of indicators: red blood cells, hemoglobin, serum ferritin, maximum heart rate, maximum anaerobic power, full race performance time.

Physiological testing tools: pocH-100i automatic triple classification blood analyzer (Japan), Beckman Access2 automatic analyzer (USA)

Athletic ability testing tools: Cortex MetaMax 3B Portable Heart Rate Tester (Germany), Polar Team 2 Team Heart Rate Monitor (Finland), Monark 839E Power Bike (Sweden), Monark 894E Power Bike (Sweden), Stopwatch SEWAN SW8-3100 (China).

Data Analysis: Microsoft Excel 2019 software was used for data collection and graphing, and the experimental data were statistically analyzed using SPSS 27.0 software, and the data were expressed as mean ± standard deviation. Paired samples T-test was used, and the difference between groups was expressed as a P-value, which indicated a significant difference when $P < 0.05$, and a highly significant difference when $P < 0.01$.

Results

Red blood cell count (RBC)

Table 2 Table of changes in the number of erythrocytes

	pre-laboratory	DAY 28	post-experimental
RBC (10^{12}/Experimental group M±SD	4.79±0.32	5.45±0.27	5.95±0.43**
RBC (10^{12}/L) control subjects M±SD	4.79±0.30	5.13±0.17	5.25±0.18

Note: * represents a significant comparison with the pre-experiment ($P < 0.05$); ** represents a highly significant comparison with the pre-experiment ($P < 0.01$).

The erythrocytes of the athletes were tested before the experiment, on the 28th day of the experiment, and after the experiment, respectively. The results showed that there was a significant difference within the experimental group (p=0.001), including a highly significant difference in the

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number of red blood cells comparing the pre-experiment to the post-experiment of altitude training (p=0.001), and a large change in RBC in the experimental group. The control group had a small change in RBC, and there was also no significant difference within the group or at each time point.

Table 3 Overall comparison of RBCs between experimental and control groups

	M±SD	P
experimental group	5.95±0.43	0.005
control subjects	5.25±0.18	

A comparison of the number of erythrocytes between the experimental and control groups showed a highly significant difference between the experimental and control groups (p=0.005).

Hemoglobin (HB)

Table 4 Table of changes in hemoglobin

	pre-laboratory	DAY 28	post-experimental
HB (g/L) experimental group M±SD	146.94±5.08	158.19±4.97	168.69±2.47 *
HB (g/L) control subjects M±SD	143.5±4.55	150.81±4.10	154±3.80

Note: * represents a significant comparison with the pre-experiment (P < 0.05); ** represents a highly significant comparison with the pre-experiment (P < 0.01).

The hemoglobin of the athletes was tested before the experiment, on the 28th day of the experiment, and after the experiment, respectively. The results showed that there was a significant difference within the experimental group (p < 0.005), with a highly significant difference between the hemoglobin comparison before and after the altitude training experiment (p < 0.005), and a large change in HB in the experimental group. The control group had a small change in HB, and there was no significant difference within the group or at each time point.

Table 5 Overall comparison of HB between experimental and control groups

	M±SD	P
experimental group	168.69±2.47	0.003
control subjects	154±3.80	

Comparison of hemoglobin between the experimental and control groups showed a significant difference between the experimental and control groups (p=0.003<0.005).

Serum ferritin (SF)

Table 6 Changes in serum proteins

	pre-laboratory	DAY 28	post-experimental
SF (ng/ml) experimental group M±SD	35.22±8.37	40.57±8	45.76±7.12
SF (ng/ml) control subjects M±SD	34.54±6.71	37.29±6.75	39.94±7.44

Note: * represents a significant comparison with the pre-experiment (P < 0.05); ** represents a highly significant comparison with the pre-experiment (P < 0.01).

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The serum ferritin of the athletes was tested before the experiment, on the 28th day of the experiment, and after the experiment, respectively. The results showed that there was no significant difference within the experimental group (p>0.005), in which there was no significant difference between the comparison of serum ferritin before the altitude training experiment and after the altitude training experiment (p>0.005), but for the altitude training experiment, serum ferritin in the experimental group increased by 14.57% compared with the control group. There was little change in SF in the control group and no significant difference within the group or at any time point.

Table 7 Overall comparison of SF between the experimental and control groups

	M±SD	P
experimental group	45.76±7.12	0.686
control subjects	39.94±7.44	

Comparison of serum ferritin between the experimental group and the control group showed no significant difference between the experimental group and the control group (p > 0.005), but for the altitude training experiment, serum ferritin in the experimental group increased by 14.57% compared to the control group.

