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ABSTRACT

Increased participation of competitive athletes in new methods of simulated altitude warrants research on changes in performances. PURPOSE: To ascertain the effects of intermittent simulated altitude exposure via re-breathing on cycling performance. METHODS: Eighteen, well-trained male cyclists engaged in the use of a re-breathing simulated altitude device for 15 days. Subjects were randomly assigned to 1 of 2 simulated altitude groups; a low constant exposure group (CON) or progressively increased exposure group (TRT). Each exposure consisted of alternating between a re-breathing device and atmospheric air for 6 min and 4 min, respectively over 1 hour. Oxygen saturation was monitored with a pulse oximeter; and either held constant (98% over 15 days; equivalent altitude equal 150 m) or progressively reduced (90% on the 1st day to 77% on the 15th day; equivalent altitudes equal 3600-6300 m). An exercise performance test was performed to familiarize subjects to the protocol (FAM), prior to simulated altitude exposure (PRE) and following simulated altitude exposure (POST). The critical power protocol was used to examine power output in a highly aerobic event (15 minute time trial) and a highly anaerobic event (3 minute time trial). Performance was also investigated through measurements of lactate, oxygen consumption, and heart rate. Blood characteristics examined include hematocrit, reticulocyte and serum Ferritin values, prior to and following simulated altitude exposure. RESULTS: There was a
significant improvement (p=.004) for the TRT group at POST in the 15 minute time trial (PRE = 325.0 ± 12.2 watts, POST = 335.0 ± 11.9 watts) and estimated 60 minute time trial (PRE = 300.1 ± 28.4; POST = 322.4 ± 36.1) compared to no improvement in the CON group. The TRT group improvement was 3-4.5% in average power output. There were no significant differences in the power outputs of the 3 minute time trial at POST for either group. There were no significant differences in haematological measures at POST for either group. A decreased VO2 Index (PRE = 0.165 ± 0.016; POST = 0.152 ± 0.023), p=.075 and a significant decrease (p = .026) in heart rate (HR) Index (HRavg/wattavg) was revealed for the TRT group (PRE = 0.564 ± 0.044; POST = 0.544 ± 0.053). CONCLUSIONS: In competitive cyclists, the use of a re-breathing device resulted in improved performance for events which rely heavily on aerobic power but none for anaerobic power. These findings are similar in regard to performance adaptations found in other acclimatization investigations, terrestrial or simulated. It is suggested that the re-breathing form of simulated altitude may be utilized as an alternative to terrestrial or other forms of simulated altitude, in efforts to mediate performance gains in endurance type events.
To my parents, Patricia L. Babcock & Ronald W. Babcock
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TERMINOLOGY

*Acclimatization*: the process of adjusting to changes in environment.

*Aerobic exercise*: requires oxygen to perform moderate intensity exercise that can be performed for extended periods of time.

*Anaerobic exercise*: is performed without oxygen, this form of exercise refers to the initial phase of exercise or any short burst, high intensity activity that is performed for a short period of time.

*Computrainer*: a bicycle ergometer measuring wattage, heart rate, and cadence.

*Ergogenic aid*: a method that helps the body work harder and perform better. Some ergogenic aids can have harmful side effects; these are banned by sports governing bodies because they are unsafe and unethical.

*Hematology*: branch of medicine concerned with blood.

*Hematocrit*: proportion of blood volume made up of red blood cells.

*Hypobaric chamber*: induces a decrease in ambient pressure as would occur in ascending to altitude.

*Hypoxia*: a condition in which the body is deprived of oxygen.
**Lactate:** Increase in blood lactate occurs under conditions where the energy demand by tissues cannot be met by aerobic respiration.

**Live high-Train low:** a method of altitude acclimatization, which the subject lives at moderate altitude and trains at sea level

**Live high-Train high:** a method of altitude acclimatization, which the subject lives at moderate altitude and trains at moderate altitude

**Live Low-Train High:** a method of altitude acclimatization, which the subject lives at sea level and trains at moderate altitude

**Live Low-Train Low:** describes a situation in which an athlete lives and trains at sea level

**Nitrogen dilution:** dilutes the oxygen present in air to concentrations below 21% by mixing the air with nitrogen.

**Normoxive:** room air.

**Pulse oximeter:** device that measures oxygen saturation.

**Power:** amount of work done per unit of time.

**Red cell volume:** red blood cells in the body.

**Serum Ferritin:** measured as part of the iron study workup for anemia.

**Simulated altitude:** simulates high altitude by maintaining a lower oxygen concentration.
VO2: volume of oxygen consumed

White cell volume: white blood cells in the body
CHAPTER 1

Introduction

The focus of this study is to examine the effects of simulated altitude via re-breathing on performance. Hypoxia and exercise physiology comprise the major components of research that follows. Given the special nature of the above subject areas, a large number of specific terms are defined in the preceding section. Theory and research practices as they apply to this study are described in the text.

