Exploratory Research on the effects of breathing high pressure oxygen after exercising to foster greater motor performance and facilitate recovery from fatigue

1. Foreword……

Hyperbaric oxygen is a hot topic in medicine today and it's finding a growing range of diversified applications including as a treatment for tumors [1], or hyperbaric oxygen used in conjunction with prednisone as a way of reducing inflammation caused by skin transplantation. Promising results are also being seen as well as a therapy to treat typical sports related ailments. But there is still much room for further development and research ahead.

Sports and Sports Medicine practitioners from around the world are applying the intake of high pressure oxygen to aid in the recovery of athletic fatigue and other sports-related injuries [2][3][4][5]. However, due to the threat of oxygen toxicity, they are still cautious about the exact application of hyperbaric oxygen in response to inconclusive data about the amount and frequency of the use of high-density oxygen. Around the world, at this moment, researchers studying oxygen respiration and sports are still focused on oxygen-based health care, oxygen therapies, and experimental application of hyperbaric oxygen used together with other medicines on animals. Yet there is still not much in-depth research on the application of hyperbaric oxygen on sport training and sports competition, as well as the relationship between oxygen intake and the recovery of an athlete's body and motor performance. The following descriptions are summaries of the research in China and overseas surrounding oxygen intake and sports.

1.1 Oxygen Healthcare

Oxygen healthcare originated in western Europe where it is considered an advanced medical treatment method. At the end of the 1960's, West Germany started its research and applications into oxygen healthcare. Since the 1980's, oxygen therapies have become popular in Mexico, the US and Japan. Especially in Japan, mini oxygen generators have become some of the most popular products in the market today. In some of the wealthy countries, pure oxygen breathing has become a ubiquitous trend with nearly 20% of all families having regular access to mini oxygen generators. According to some reports, there are obvious effects associated with oxygen healthcare including the enhancement of the aerobic metabolism of human cells, which in turn, strengthens the body's ability to resist disease and improves overall health. This is important especially for those involved in intellectual pursuits who tend to over tax their brains, as well as urban dwellers who are exposed to higher concentrations of harmful pollutants. In Hong Kong, some doctors even combine Chinese medicines, acupuncture and hyperbaric oxygen to aid in the prevention of urban-based diseases, plus ailments of the elderly and chronic diseases. According to reports, this combination-type therapy is showing positive effects. Criner (1987) [6] reports that breathing in oxygen densities of around 30% could help cure patients who suffer from light to moderate hypoxemia. However, the report states that more in-depth research should be conducted on the overall effects and applications of oxygen therapy.

1.2 Oxygen Exposure and Oxygen Toxicity

At present, research into various densities of oxygen used to assist other therapies has been mainly focused on animal experiments. There has not been much research done on athletes.

It was also reported that more obvious effects were present with high-density oxygen regimens improving the AOE vitality in lungs of newly born rats. The incidence and level of pulmonary fibrosis increased as the period of oxygen breathing was extended. Research from Yuyanqiu (2000) [7] points out that the combined use of hyperbaric oxygen together with prednisone helped reduce the destructive effect of rejection after transplantation, causing the fluorescent area of CD3, CD4, CD8, CD11a, CD18 +cells to become smaller than that of a control group. It also reduced the invasion and adhesion molecules of transplanted local T-lymphocytes and their sub-population, thus achieving unexpected therapeutic results.

In China, scholars have conducted in-depth research and achieved remarkable results on the effect of certain dosages of oxygen on the immunity of free radicals and red cells. The peak value of the free radical spectrum in the lung tissues increased as the dosage of oxygen increased, while the red cell immunity RCR showed progressive declines [8].

Continuous pure oxygen breathing may cause damage to the body, especially to the nervous system and lung capillary endothelium. Sometimes this damage can be quite serious. We call this ‘oxygen toxicity’ in medical parlance. Arieli and Gutterman [9] (1996) published a report on oxygen respiration and oxygen toxicity, pointing out a calculation formula of hyperbaric oxygen and recovery time. Through comparative experiments on the nervous systems of rats, they achieved the following result: The recovery effects of continuous exposure to a pure oxygen environment of

PO_2=608kpa (1 standard atmosphere =101kpa) was less obvious than first seen in the pure oxygen environment of PO_2=608kpa. It was adjusted to 3.5%O_2 under a standard atmosphere and lastly changed to a pure oxygen condition of 608kpa. Their experiments gave us these insights: Can we make reference to this and design various levels of oxygen density exposure to affect faster recovery while still avoiding occurrences of oxygen toxicity?