Maximum heart rate (HRmax)

Table 8 Table of changes in maximum heart rate

	pre-laboratory	DAY 28	post-experimental
HRmax (b/min) experimental group M±SD	198.50±4.76	192±3.96*	199.50±4.99* ##
HRmax (b/min) control subjects M±SD	198.06±4.55	198.63±4.45	199.43±4.46

Note: * represents a significant comparison with the pre-experiment (P < 0.05); ** represents a highly significant comparison with the pre-experiment (P < 0.01).

The maximum heart rate of the athletes was tested before the experiment, on the 28th day of the experiment, and after the experiment, respectively. The results showed that there were significant (p=0.005) and very significant (p=0.001) differences within the experimental groups, including significant differences in the maximum heart rate of athletes before the altitude training experiment compared with the 28th day of altitude training (p=0.005); there were significant differences in the maximum heart rate of athletes before the altitude training compared with the post altitude training (p=0.003 < 0.005), and there was a highly significant difference in the maximum heart rate of the athletes comparing the day 28 of altitude training to the post altitude experiment (p=0.001); The experimental group had a large change in HB. The control group had a small change in HRmax, and there were no significant differences within the group or at the time points.

Table 9 Overall comparison of HRmax between experimental and control groups

	M±SD	P
experimental group	199.50±4.99	0.405
control subjects	199.43±4.46	

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Comparison of maximum heart rate between experimental and control groups showed no significant difference between experimental and control groups ($p > 0.005$).

Maximum oxygen uptake (VO_2max)

Table 10 Changes in maximum oxygen uptake

	pre-laboratory	post-experimental	P
VO_2max(ml/min/kg) experimental group M±SD	67.17±1.77	71.76±3.40**	0.001
VO_2max(ml/min/kg) control subjects M±SD	65.81±1.85	66.92±1.60	0.078

Note: * represents a significant comparison with the pre-experiment ($P < 0.05$); ** represents a highly significant comparison with the pre-experiment ($P < 0.01$).

The maximal oxygen uptake of the athletes was tested before and after the experiment, respectively. The results showed that: there was a highly significant difference within the experimental group ($p=0.001$), and a highly significant difference between the maximal oxygen uptake of the athletes before and after altitude training ($p=0.001$), and there was a large change in VO_2max in the experimental group. The change in VO_2max in the control group was small, and there was also no significant difference within the group.

Table 11 Overall comparison of VO2max between experimental and control groups

	M±SD	P
experimental group	71.76±3.40	0.002
control subjects	66.92±1.60	

Comparison of maximal oxygen uptake between the experimental and control groups showed a significant difference between the experimental and control groups ($p=0.002<0.005$).

Absolute maximum anaerobic power (Peak Power)

Table 12 Changes in absolute values of maximum anaerobic power

	pre-laboratory	post-experimental	P
Peak Power (w) experimental group M±SD	684.30± 98.39	714.15±98.18*	0.004
Peak Power (w) control subjects M±SD	685.11±81.16	706±82.69	0.088

Note: * represents a significant comparison with the pre-experiment ($P < 0.05$); ** represents a highly significant comparison with the pre-experiment ($P < 0.01$).

The absolute value of the maximal anaerobic power of the athletes was tested before and after the experiment, respectively. The results showed that there was a significant difference within the experimental group ($p=0.004<0.005$), there was a significant difference between the absolute value of maximal anaerobic power of the athletes comparing the pre-experimental and post-experimental altitude training ($p=0.004<0.005$), and there was a large change in Peak Power in the experimental group. The change in Peak Power in the control group was small and there was also no significant difference within the group.

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Table 13 Overall comparison of Peak Power between experimental and control groups

	M±SD	P
experimental group	714.15±98.18	0.487
control subjects	706±82.69	

A comparison of the absolute values of maximum anaerobic power between the experimental and control groups showed no significant difference between the experimental and control groups (p > 0.005).

Results of the full marathon

Table 14 Changes in full marathon performance

	pre-laboratory	post-experimental	P
Full race results (TIME/min) experimental group M±SD	149±6.40	141±6.42**	0.001
Full race results (TIME/min) control subjects M±SD	148.63±6.72	145.88±6.35	0.127

Note: * represents a significant comparison with the pre-experiment (P < 0.05); ** represents a highly significant comparison with the pre-experiment (P < 0.01).

The athletes' full marathon performance was tested before and after the experiment respectively. The results showed that there was a highly significant difference within the experimental group (p=0.001), and a highly significant difference between the athletes' marathon performance before and after altitude training (p=0.001), with a large change in the experimental group's marathon performance. The change in the marathon performance of the control group was small, and there was no significant difference within the group.