Background on Altitude Research related to Human Performance

The effect of high altitude usually described as 1500 meters or higher, has been of considerable interest to those studying factors which affect human performance. Athletic performance pursuits in all areas, most notably skiing, cycling, running and of course climbing have been the subject of scientific investigations in an attempt to reduce the negative influence of higher altitudes on performance. There is considerable evidence that this interest has been the subject of scientific inquiry for more than 200 years.

In the 1880’s, an Italian physiologist, Angelo Mosso, conducted a series of experiments on the physiological effects of high altitude in the Alps. His work evaluating muscular fatigue, while certainly not definitive, demonstrates the long
standing interest in the physiological effects of exercise at altitude and methods to enhance performance.

However, it was not until the Olympic Games were awarded to Mexico City in 1968, that many questions regarding the issue of altitude effects and human athletic performance became a significant concern for the elite athlete who had not been challenged by the effect of altitude. This occasion would prove to be an influential impetus regarding the limiting effects of altitude on performance as well those means by which these effects could be mitigated. Shortly following the 1968 games, athletes and scientists began to explore the potential of improving performance at sea level by using the challenge of altitude.

In fact, at the Mexico City altitude of 2,240 meters, essentially all of the athletes and coaches fears of endurance competition were realized. Some previous experience and basic understanding of physiology led many to expect a decrement in performance. Expectation became reality when, on the first day of competition several runners were unable to finish the 10,000 meter race. It appeared that performance was not significantly affected for those who were living at higher altitudes. The top three spots in the 10,000 meter race went to runners from the high altitudes of Africa. Furthermore, the top 8 finishers in the race had lived or trained at altitude.

Frustrated by poor performances in the endurance events both coaches and athletes from countries of low altitudes were certain that altitude had diminished their ability to perform. They turned to the scientific community to explain the effects of altitude on performance and to provide answers to questions regarding the physiological advantage of training and living at altitude.
At the completion of the 1968 Olympics, Roger Bannister, the first 4-minute miler and a noted physician, analyzed the competitions and placed blame on the International Olympic Committee for allowing the events to be held at altitude. Further studies into Olympic performances would clearly reveal alterations in performance relative to those at sea level. Howley (1980) compared the 1968 Olympics at Mexico City to the Olympic competition held at sea level in Tokyo. Typically performances improve over the 4 year cycle but Howley’s results describe decreases in running performance time from 1964 to 1968. His analyses indicate a decrement in running time in all men’s events over 3,000 m (3,000 m = -3.9%, 5,000 m = -1.9%, 10,000 m = -3.7%, and marathon = -6.2%).

In a study designed to evaluate the physiological consequences of moderate altitude (such as that of Mexico City) on endurance running events Sucec compared results of 168 runners competing in events form 800 meters to the marathon. Based on his analysis of times at sea-level vs. moderate altitude it was concluded that the degree of impairment in performance is highly related to the relative degree of aerobic contribution to the event. This would indicate that the longer the event the greater the relative decline in performance at moderate altitude (Sucec, 1996).

Coaches, physicians, and scientists backed athletes’ concerns and prompted several conferences with international audiences that brought prominence to problems observed in competition at altitude and provided stimulus for more definitive studies (Buskirk, 1996). Questions that were raised were not easily answered: What was the effect of altitude? Does living at altitude or training at altitude provide an advantage to performance at sea-level or altitude, or both? What is the most effective form of altitude
training? Researchers continue to provide insight into possible answers to questions as they study the effects of altitude on athletic performance and different training methods to improve performance at altitude.

One practical finding which is evident from world-class endurance competitions is that those living at altitude performed better when racing at altitude. Altitude laboratories and research have made many attempts to understand the phenomenon and to refine answers to questions such as: How much exposure to altitude is necessary? Should athletes live at altitude and train at altitude? The four potential approaches which have helped shed light on these questions, are the following: live high and train high, live low and train low, live high and train low, and live low and train high.

To date these options have been studied to varying degrees, often limited by the practical concerns of living at one level while traveling to train daily at another and the random assignment of high quality endurance performers to train under conditions which may be detrimental. For example, being assigned to the live high and train high group may negatively impact an athlete’s ability to train, leading to a decrease in subsequent performance. This is the type of situation most athletes and coaches try desperately to avoid. In order to overcome practical impediments new technology is being developed. One such recent innovation is the basis for and independent variable in this investigation.

It should be noted that the majority of research related to altitude exposure has examined endurance performance. This is to be expected, since the physiological adaptations related to altitude exposure and altitude training has been found to primarily affect aerobic power. More recently, some researchers have examined the effects on
short-term high-intensity performance that requires a substantial contribution from anaerobic systems.

In this regard, there is modest research into the effect of altitude and altitude training on high intensity, short duration exercise. But, at the same time, little effect is likely as a consequence of altitude training on high intensity exercise due to its large anaerobic power requirement. In the 1968 Mexico City Olympics, Bob Beaman, in a short duration power related event (long jump) broke the world record with a jump of 8.9 meters, .55 meters (21 ¾ inches) longer than the previous mark, a truly remarkable accomplishment. None of the other competitors came close to Beaman’s achievement, and the record held until 1991. It is likely that the “thinner” air associated with altitude contributed to this performance which is indicative of an advantage of performance at altitude in short duration, anaerobic power related events. It is possible, however that other anaerobic power related considerations (e.g. skeletal muscle adaptation, anaerobic metabolism, etc.) may have influenced performance as well. There may be a mechanism that influences not only aerobic but also anaerobic performance and although the general objective of this study is to quantify the effects of a novel acclimatization approach on endurance performance, anaerobic endurance will also be investigated.