Recent reports (2000) [10] have highlighted the correlation between the number of repeated pure oxygen exposures and the immune response function of lymphocytes in rats. The research report further points out as well that free radicals in the hyperbaric oxygen itself are involved in damaging the body's immune system. This damage was linked to the number of oxygen intake exposures. In the early stages of exposure, the adhesion function of lymphocytes was lowered. As the number of exposures increase, the level of lipid peroxidation also decreased and the immune function of the lymphocytes increased to different levels. Medical practitioners such as Lianqinglin, Huchanghong, Xubo [11] have seen great progress in the research results linking hyperbaric oxygen to tumors and lung cancer. Through high-low oxygen radiotherapy, they found that they could enhance the tissue of the tumor, which in turn, helped improve the activity of NK, LAK and CTL cells in the rats with lung cancer and could actually control the cancer's growth.

1.3 The application of hyperbaric oxygen breathing in athletic training

The application of oxygen intake therapies in athletic training is still at the exploratory stage. There are many different points of view about the effects of oxygen breathing before, during and after exercise. And there is still no conclusion about the effects of different densities of oxygen for athletes.

Oxygen breathing research at present is focused primarily on hyperbaric oxygen breathing and low pressure oxygen (the physiological foundation of low pressure oxygen research is directed at Altitude Training Theory, which is itself centred on the enhancement of aerobic endurance in athletic training.) However, due to the existence of the oxygen toxicity as a result of hyperbaric oxygen intake, sports medicine practitioners are taking a very cautious approach to this area of research and application. Some scholars are starting to conduct research on the effects of atmospheric-pressure high density oxygen on the body.

1.3.1 Oxygen breathing before exercise

There is evidence of positive effects if the an athlete breaths pure oxygen right before taking part in exercise. This may stem from the purging of more carbon dioxide during the end of exhale cycle. For example, swimmers take a deep breath right before the starting gun goes off in a race. This may have a positive effect in achieving better results, but it also enhances the very, very slight chance of drowning too. [12].

For exercises in which holding your breath is not needed, research results show that breathing in oxygen before the start of the sporting activity has little, if any, effect on the results. But, experiments on firemen, including Petersen (2000) [13] ,showed that breathing in a gas mixture containing 40% pure oxygen had a somewhat obvious effect on the outcome of the high endurance sports.

1.3.2 Oxygen breathing during exercise

In 1996, Sunno (1996) [14], using P [31] marks, took measurements and did analysis on the ATP, PCr, Pi and blood's PH value of quadriceps femoris of rats when they breathed in different densities of oxygen calibrated at 50%, 28%, 21%, 11% and 8% respectively. The research discovered that the peak value of oxidative phosphorylation did not happen at a density of 50%, but did occur at the density of 21% or below. The results showed that high density oxygen was meaningless to the body's energy metabolism, which directly contradicts the notion that oxygen breathing can have a positive effect on exercise. Bell (1999) [15] also conducted an oxygen breathing experiment on the elderly on and off for nine years. The results showed that the characteristics of oxygen uptake kinetics (including the ability of oxygen uptake and oxygen transporting) of elderly decreased mainly due to an increase of age. There was no obvious effect of breathing high density oxygen on oxygen uptake kinetics of the elderly when doing exercises. This proves that oxygen supply is not the restrictive factor to the decrease of oxygen uptake kinetics in the elderly.

Strueder and Hollmann (1996) [16] conducted training on three groups of athletes under conditions of high oxygen (100%), low oxygen (14%) and normal air (21%). The athletes had to ride a bicycle for 60 minutes, while breathing oxygen or normal air during and after the exercise. Research found that the PO2 and saturation of oxygen in blood of the high oxygen group was comparatively mild, while the PO2 and saturation of oxygen in the blood of the low oxygen group and normal air group decreased. The results revealed that there was an obvious increase of PRL after doing exercises under a high oxygen environment for 30 minutes, while there was no obvious change in the density of other ions and hormones. A reasonable explanation for the dramatic increase of PRL density with the increased saturation of oxygen in the blood was not found.