Table 15 Overall comparison of full marathon performance between the experimental and control groups

	M±SD	P
experimental group	141±6.42	0.892
control subjects	145.88±6.35	

Comparison of the full marathon performance of the experimental group and the control group showed no significant difference between the experimental group and the control group (p > 0.005), but the comparative performance was improved by nearly 5 minutes, and the overall performance was improved by 3.4%.

Conclusion

The results of the study showed that eight weeks of altitude training at an altitude of 2366 meters, can improve the marathon performance and aerobic capacity of athletes and can be used in the training of marathon runners. This research seeks to provide valuable insights into the effects of altitude training on elite Chinese male marathon runners. By utilizing a comprehensive range of research tools and statistical analysis methods, this study aims to contribute to the optimization of training programs and the understanding of physiological adaptations in high-altitude environments. Ultimately, the findings can inform training strategies for elite marathon runners, helping them achieve better performance outcomes.

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Discussion

Red blood cell count (RBC)

Red blood cells, as carriers of oxygen in the blood, have a significant impact on the exercise capacity of athletes in endurance events such as long-distance running and marathons. Red blood cells (RBC), also known as red blood cells, are a major cellular component of blood. The number of RBCs is a very important evaluation index for athletes of marathon endurance events under the condition of altitude hypoxia, and the number of RBCs affects the athletes' physical functioning status. Erythrocytes are the most abundant blood cells in the peripheral blood of the human body, which can transport oxygen, carbon dioxide, and nutrients. Therefore, altitude reaction may lead to an increase in red blood cells. Erythrocytes are sensitive indicators of change during altitude training.

In this study, the red blood cells of male marathon athletes were examined before and after the altitude training experimental group, and it was found that the number of red blood cells before the altitude training experiment was 4.79±0.23 (1012/L), and the number of red blood cells after the altitude training experiment was 5.95±0.43 (1012/L), which was a highly significant difference (P=0.001) and a comparison of erythrocyte counts of experimental and control groups, the results showed that there was a highly significant difference between the experimental and control groups (p=0.005). Meng (2018) studied 18 male kayaking athletes who trained for 8 weeks at an altitude of 2300 m above sea level and found that red blood cell and hemoglobin counts were significantly higher (p<0.005) before and after altitude training, while Kamila (2018) et al. found that hemoglobin erythrocyte counts (RBCs) were significantly (p<0.005) higher (p<0.005) after altitude training. significantly higher (P < 0.005), which is consistent with the present study. The reason for this may be due to the decrease in oxygen partial pressure of the altitude atmosphere, resulting in a decrease in blood oxygen saturation, which would stimulate the release of EPO, and consequently an increase in erythropoiesis and an increase in aerobic capacity (Czuba, 2014). This result suggests that athletes' erythrocyte levels fluctuate greatly during altitude training and that the altitude environment can influence erythrocyte levels to a great extent. There was no significant difference in the comparison within the control group and at all time points. This indicates that altitude training has less effect on red blood cell levels and that red blood cells are not a sensitive indicator during altitude training.

Hemoglobin (HB)

Hemoglobin (Hb), also known as hemoglobin, has the main functions of transporting oxygen and carbon dioxide, buffering acidic substances, and is the core substance of the oxygen transport link; meanwhile, hemoglobin concentration has a great influence on athletes' athletic ability and is particularly important for the special qualities of endurance athletes. During training and competition, the hemoglobin concentration of athletes is affected by nutritional supplementation, exercise load, rest, and other factors. In athlete function evaluation and training monitoring, the hemoglobin concentration measured during training and before competition can be used to understand the athlete's functional status and adjust the training plan and competition arrangement to prevent overtraining and anemia. Regular measurement of hemoglobin concentration helps to understand the athletes' functional status, adaptation to the training load, and level of physical functioning.

In this study, hemoglobin was measured before and after the experimental group of altitude training for male marathon runners, and it was found that the hemoglobin before the experimental group of altitude training was 146.94±5.08 (g/L), and the hemoglobin after the experimental group of altitude training was 168.69±2.47 (g/L), which was a significant difference (P<0.005) and the results showed that the hemoglobin concentration of the experimental group was higher than that of the control group, and the results showed that the experimental group had a significant difference (P < 0.005) and compared with the control group. hemoglobin, the results showed that there was a significant difference between the experimental group and the control group (p < 0.005). A study by Sun (2019) found a significant increase in hemoglobin in good marathon runners after 6 weeks of altitude training. Wachsmuth (2013) found that the potential for an increase in hemoglobin by altitude training was 3% after 12 days at 3600 m altitude in youth football players. This study shows that altitude training and

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environment can stimulate the athlete's organism and also shows the improvement in the physical functioning of the athletes after altitude training.