**Directions in Altitude Research related to Human Performance**

With impetus from the ’68 Olympics many researchers have evaluated a variety of training methods. Only recently has a specific approach to improving performance, i.e. living at altitude or its equivalent, become clear. Although not yet the definitive solution, the most promising and presently the most accepted training method, for those
not native to high altitude living, is the live high (i.e., at altitude) and train low (Levine et al., 1997). This generally well accepted approach to achieve optimal endurance performance, particularly when the performance occurs at altitude, is not without practical drawbacks. Daily trips to lower altitudes are time consuming and difficult. Needless to say that living at altitude is impossible in many countries and prohibitive in many others.

In an attempt to solve these problems, novel technological approaches to providing “simulated” altitude have been implemented and continue to be developed. While straightforward and less impractical than changing physical location daily, their effectiveness must be established through controlled investigation if they are to be credible and truly capable of eliciting the physiological changes needed to insure optimal performance. One such device, the AltO₂Lab®, dependent upon a re-breathing principle, has shown promise in pilot work and will be used to provide simulated altitude exposure, and as the independent variable in this investigation.

**Re-breathing Device**

This device provides simulated altitude by creating a hypoxic environment (reduced amount of oxygen) to which the athlete is exposed while at rest. The technique has unique qualities which make it quite different from other forms of simulated altitude exposure. Most methods in use at this time provide simulated altitude exposure via a chamber or tent-like structure, to create a hypoxic environment which is equivalent to moderate altitude (2,000 to 3,000 m). While at rest the athlete “lives” in this environment, for 6-12 hours at a time, usually on a daily basis. This provides the
simulation for the “live high” aspect of the most common approach while training under normal sea level conditions. Outside the chamber is the “train low” aspect.

Contrary to the more common method of simulated altitude methodologies, re-breathing utilizes a small apparatus that a subject breathes into for less than an hour per day. It is lightweight, extremely portable and made up of a mouthpiece and tube connected to an uncomplicated system which allows the user to re-breathe a certain adjustable portion of expired air. The re-breathing method is capable of creating a high altitude environment (4,000 to 6,500 m) compared to the more moderate altitude environment of chamber/tent based simulated altitude methods. The re-breathing device offers the advantages of relatively low cost and a time requirement of less than 1 hour per day.

The assumption here is that short term exposure to very high altitudes will result in physiological changes and performance enhancements equal to or more advantageous than those found in response to moderate altitude. Numerous moderately-high to high altitude investigations, terrestrial and simulated, have shown performance enhancements. But, the duration of time exposed to altitude has been substantially greater than that suggested with the re-breathing methodology.

Woods and colleagues reported improved performances in field tests, using the re-breathing device with professional athletes (2006). To our knowledge this is the only published work related to athletic performance and this form of simulated altitude. Concerns related to the study done by Woods are that the performance measures were for highly anaerobic events - repeated maximal effort sprints. This research took place in a
non-laboratory setting and among fellow teammates which may have contributed to measurement errors and enhanced motivation to perform.

Put simply, studies to assess the effectiveness of this more practical and less costly concept are severely lacking. Despite the gap, particularly in relation to evaluating the effects of short term exposure to very high altitudes, many athletes including professional and elite level performers are adopting re-breathing in an attempt to improve performance both at altitude and sea level. A clear understanding of physiological and performance related effects would help to insure that utilizing this approach is supported by ‘hard’ empirical evidence. In order to do this we will test the following hypotheses.

HYPOTHESES

There were 7 specific hypotheses which have been placed into 3 main categories of interest. The purpose of category 1 is to determine if simulated altitude via re-breathing improves performance in cycling; in either a longer duration event which relies highly aerobic power (15 minute time trial) or a shorter more intense event which is based more heavily on the anaerobic energy system (3 minute time trial). Category 2 and 3 hypotheses are for the identification of mechanisms by which intermittent simulated altitude exposure via re-breathing may improve athletic performance in cyclists. Specifically, Category 2 hypotheses deal with physiological measures of efficiency (oxygen consumption index, lactate index, and heart rate index), while Category 3 hypotheses address hematological characteristics (hematocrit, and reticulocytes). All of the hypotheses are predicated upon previous research. They are:
Category 1

- Cycling performance which relies heavily upon aerobic power (average watts elicited in a 15 minute time trial) will show an advantage for the treatment group.
- Cycling performance in an event which relies heavily upon anaerobic power (average watts elicited in a 3 minute time trial) will show an advantage for the treatment group.