Japanese scholars (1990) [17] conducted experiments on the effects of high atmospheric pressure oxygen training on the endurance and results. Experiments found that there was an obvious increase of endurance and lactation. This shows that high oxygen training can have a significant impact on improving endurance. Scholars including Peltonen (1999) [18] conducted an experiment with oxygen breathing during exercise on 6 elite athletes who have strong endurance. The experiment showed that there was a co-relation between the saturation of oxygen in the blood of elite athletes to the supply of oxygen density from outside. Several research studies have shown that breathing air with a high oxygen content (33% - 100%) has a positive effect on achieving good results in athletic events. Taiwan scholar Linzhengchang (1998) [12] pointed out that this might be due to the increase of PO2. The idea being that the increase of PO2 may also increase the mixing of hemoglobin and oxygen and the ability to dissolve body fluids. It also increased the diffusion ability of alveoli (capillary and tissue) capillary membranes. However, it still must be pointed out that it may be unrealistic to achieve good results by merely breathing pressurized oxygen during exercise.

1.3.3 Oxygen breathing after exercise

Fengyurun (2001) [3] conducted a post-exercise oxygen breathing experiment on mid to long distance runners. Five of these athletes (the experiment group) underwent the same amount and strenuous level of exercise as the control group. Afterward, the experiment group entered a hyperbaric oxygen cabin, breathing 99.2% oxygen for 20 minutes under 2ATA, then took a 5-minute rest. This cycle was repeated 4 times. Research results showed that the athletes obviously felt relaxed after the hyperbaric oxygen process. The athletes who didn’t undergo the hyperbaric oxygen process felt tired after the normal recovery period. There was an obvious difference with the blood lactate densities between the two groups after recovery. The recovery time of the oxygen breathing group was faster than that of the non-oxygen breathing group. Moreover, the hear rate recovery time of the oxygen breathing group was faster than that of the non-oxygen breathing group. The blood ammonia test showed that there was no obvious effects of hyperbaric oxygen on the clearance of ammonia. There was also no statistical deviation in the amount of blood urea nitrogen and white cell count.

Liyixue (1995) [19] conducted some groundbreaking experiments on hyperbaric oxygen. For one month the experiment involved rats breathing medical-use pure oxygen (2ATA) for one hour after exercise. The results showed that fatigue accumulation may cause injury to the liver cells and tissues. But breathing oxygen after exercise causes liver cells to recover more quickly and even makes their structure and function better than they were before exercising. There was an obvious effect on the improvement of the function of the liver tissues and cells and quicker recovery from fatigue.

A Japanese scholar [4] made observations on the effects of breathing oxygen after exercise and recovery process from fatigue. Observations were made on ventilation, blood lactate, and pyruvic acid. It was discovered that the higher the density of oxygen, the earlier the recovery took place. Under conditions of breathing pure oxygen, incorporating a suitable percentage of carbon dioxide will have a great effect on the enhancement of the amount of oxygen uptake. Russian scholar Agadzeraniam (1986) [20] had a relevant report as well that the combination of 1% of CO2 and 35% of O2 helped promote the clearance of blood lactate.

But, some other scholars conducted experiments on cyclists. They breathed 10-20h of 100% pure oxygen during the recovery stage. However, there was no meaningful statistical change. Therefore, based on this result, some scholars think that there is no obvious effect of oxygen breathing on the recovery process or on the subsequent competition. The effects are just psychological and there is no theoretical physiological foundation.

In fact, we find that most research on oxygen breathing after exercise mainly focuses on the recovery effect of hyperbaric oxygen. There is still not much research on the relationship between breathing atmospheric pressure high-density oxygen and The body’s recovery and motor performance. Moreover the research results have wide variances among each other.