Serum ferritin (SF)

Serum ferritin (SF) is a complex formed by desferritin and Fe3+, which is the storage form of iron, and it is an effective indicator for determining whether the body is iron deficient or overloaded with iron. Serum ferritin is one of the most sensitive indicators of iron reserves in the body. Serum ferritin is important for the maintenance of athletic performance and for the synthesis of hemoglobin in athletes.

Neumann (2021) The main role of serum ferritin in exercise: (1) involved in the composition of hemoglobin in the body, determining the transport capacity of oxygen in the body, and therefore closely related to the aerobic metabolism of the body; (2) is an important component of the respiratory chain, which is an important part of the body's energy metabolism; (3) is the constituent of many enzymes, which are the material energy metabolism (4) It is involved in protein synthesis, which is the main structural material of the organism and the material for various functions, and is closely related to the muscle contraction ability. When serum ferritin is deficient in the organism, it causes a decrease in the oxygen-carrying capacity of hemoglobin, which in turn affects the overall low-functioning oxygen transport system of the athlete.

In this study, serum ferritin was examined in male marathon athletes before and after the experiment in the altitude training experimental group, and it was found that the serum ferritin before the altitude training experiment was 35.22±8.37 (ng/ml) and that the serum ferritin after the altitude training experiment was 45.76±7.12 (ng/ml) There was no significant difference ($P > 0.005$). Su Linyuan (2019) conducted altitude training of 16 outstanding male athletes of the swimming team at an altitude of 2800m for 21 days, the results showed that serum ferritin values of the experimental and control group athletes before and after the experiment were in the normal range with no significant difference.

This indicates that altitude training does not cause iron loss in athletes. In addition to the synthesis of hemoglobin, iron is also a component of myoglobin and mitochondrial cytochromes, so iron deficiency not only impairs oxygen-carrying capacity, but also affects the ability of tissues to take up and use oxygen, and reduces maximum oxygen uptake and exercise capacity.

Maximum heart rate

Maximum heart rate is an important reference index for evaluating cardiorespiratory function, and the strength of cardiorespiratory function will have an impact on aerobic exercise capacity, so evaluating the aerobic capacity of athletes can also be used as an evaluation index of maximum heart rate.

At the same time, the maximum heart rate is also one of the important indexes to control the training intensity load of athletes.

In this study, the maximum heart rate of male marathon athletes in the altitude training experimental group was detected before and on the 28th day of the experiment and after the experiment, and the maximum heart rate before the altitude training experiment was 198.50±4.76 (b/min) and the maximum heart rate on the 28th day of the experiment was 192±3.96 (b/min) with a significant difference ($p=0.005$);

There was a highly significant difference between the maximum heart rate of 192±3.96 (b/min) on the 28th day of the experiment and the maximum heart rate of 199.50±4.99 (b/min) at the end of the experiment in the altitude training experimental group ($p=0.001$). Gao et al (2019) conducted an 8-week altitude training study on Chinese outstanding rowers and found that there was a significant difference between the pre-experimental maximal heart rate and the heart rate on the 28th day of the experiment and the post-experimental heart rate of their athletes ($p<0.005$), and all of them were in the trend of decreasing in increasing.

The reason for this may be because, the athletes' first visit to the altitude will produce a non-adaptation situation, which never caused the maximum heart rate on the 28th day of the experiment will be reduced, but when the athletes adapt to the altitude environment as well as their aerobic capacity has

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been improved to a certain extent, the maximum heart rate will also increase. Feriche et al (2017) et al.'s study found that the maximum heart rate in different environments has been correlated, and it is believed that the low-oxygen environments lead to increased sympathetic and parasympathetic activity and insufficient arterial blood oxygenation, making lower cardiac output and causing a decrease in maximum heart rate.

Maximum Oxygen Uptake

Maximum oxygen uptake and anaerobic threshold can reflect the body's ability to inhale oxygen, transport oxygen and utilize oxygen, so the parameters related to maximum oxygen uptake are usually chosen as important indicators for assessing the human body's aerobic exercise capacity, and maximum oxygen uptake reflects the maximum aerobic capacity.