Category 2

- The treatment group will improve in the efficiency of oxygen consumption (VO$_2$ Index) as compared to the control group.
- There will be a decrease the amount of lactate build up (Lactate Index) in the treatment group and there will be no effect in the control group.
- Submaximal heart rates (HR Index) will decrease in the treatment group with no similar effect on the control group.

Category 3

- Hematocrit levels (HTC) will improve in the treatment group
- Similarly, reticulocyte values (RTC) will improve in the treatment group.

The general goal of this study is to examine the AltO2lab® in relation to cycling performance. A single-blind study design was used for a sample of well-trained cyclists. In a single-blind design, the researcher is aware of the treatment group into which each
subject is assigned. This was a necessary part of this investigation, since the investigator was responsible for each subject’s response during the treatment and adjusting the device to insure appropriate altitude simulation was applied.

Potential subjects were screened for inclusion/exclusion criteria (see Chapter 3) and upon entry into the study were randomly placed into the treatment (TRT) or the control group (CON). TRT subjects were exposed to 15 days of simulated altitude as described in the procedures section. The CON group received a low constant exposure, equivalent to conditions slightly above sea level over the same 15 day period for an equal amount of time per day. The “treatment” provided to control subjects was intended as a placebo since there is no expectation for physiological change or related performance effect. The TRT group received a progressively hypoxic exposure, comparable to moderate to high altitude, equivalent to 3600 to 6300 meters.

**Objectives of Research**

One specific objective of this investigation was to evaluate the response of well-trained elite endurance cyclists to short periods (approximately 1 hour) of artificially induced exposure to high altitude daily for 15 days. The physiological responses previously associated with traditional altitude training and performance measures were a second objective looked at in this study. Specifically hematological characteristics, physiological markers of anaerobic and aerobic power, and performance power output were assessed and used to compare the groups and determine the effect of re-breathing using the AltO₂Lab®.
Study Considerations

The primary variable of interest was the effect of simulated altitude exposure on well-trained elite cyclists. The ability to precisely and accurately measure performance variables based on power output was critical to the successful completion of this effort. Cycle ergometers offer a fast, easy method to collect such data but were deemed inappropriate. The upright nature of most cycle ergometers is not consistent with the performance positioning of a road bike designed to suit the individual cyclist. Additionally, the positioning of the seat and handle bars are limited. This small but definitely recognizable difference in positioning could affect the potential power output of some cyclists who were not accustomed to this type of ergometry. Since a competitive cyclist’s racing bike is designed to be in exact alignment for the individual and is precisely tuned for best performance it was decided to employ a measurement tool which allowed for each subject the use of his own bike. The Computrainer® a commercially available device designed to measure power output using a cyclist’s bike was used to measure performance.

As explained in detail in the Methods section, particular attention was placed on protocol selection. Power output was averaged for 2 time trials (TT) of varying duration and intensity. Results were used to predict real world performance measures. Measurements also examined physiological efficiency characteristics and blood characteristics. These data were collected in an effort to determine mechanistic properties of change, if any.
In implementing the study, a very concentrated effort was made to control extraneous variables. This was accomplished by random assignment of subjects to treatment conditions, controlling factors known to influence outcome measures, precision of measurement, replication of testing conditions between and within subjects, and attention to detail.

**Limitations and Delimitations**

A single-blind experiment may encounter bias on the part of the researcher conducting the study as a source of invalidity. The researcher could subtly convey confidence or a lack of it if they know who is receiving the true treatment and who is not; thus there is the possibility of subtly influencing results. For this reason, practice monitoring sessions were held prior to subject interaction. Scenarios, questions and responses were rehearsed so that researchers working directly with subjects made their best effort to conceal the treatment condition and to be as fair and as objective as possible.

Only male subjects were eligible to participate in this investigation, eliminating the ability to generalize results across genders. This study was limited in this way for a number of reasons both practical and theoretical. One reason for exclusion of women was markers which may help to explain changes in performance would include hematological factors. These have been shown to be significantly influenced by hormonal fluctuations associated with different periods of the menstrual cycle. Efforts to control for these fluctuations would be difficult, if not impossible in a study which must be completed in a 20 day “window”. Additionally, the number of highly trained elite
women cyclists is not large and efforts to attract suitable subjects in a sufficient sample size may have been futile in the local context.

All subjects were required to possess and use their own competitive racing bike, in testing performance and familiarization sessions. Although virtually all high quality competitive cyclists own and ride a bike specific for them personally, this delimits the study due to the expensive nature of this high quality machinery. As such the results of this study could not be applied to those who are not competitive cyclists or unable to afford such equipment.

The importance of control in regards to diet and training was discussed with each participant. Efforts were made to educate subjects about diet, and deter athletes from any Recommended Dietary Intake deficit of any kind during the study. All subjects were provided instructions for keeping a food intake diary and were asked to keep an accurate record of all they ate or drank. Registered Dietician’s met with each subject and food records were collected and analyzed. Similarly, training was discussed and the maintenance of current training practices was emphasized.