1.4 Conclusion

There are several research studies on the effects of oxygen breathing and fatigue recovery as well as motor performance [1] [2] [3]. However, due to the special side effects of toxicity from hyperbaric oxygen, athletes and coaches must use hyperbaric oxygen regimens with a great deal of caution. The application of atmospheric pressure high-density oxygen mainly focuses on the oxygen breathing during exercises [21] [22] [23] and it's efficacy and importance remain suspicious. There are still not many research reports that clearly show the advantages of breathing atmospheric pressure high-density oxygen after exercising. In fact, is there any effect at all on the body when breathing high-density oxygen after exercise? How great is that effect? Is the effect positive or negative? We still don't know.

This paper will attempt to find a reasonable oxygen breathing method which can help promote the body's recovery after exercise while avoiding the toxicity associated with hyperbaric oxygen by researching the relationship between oxygen breathing after exercise and body function recovery as well as motor performance.

2. Materials and Methods

2.1 Target of the experiment and grouping

8 mid to long distance runners from the Hong Kong Institute of Sports, were included in the research. They comprised four males aged 18.8±0.96, height 1.72 ±0.03m, weight 58.3±1.59kg, best result for 1500m 4'22"±2.7"; and four females aged 15.8±0.43, height 1.60±0.02m, weight 48.7±0.59kg, best result for 1500m 5'35"±6.6". They were randomly separated into two groups: Group A and Group B (N=4), with 2 males and 2 females in each group.

2.2 Training regimen and oxygen breathing

The sample groups underwent two phases of the study, each phase lasting for 4 weeks, for a total of 8 weeks. In the first phase, after the normal training every day, the 4 athletes of Group A breathed oxygen for 20 minutes with a density of about 60% - 80%. Athletes of Group B recovered in the normal way without oxygen. In the second phase starting from the 5th week, the athletes of Group A didn't breath oxygen after training and recovered in the normal way, while the athletes of Group B recovered by breathing oxygen for 20 minutes after training. In the two phases, Group A and B took turns as the designated control group. A 1500 metere running test was conducted on the last day of each phase.

2.3 Equipment

Monitoring equipment used in the tests included: the CELL-DYN1700 Hematology Analyser (made in US), Reflotron Hematology Analyser (made in Germany), YSI Lactate Analyser (made in US), Sports Tester (made in Finland), and the IRMA Analyser (made in UK).

All high-density oxygen used in the experiment was supplied by the OXYVITAL oxygen generator from the OXYVITAL Corporation. This generator can provide high-density oxygen rated at 60% - 80% with a maximum delivery speed of 20L/min.

2.4 Testing Method

2.4.1 Questionnaires

During the entire experiment process, all athletes had to fill in a training capacity examination form that assessed their psychological status, muscle stiffness, sleeping times, sleep quality, appetite and other factors.

2.4.2 Regular blood examinations using biochemical markers

About 500µl -700µl of blood was drawn from the athletes' fingers every three days. The blood then underwent seven biochemical marker examinations to monitor Hb, WBC, RBC, Testosterone, Cor, CK and urea. Among theses factors, Hb, WBC and RBC were tested by the CELL-DYN1700 Hematology Analyser. Testosterone, Cor, CK and Ferritin (extra test every Monday) were monitored using the MiniVADIS Serum Analyser. 400µl of additional blood was obtained from athletes' fingers for Ferritin testing.

2.4.3 1500m test

On the last day of each phase (i.e. the last day of the 4^{th} and 8^{th} week), A 1500m running test was conducted on the laboratory treadmill. The speed was controlled using calculations of each runner's best personal result. After running, the oxygen therapy group breathed oxygen with a density of 60% - 80% while the control group recovered in the normal way. Athletes' results and the completed group results were recorded. The average and maximum heart rates during running were tested by the Sports Tester while lactate levels during running were tested using the lactate analyzer. When the group results were completed, blood was obtained from all the athletes' fingers and a blood gas analysis was taken using the IRMA Analyser.

2.5 Statistics Methods

The experiment data were processed by the STATISTICA, taking oxygen breathing as an influencing factor to analyze all markers. All data were presented with standard deviations and average values and were gathered using an ANOVA analyser. Since there were just 8 samples, the significance level in our ANOVA analysis was $P<0.1$.