In this study, the maximal oxygen uptake of male marathon athletes in the experimental group of altitude training was examined before and after the experiment, and it was found that the maximal oxygen uptake before the experiment of altitude training was 67.17±1.77 (ml/min/kg), and the maximal oxygen uptake after the experiment of altitude training was 71.76±3.40 (ml/min/kg), which was a highly significant difference (P=0.001). 0.001). Sun (2022) selected 12 middle-distance runners who underwent altitude training for 6 weeks at the Doba training base at 2366 m. He found that the maximal oxygen uptake of the athletes increased from 73.42±3.53 (ml/min/kg) before altitude training to 78.76±4.02 (ml/min/kg), which is a 7.27% increase, with a significant difference (P<0.05). 0.05). The study proved that VO2max was improved and aerobic capacity was enhanced in athletes after altitude training, this study is consistent with the present study, the reason for this phenomenon may be because the human body stimulates the kidneys to release erythropoietin (EPO) in a low oxygen environment, which increases the concentration of hemoglobin and enhances the capacity of the oxygen transport chain and the capacity of the lactate tolerance in the skeletal muscle so that the oxygen utilization of tissue cells is increased, This leads to an increase in VO2max.

Maximum anaerobic power

Maximum anaerobic power is the ability of limb muscles to output maximum power in a short period, reflecting the explosive power of the athlete. The greater the value of maximum anaerobic power, the greater the explosive power of the athlete's instantaneous explosive power. The average anaerobic power is the average value of the power output of a 30s all-out exercise. The average anaerobic power reflects the energy supply capacity of the anaerobic metabolic energy supply system, which depends on the maximum decomposition rate of adenosine triphosphate (ATP) and the maximum synthesis rate of phosphocreatine (CP) and sugar anaerobic fermentation in the 30s. Sugar anaerobic fermentation is the energy basis of speed endurance, which embodies the overall level of anaerobic exercise capacity, and also is an indicator of the body's anaerobic capacity, which indicates the muscle's ability to sustain a high power output. The greater the value of average anaerobic power, the greater the subject's anaerobic work capacity, and the limb muscles have the endurance to maintain high power. Both maximum anaerobic power and mean anaerobic power are expressed in both absolute and relative terms, with the absolute value being the value of power output by the body as a whole and the mean value being the power output per unit of body weight (per kg).

In this study, the maximum anaerobic power of male marathon athletes was examined before and after the experiment in the altitude training experimental group, and it was found that the maximum anaerobic power of the pre-experiment of altitude training was 684.30±714.15±98.18 (w), and the maximum anaerobic power of the post-experiment of altitude training was 714±98.18 (w), which was a significant difference (P<0.005). Ma (2013) found a significant increase in maximal anaerobic power in male cyclists who underwent altitude training for 4 weeks (P < 0.005). This study is consistent with the results of the present study, and the reason for this result may be that altitude training can have a more significant effect on the blood's ability to transport oxygen due to longer exposure to low-oxygen environments, increasing the body's aerobic metabolism, which indirectly affects the cyclist's ability to maintain power output (Schmidt, 2018).

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Marathon Performance

The current standard distance for the marathon was established in May 1921 by the then International Amateur Athletic Federation (lAAF) as 42.95 kilometers (26 miles, 385 yards). This race distance is now legal. The time it takes to complete a full marathon, i.e. 42.95km, is the full marathon exercise performance and is the best indicator of marathon exercise capacity.

In this study, the maximum anaerobic power of male marathon athletes was tested before and after the experiment in the altitude training experimental group, and it was found that the full marathon performance before the altitude training experiment was 149±6.40 (min), and the full marathon performance after the altitude training experiment was 141±6.42 (min), which is a highly significant difference (P=0.001). A study by Feng (2019) found that 16 marathoners had a significant improvement in full marathon performance after an 8-week altitude training ($P < 0.005$). This is consistent with the results of the present study, which suggests that altitude training can improve the athletes' aerobic capacity thereby improving the performance of the full marathon.

Recommendation

To make altitude training achieve an ideal training effect, it is necessary to consider many factors, such as the choice of altitude for altitude training, the time of altitude training, the training level of athletes and individual differences, the control of load and load intensity, the nutrition and recovery of altitude training, as well as the coach's experience of altitude training and the knowledge of the law of altitude training and so on. All these factors affect the success or failure of altitude training. However, among the factors constituting altitude training, the most central factors are training volume and training intensity, and the most difficult to control factor is training intensity. Most of the reasons for the failure of altitude training will be attributed to the lack of scientific monitoring of the athlete's physiology and improper control of intensity. It is the inherent advantages and disadvantages of altitude training that make altitude training a "double-edged sword". Reasonable training arrangements can improve competition results: a little carelessness in training arrangements will result in a drop in performance. To maximize the benefits and minimize the risks associated with altitude training, physiological indicators must be monitored and a personalized altitude training plan developed.

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