Training records detailing time and intensity were kept by each subject and collected at the conclusion of the study. Review of diet and training records indicated that all subjects (except 1 who was omitted due to lack of following through on this dimension of the research) were compliant with requests for maintaining a stable, adequate diet and consistent training program. Yet, the possibility still exists that the record kept did not reflect the true circumstance and be a limitation of the study.
A delimitation of this research includes the selection of dependent variables. Blood assays such as erythropoietin could have been included. Additional performance measures such as maximal graded exercise tests may have provided useful information. Dependent variables that were thought to best answer the hypotheses were selected. Financial constraints and subject burden were also considered as part of the selection process. To reiterate, based upon considerations like these, variables which held the most potential to answer hypotheses were chosen.

**Summary**

Investigation of altitude exposure as it relates to performance enhancement has been popular for over 40 years. Living high and training low has been established as the premier method in which to achieve performance enhancements. Due to practical inconveniences associated with this acclimatization process, many efforts have been made to simulate altitude at sea level, while maintaining training practices. One novel device that simulates high altitude, is the under investigated AltO₂Lab®. It will be utilized in this investigation for 15 days, in the treatment condition.

The aim of the research is to determine the effect of simulated altitude via re-breathing on cycling performance. The hypotheses related to this task are aimed at cycling performance measures and probable mechanisms related to improvements in performance. The grounds for the specific hypothesis and methodology are drawn from the literature review and are presented in Chapters 2 and 3.
CHAPTER 2

Review of Related Literature

This literature review is focused on previously established findings which may provide building blocks for the under-researched, re-breathing methodology. The strategies utilized in previous studies of terrestrial and simulated altitude have examined performance adaptations in a variety of endurance events and also the mechanistic properties associated with performance.

ALTITUDE EXPOSURE: EFFECT ON PERFORMANCE AT ALTITUDE

When athletic competitions are held at altitude, it is no longer surprising that the winner and top finishers have a tendency to come from a chronic altitude environment. Living in such a condition has previously led to improved performances at altitude and sea level. The Olympics of 1968 produced many examples of this phenomenon. In every event over 800 meters, a native of the moderate-high altitude of Africa easily took the gold.

Altitude Natives

Tibetan altitude natives were compared to the Han non-altitude natives. Han were acclimatized to altitude for a period of 5 years. Yet, the Tibetan had greater vital capacity and maximal voluntary ventilation than the Hans at rest including a higher maximal O₂
uptake (42.2 ± 1.7 vs. 36.7 ± 1.2 ml · min\(^{-1}\) · kg\(^{-1}\) at 3,417 m, p < 0.01), greater maximal cardiac output (12.8 ± 0.3 vs. 11.4 ± 0.2 l/min at 3,417 m, p < 0.01), and differences in arterial O\(_2\) saturation at higher exercise workloads. The conclusion drawn in this case was that exposure to high altitude from birth resulted in a more efficient O\(_2\) transport and a greater aerobic exercise performance in the altitude native when exercising at altitude (Chen, Ge, Wang, et al., 1997).

**Low-Landers**

Not every athlete is born and raised in the highlands of East Africa, the mountainous Andes, the high altitudes of Mexico, or the mountains of Asia. Scientists have found that despite being born and raised at sea level conditions, it is possible to improve performance at altitude.

*Acute Exposure:* When a group of sea-level resident males were exposed to an environment of 1700 m above sea level, changes in submaximal exercise performance were measured 6, 18 and 47 hours after arrival. A decrease in performance in a 5 minute submaximal cycle ergometer test was shown to be greatest at 6 hours after arrival, and improved at 18 and 47 hours. Still, performance at 47 hours was not restored to initial sea level values.

These findings are important for coaches and athletes who are under the popular but untrue assumption that decreases in performance are not seen until 2 days after arrival at altitude. Because of this myth they often delay arrival until the day of competition. This way of thinking may have come from the early studies of Dill and colleagues who made their first baseline measurement 2 days after arrival to moderate altitude. They
(1968) determined VO₂ max in athletes 2 days after they arrived at altitude and found performance values had dropped to 82% of the sea level values. In a subsequent investigation Dill measured these same performance parameters within hours of exposure to altitude and noted similar detriments. These findings indicate sea level athletes experience performance deficits upon arrival to altitude. Hence, when sea level athletes are traveling for competition at altitude, they should allow as much time as possible to acclimatize.

**Chronic Exposure:** Athletes from sea level residency exposed to continuous altitude for 2-3 weeks at a time have shown improvement in muscular performance (Fulco, Friedlander, Muza, et al., 2002). Similar improvements have been discovered with intermittent simulated altitude exposure in a hypobaric chamber. Beidelman and colleagues found improvement in muscular endurance and time to exhaustion in the altitude equivalent of 4,300 m for 4 hours per day; 5 days per wk (2003). Three weeks of intermittent altitude exposure improved cycle time-trial performance (21 ± 6%) and adductor pollicis endurance (63 ± 26%) at an altitude of 4300m. These results were comparable to those reported previously after chronic altitude residence.