3. Experiment results

3.1 Training capacity form and psychological feeling

After analysis of the information obtained from the training capacity form filled in by athletes everyday, it was discovered that there was no obvious difference in muscle swelling, sleep time, sleep quality and appetite between the oxygen breathing (oxygen therapy) group and the non-oxygen therapy group. But, in terms of muscle stiffness, athletes claimed that oxygen breathing obviously helped relieve muscle stiffness and aided in recovery, $p<0.1$. (table 1)

Table 1 Comparison of muscle stiffness between oxygen breathing group and control group

Groups	Number	Muscle stiffness
Oxygen therapy	8	0.23±0.31
Control group	8	0.26±0.32
P value	/	<0.1

3.2 Regular testing every three days

After analyzing the data gathered from regular tests conducted every three days, it was more obvious that for the oxygen breathing group there was a decrease in CK percentage levels compared with athletes' personal CK in the past, $P<0.1$. For other markers such as Hb, RBC, WBC, Cor, Testosterone, Urea and Ferritin, there was no statistical deviation. (table 2)

Table 2 Comparison of CK between Oxygen breathing group and control group

Groups	Number	% of CK
Oxygen therapy	8	42%±3%
Control group	8	57%±2%
P value	/	<0.1

3.3 1500m test results

3.3.1 The completed results of 1500m run

Table 3 Comparison of individual results amongst oxygen breathing group and control group after finishing the 1500m run

Groups	Number	Individual result of finishing 1500m
Oxygen therapy	8	2.71±0.54
Control group	8	2.17±0.76
P value	/	<0.1

Based on the data from table 3, we see that the individual results of the oxygen breathing group exceeded that of the control group.

3.3.2 Heart rate and blood lactate volume

We recorded the blood lactate, the average heart rate and maximum heart rate during the first and second 1500m run. Viewing the data on table 4 and 5, we can see that there is no statistical deviation in the average heart rate, maximum heart rate and the blood lactate of the two runs amongst the oxygen breathing group and control group, P>0.1. However, it is noteworthy that the average heart rate and maximum heart rate of the oxygen breathing group was lower than that of the control group. The same trend holds true for blood lactate volume as well. (see table 4 & 5)

Table 4 Comparison of heart rate upon completion of the 1st and 2nd 1500m run amongst oxygen breathing group and control group

Groups	Number	AverHR1	AverHR2	MaxHR1	MaxHR2
Oxygen therapy	8	164±29	166±30	178±34	179±35
Control group	8	169±9	174±11	189±8	194±8
F value	/	0.197	0.410	0.641	1.050
P value	/	>0.1	>0.1	>0.1	>0.1

Table 5 Comparison of blood lactate volume upon completion of 1st and 2nd 1500m run between oxygen breathing group and control group

Groups	Number	Average lactate(mmol/l) AverHR1	Average lactate (mmol/l) AverHR2
Oxygen therapy	8	12.296±1.732	14.164±1.956
Control group	8	12.659±2.361	14.169±3.073
F value	/	0.102	1.585
P value	/	>0.1	>0.1

3.3.3 Blood gas analysis

Table 6 Comparison of blood gas analysis upon completion of 1st and 2nd 1500m run amongst oxygen breathing group and control group

Groups	Number	PH-1 (Pre-test)	PH-2 (After-test)	PCO_2-1 (Pre-test)	PCO_2-2 (After-test)	PO_2-1 (Pre-test)	PO_2-2 (After-test)

Oxygen therapy	8	7.44±0.06	7.17±0.10	37.3±4.89	31.5±2.39	85.0±12.4	104.8± 19.9
Control group	8	7.41±0.02	7.19±0.10	40.2±2.17	33.6±4.32	87.7±6.28	105.1± 22.6
F value	/	0.863	0.104	1.72	1.27	0.242	0.001
P value	/	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1

4. Analysis and discussion

In order to analyze the effects of oxygen breathing on bodily function, fatigue recovery and motor performance after exercise, we conducted a subjective impression questionnaire, together with regular check ups conducted once every 3 days plus a 1500m run. There are just a few samples, so in order to minimize the experiment's deviation and the effects of training, we divided the experiment into two phases and each of the two groups of athletes took turns serving as control group.

4.1 The effect of oxygen breathing on subjective feelings concerning body function and recovery of fatigue.

4.1.1 Positive subjective impressions

From the results of the questionnaires, athletes had positive subjective feelings, especially in terms of muscle stiffness, when there was oxygen breathing after exercise. This result is consistent with other research results from China and other overseas countries that showed oxygen breathing after exercise may have greater psychological rather than quantifiable physical effects on the body. Lin zheng chang [12] even pointed out that the positive effects of oxygen breathing is most likely psychological. However, from this experiment, we cannot conclude whether or not it is just a psychological effect.

4.1.2 Recovery from fatigue

CK is one of the key enzymes of the ATP-CP system. Under the normal conditions when myocyte counts are full, CK seldom passes through cell membranes, resulting in very low levels of serum CK. When exercising, muscles begin to lose oxygen gradually and free radicals increase. Moreover, muscle cell membranes become injured and incidences of penetration increase. This allows CK to enter the blood through muscle cell membranes. So, the stronger the muscle, the more obvious we'll see an increase in CK. Therefore, the change of CK activation can be regarded as a marker for the adaptive abilities of myoid cells to exercise training. This can then be used to evaluate the strength of the exercise and the volume of training. Recently, the change of CK has even been regarded as a foundation for all exercise training [24]. From a micro point of view of scientific training, the avoidance of fatigue and change of CK are greater scientific indicators than blood lactate. But it is obvious that CK is greatly affected by individual differences and, therefore, its absolute value is not suitable for direct use in evaluating muscle fatigue. On the other hand, more and more research has proven that it is more effective to use an individual's past CK levels to calculate the overall CK percentage level [25]. The recovery of serum CK activation in some athletes under training is faster, with recovery rates going back to normal in 24 hours [26]. In regular tests conducted once every 3 days, the CK percentage level of the oxygen-breathing group showed a more obvious recovery tendency ($P<0.1$) than the control group. Therefore, we can infer that oxygen breathing after exercise helps promote the amelioration of muscle fatigue. However, there is no statistical meaning in the change of Hb, RBC, WBC, Cor, Testosterone, Urea and Ferritin from the regular tests conducted once every three days. Therefore, we are not sure if there is any effect of oxygen breathing after exercise on other aspects of body function. From the descriptions above, we can also see that despite the samples' subjective psychological feelings or data from regular biochemical tests of the body, oxygen breathing after exercise seems to have a positive effect on the recovery of muscle function.

4.2 The effect of oxygen breathing after exercise on motor performance

From the results of the 1500m test during each phase, oxygen breathing after exercise enhances motor performance by 25%. Linossier (2000) [27] reported that breathing 65% oxygen during exercise resulted in a 38% longer workout time before exhaustion set in than the control group. Plet (1992) [28] even reported that breathing 55% oxygen during exercise extends workouts 38% longer until exhaustion than the control groups. But he also pointed out that there were greater individual differences among the athletes. We also note in our experiment that in the 2nd 1500m test, some oxygen breathing athletes showed no differences compared with occasions when they breathed oxygen before exercise. Adams (1980) [29] had a similar results. We think that the enhancement of aerobic endurance results from the combined effects of the accumulation of oxygen breathing after exercise in normal times and the intermittent breathing of oxygen during the testing process. But, further exploration needs to be made on determining which is the dominant factor.