**Summary**

Performance at altitude is enhanced by either being born and residing at altitude, or by sea-level residents acclimatizing to altitude prior to performance. It has been suggested that those who have chronically lived at altitude may have higher maximal VO₂ values, and be more efficient at delivering oxygen to working muscle when working at altitude.
ALTITUDE EXPOSURE: THE EFFECT ON PERFORMANCE AT SEA LEVEL

There are certainly some races at altitude, but the majority of competitions take place at or near sea level. Many questions related to improving sea level performance have been raised. What type of altitude training aids in sea level performance? How high an altitude is necessary to elicit changes in performance? How long should an athlete be at altitude to see a benefit? Should one train and live at altitude? Numerous questions have been asked, and some have been answered.

Hypoxic Training

Some altitude investigations have had athletes perform fitness training in a hypoxic environment in efforts to improve sea level performance. This method has not brought forth improvements at sea level, and in some cases has demonstrated a detrimental effect on performance measures. These results arise from the lower partial pressures of oxygen, which impairs athletes ability to maintain sea level training intensities (Levine & Stray-Gundersen, 1992; Levine & Stray-Gundersen, 1997), and leads to a de-training effect, and ultimately performances suffer (Truijens, Toussaint, Dow, et. al. 2003).

Live High Train Low

Living high training low has previously been shown to be an effective method for improving sea level performance in athletes (Baker & Hopkins, 1998). When reviewing studies involving the 4 possible scenarios of: live high and train high, live low and train low, live high and train low, and live low and train high; one, live high and train low has
proved to be the most effective strategy (Levine & Stray-Gundersen, 1997; Baker & Hopkins, 1998; Chapman, Stray-Gunderson & Levine, 1998).

Levine and colleagues (1997) placed well-trained endurance runners in each of the following conditions for 4 weeks: living at moderate altitude and training at moderate altitude of 2500m (live high and train high), living at moderate altitude of 2500 m and training at sea level (live high and train low), and living and training at sea level (live low and train low). It is noteworthy to point out; the live low and train low group was put in a mountainous environment in efforts to give the impression of altitude, but this environment was only 150 m above sea level. The main performance variable was a 5km TT performance. The only group to display an improvement in performance was the high-low group (13.4 ± 10 s). This increase was found to be proportional to increased oxygen consumption (5%). Both groups which lived at altitude exhibited increased red cell blood volume 5-8% from initial values.

The mechanism and magnitude of adaptation to the reduced availability of oxygen has been demonstrated to be similar in athletes of varying abilities, from less accomplished to elite endurance athletes (Hahn et al., 2001). Although the “live high train low” strategy is not effective in a small percentage of athletes, there is a performance benefit of 2-3% for the average one (Baker & Hopkins, 1998; Chapman et al., 1998). Other studies have reported elite athletes to improve performance in endurance events by 1-2 % (Julian et al., 2003).
PHYSIOLOGICAL MECHANISM OF CHANGE

The study of altitude’s effect on performance has been of wide interest for forty years and it has been well established that appropriate exposure to altitude or simulated altitude can positively enhance sea level performance. What are attributes of this change relative to performance? Interestingly, despite intensive research on the subject, the mechanism which leads to the increased performance is not fully elucidated and still hotly debated.

**Increased Red Blood Cell Volume**

Conventional wisdom suggests chronic exposure to altitude aids in athletic performance by increasing red blood cell volume. When a person is exposed to high altitude, prediction is that this causes an erythropoietic response, resulting in an increased number of red blood cells which deliver oxygen to the working muscles.

Levine and colleagues observed an increased red cell volume of 8% in a group of elite runners who lived high (2500 m) and trained low for a period of 4 weeks (1997). Levine posited that the increase accounted for increases in running performance.

Other researchers have examined blood characteristics of sedentary sea level volunteers at sea level, and after 1 and 5 weeks exposure to 5100 m (Samaja, Brenna, Allibardi, et al., 1993). The findings indicate that 1 week of exposure to be inefficient in eliciting a change in the proportion of red blood cells. Findings after 5 weeks provide evidence of an increase in red blood cell mass, which the author links to an erythropoietic response to generate young red blood cells (reticulocytes).
For a large number of runners (n>100) who had lived high and trained low, researchers observed no change in running economy (Levine & Stray-Gundersen, 1992; Levine & Stray-Gundersen, 1997), in which less energy is required to perform the same workload. Their anaerobic capacity showed no adaptation (Levine & Stray-Gundersen, 1992; Levine & Stray-Gundersen, 1997; Levine, 2002), nor did muscle biopsies increase in buffering capacity or oxidative enzymes (Stray-Gundersen & Levine, 1999). Given this evidence, Levine proposes an erythropoietic pathway as mechanism responsible for change (2005). Levine felt that increased red cell volume explains increases in maximal oxygen consumption, and thus improve performance.

**Improved Mechanical Efficiency**

Gore and Hopkins (2005) advocate another point of view. They claim there is insufficient evidence to support the theory of an increased red cell volume as the primary mechanism for an increase in oxygen consumption; in effect leading to an increase in performance.