Adams (1980) [29] reports that the oxygen breathing group conducted exercises when breathing in 60% oxygen during workouts. So 60w was the starting point, with an increase of 15w every 3 minutes until they reached exhaustion stage. Heart rate and lactate was checked during the last 5 minutes of each phase. It was found that compared with the control group and low oxygen group (17% oxygen), during the exercise, the heart rate of the oxygen breathing group decreased more obviously and the decrease of lactate was also more obviously at the range of around 60%. However, at the exhaustion stage, compared with the control group, there was no obvious difference of lactate and heart rate of the oxygen breathing group. Plet's research [28] found that when breathing in 55% oxygen during exercise, the lactate density decreased more markedly and the maximum heart rate varied according to the sex of the athlete. The maximum heart rate of females in the oxygen breathing group tended to increase markedly while there was no significant difference for males. In our experiment, compared with the control group, the average and maximum heart rates of the oxygen breathing group tended to decrease after the 1st and 2nd 1500m run test. There was no obvious change in the average lactate change, but it still tended to decrease. This result was similar to research conducted in China and overseas. But, the sexual difference reported by other scholars was not found in our experiment. We know that blood lactate is a widely applied marker in sports training. It is regarded as a measurement tool for mastering the endurance in an exercise, as well as evaluating the adaptation level of the body to the training, and an athlete's other motor performance. Blood lactate's recovery rate is also a strong indicator [29] to evaluate an athlete's body recovery abilities. Although we didn't check the blood lactate and heart rate after exercise of the oxygen breathing group at the exhaustion stage, we can infer that there is no obvious difference in the maximum heart rate and lactate at exhaustion stage between the oxygen breathing group and control group.

From the above experiment data and analysis, we can conclude that: oxygen breathing after exercise will decrease the rate of test sample's heart rate and lactate during the stage of sub-maximum exercise, and increase the overall anaerobic performance of athletes.

4.3 Possible mechanism for the enhancement of anaerobic performance by oxygen breathing after exercise

After the 1500m run test, we conducted a blood gas analysis of the athletes. From the statistical data on table 6, we found that there were no significant changes.

Much research [29] [31] [32] has pointed that breathing oxygen during exercise will increase the PO2 count in the blood. However, it cannot increase the clearance rate of carbon dioxide in the blood but does indeed increase the carbon dioxide content and thus increase the density of HCO_3. This was not found in our experiments of oxygen breathing groups after exercise. Our blood gas analysis after exercising pointed out that, compared with the oxygen breathing group to the control group, there was no obvious statistical change in the gas metabolism. We think that, no matter whether its during or after exercise, breathing oxygen to change blood gases is just an temporary effect. When the factor of breathing oxygen was removed, the gas content in the blood recovered to normal in a very short time. This was consistent with the conveyance theory of the gas in the blood and coincides with the basic physical nature of the blood. The conveyance of oxygen in the blood is done though a combination of hemoglobin. For carbon dioxide, part of the conveyance includes combinations of Na^+, K^+. Under atmospheric pressure, just a small amount [30] of gas was conveyed by physical dissolution. Under conditions of hyperbaric oxygen, the physical dissolution of gas increased dramatically and this was the crucial factor of many therapeutic effects of the hyperbaric oxygen. Adams [29], Trzebski (1995) [33], in their research on oxygen breathing during exercise, came to the same conclusion that oxygen breathing did not change the utilization rate of oxygen by the body. There was an obvious increase in the maximum amount of inhalation, but an obvious decrease in ventilation; they thought that the decrease of ventilation was due to the increased oxygen density.

This research doesn't include a special test on maximum inhalation and maximum ventilation amounts. Originally we thought that oxygen breathing during exercise would increase the oxygen content in the blood. But, from the blood gas tests conducted before and after exercise, we found no significant evidence. During the exercise, the increased range of lactate was comparatively low for the oxygen breathing group after exercise. From this, we can infer that the restrictive factor of motor performance is due to $[H^+]$ /the accumulated density of lactate. The effect of oxygen breathing after exercise may be the enhancement of lactate clearance from the body. However, whether the enhancement of aerobic oxidation speeds up this lactate clearance or not needs to be explored further.

5. Conclusion:

1) Oxygen breathing after exercise provides positive psychological effect to athletes, especially to the way their muscles feel.
2) Oxygen breathing after exercise has a positive effect on muscle recovery
3) Oxygen breathing after exercise may lower a test samples' elevated heart rate and lactate during the sub-maximum exercise stage, and enhance an athletes aerobic performance. However, this enhancement is due to the combined effects of the

accumulation of oxygen breathing after exercise in normal situations and intermittent oxygen breathing during exercise. But, in our experiments, we are not sure that which is the dominant factor.

4) We can infer that the restrictive factors of motor performance are [H^+] and the effect of oxygen breathing after exercise may result in the enhancement of lactate clearance from the body. Whether there are other mechanisms involved in this process will require further exploration.

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