For them, Levine’s finding of 5-8% increase in red cell volume, in live high train low athletes, may likely be due to measurement error. Gore et al. question Levine’s methods of measurement and point out that many altitude studies use the measurement of haemoglobin mass, in lieu of red cell volume. Their perception is that haemoglobin mass has a 2% measurement error, which is consistent with little or no change in many altitude studies (Ashenden, Gore, Dobson G., et al., 2000; Ashenden, Gore, Dobson, et al., 1999; Saunders, Telford, Pyne, et al., 2004). Therefore, exercise economy is the most likely cause for increased performance. This is defined as athletic performance at less energy
cost. Improvements in economy of 3-6% have been reported following altitude exposures (Gore, Hahn, Aughey, et al., 2001; Katayama, Matsuo, Ishida, et al., 2003; Katayama, Sato, Matsuo, et al., 2004).

In other altitude acclimatization studies, there is evidence of a decreased production of lactate or increased clearance of lactate in the muscle (Hahn & Gore, 2001 and Gore, Hahn, Aughey, et al., 2001). Lactate accumulation is a marker of high intensity effort and anaerobic metabolism. Such accumulation in the blood is an indicator of cellular lactate which changes in pH and decreases both the rate and strength potential of muscular contraction. This of course is highly associated with muscular fatigue. The previous authors noted an increased mechanical efficiency and muscle buffering capacity to clear lactate as the primary means for performance improvement.

Gore examined muscle buffering capacity via muscle biopsy, prior to and following a live high train low simulated altitude exposure for 23 days. Results were an increased buffering capacity (18%) of the live high group compared to the control. The high low group exhibited a decrease in submaximal VO\(_2\) (4.4%, \(P < 0.05\)), an increased efficiency (0.8%, \(P < 0.05\)) which the author’s relate to a change in fuel utilization (Gore, Hahn, Aughey, et al., 2001).

**Summary**

Many researchers agree acclimatization to altitude is effective in improving athletic accomplishment. Yet, despite over 40 years of investigation, the mechanism responsible for this change is passionately debated and seen from different perspectives. In late 2005, major contributing authors in this area, Levine, Stray-Gunderson, Gore, and
Hopkins debated the topic in the prominent and peer-reviewed Journal of Applied Physiology. After 4 issues about the debate (red cell volume vs. mechanical efficiency and buffering capacity) agreed to disagree, and concluded more investigation into the topic was necessary.

**ALTITUDE AND SERUM FERRITIN**

Exposure to high altitude without supplemental doses of iron, results in a marked decrease in serum Ferritin (Roback, Fulla, Westerterp, et al., 2004). The decrement in serum Ferritin is directly associated with the degree of altitude. Roback and colleagues (2004) measure serum Ferritin at sea level and 4 simulated altitudes, the highest equaling 8,000 m, which is the highest recorded measurement of serum Ferritin. Results drop sharply with exposure to increasing altitudes (sea level = 70µg/L; 5,000 m = 40 µg/L; 6,000 m = 18 µg/L; 7,000 m = 10 µg/L; 8,000 m = 9 µg/L).

Levine and Stray-Gunderson (1997) also show a decrease in serum Ferritin levels with exposure to altitude. Athletes who lived high and trained low significantly decreased their values (sea level = 69 µg/L ± 79 µg/L; acute high low = 39 µg/L ± 41 µg/L; chronic high low = 37 µg/L ± 33 µg/L; sea level post high low = 34 µg/L ± 22 µg/L). Low levels of serum Ferritin are indicative of low iron stores in the body, with extremely low values being a sign of anemia. Anemia is a very serious condition which results in feelings of extreme fatigue. High iron stores are necessary for red blood cell multiplication; part of the erythropoietic process.
Summary

Due to possible serious side-effects and decreases in performance, iron supplementation may be warranted in altitude investigations, especially those which participants are exposed to high levels of altitude. Most recent altitude investigations have utilized iron supplementation to reduce the major decline in serum Ferritin values.

ALTITUDE AND ANTIOXIDANTS

Antioxidants help to protect the body against free radicals, potentially harmful bi-products which are produced by the body’s metabolism. Free radicals can contribute to damaging cellular walls. Tocopherol, also known as Vitamin E, is a fat soluble vitamin that is a valuable antioxidant. It exhibits protective qualities for the skeletal muscle cell wall and aiding in the formation of red blood cells.

The interest in regard to Vitamin E and exercise is not a recent phenomenon; in the 1950’s when animal studies demonstrated that Vitamin E deficiency can lead to a decreased exercise performance. Vitamin E has also been considered in human exercise and altitude studies as a supplement to enhance aerobic work. Results of these studies do not support Vitamin E supplementation as an effective manner to increase aerobic work at sea level (Sharman, Down & Norgan, 1976; Shephard, Campbell, & Rimm, 1974; Watt, Romet, McFalane, et al., 1974).

Studies at Altitude

Vitamin E supplementation at altitude has revealed different results than sea level investigations. In a study of elite distance runners, one group was supplemented with
Vitamin E and the other group with a placebo. Those with the Vitamin E performed better in a race held at 5000 m altitude (Tatsuo, Hiroshi, Yunichiro, et al., 1968).

Several years later, in a cross-over design, subjects received both treatments (1200 IU/day vitamin E or placebo) in random order for 6 weeks. Subjects receiving Vitamin E improved aerobic work capacity 9% at simulated the altitudes of 1524 m and 14% at 4572 m (Kobayashi, 1974).

Summary

Vitamin E is a powerful antioxidant with valuable cellular protective mechanisms. Deficient amounts of Vitamin E lead to increased lipid peroxidation, resulting in mitochondrial dysfunction and cell membrane damage. Vitamin E has been proposed to increase work capacity at altitude. The mechanism of protection is attributed to maintenance of the cellular membrane and aiding in the regular formation of the red blood cell. For these reasons, Vitamin E has often been used as a supplement in altitude investigations.

ASSOCIATED INCONVENIENCES OF ALTITUDE EXPOSURE

Increasing athletic performance is a paramount matter to athletes and coaches. So, if exposure to altitude improves athletic performance, why do not all athletes utilize this approach? Indeed, many elite athletes do. At the same time it is important to recognize that considerable inconveniences exist. Living at a moderately high altitude and travelling daily to lower altitudes to train, for weeks at a time is not a simple task.
The travel, time, cost, and facilities necessary for this endeavour often make it an improbable training strategy.

Consider the places in the world where it is actually convenient to live in a moderately high environment and train at a low environment. These conditions exist in the Western United States, Mexico, Northern and Eastern Africa, to name a few. In many locations in the world these conditions are not readily available. The travel involved to reach such a destination can be quite an expedition for an athlete.

- When the athlete reaches his location, where should he/she lodge? It is quite expensive to stay at a hotel or such accommodations for weeks at a time.
- The athlete must bring training gear, a vehicle for travelling to training ground, and possibly a coach.
- Often the athlete is separated from family and friends for long period of time, which adds a social burden.
- To make matters worse, individuals often complain of poor sleep at altitude which could possibly lead to a decreased recovery and thus influence the athlete’s quality of training.

Due to such factors associated with the living high and training low theory, a great deal of attention has been given to simulating altitude exposure so athletes may conveniently live and train at sea level.
METHODS USED TO SIMULATE ALTITUDE

A variety of strategies have been developed to reduce the availability of oxygen at sea level. Hypobaric chambers, altitude tents, nitrogen diluted mask drawn air, and re-breathing devices have been used to simulate altitude for athletes who seek performance gains. A discussion of each methodology follows.

Hypobaric Chambers

The hypobaric chamber is utilized to study the effects of high altitude, primarily the effects of hypoxia (low oxygen) by controlling hypobaria (low ambient air pressure). Inside the chamber, atmospheric pressure can be reduced to simulate the intended altitude, up to thousands of meters. A safety observer is always present when this device is being employed such as in flight schools and military applications.

Hypobaric chambers have been used to expose subjects to moderate altitude for 8-12 hours per day for weeks at a time, resulting in similar findings of that in terrestrial live high and train low investigations. They have also been used to expose individuals to moderately high altitude (2500-5500m) over short periods of time (e.g. 3hours/day for 2 weeks); with significant improvements in performance variables (Casas, Casas, Pages, et al. 2000; Nummela & Rusko, 2000; Katayama, Matsuo, Ishida, et al., 2003; Katayama, Sato, Matsuo, et al., 2004).
Summary

Hypobaric chambers simulate altitude by changing the pressure within them. These devices are valuable because various levels of altitude, including high altitude, may be examined quite easily. Research has shown that less time (3 hours per day/2 weeks) spent at a relatively higher altitude (2500-5500m), results in similar performance improvements as seen in the live high train low practice (a 3-4 weeks stay at a moderate altitude of 2000-2500m). Significant drawbacks to this method are limited availability and the associated large financial cost.

Altitude Tents

An altitude tent or hypoxic tent simulates altitude by maintaining a lower concentration of oxygen than what is found in room air (21%). The oxygen concentration in the tent may be as low as 10%, the remainder being the inert gas Nitrogen. The process of lowering the concentration of oxygen is called nitrogen dilution which is achieved by using stored nitrogen or more commonly, a filtration machine to separate oxygen and nitrogen. A “hypoxic generator” a pump outside the tent displaces oxygen and replaces it with nitrogen, and then pumps this gas concentration inside the tent. Athletes will typically set the reduction of oxygen to match a moderate altitude of 2,000 to 3,000 m. The athlete sleeps or resides in this environment for 8-18 hours per day. Performance gains of 0.6-1.5% in mean power have been observed with this approach (Hackett & Roach, 1995; Hahn & Gore, 2001).
Inconveniences

There are of course problems inherent associated with this device. Unless specifically designed, the altitude tent is made for one. If two people were to sleep in the tent, the concentration of oxygen would fall to dangerous levels. Wisely, altitude tents are designed with an alarm if oxygen concentrations reach dangerously low values.

The altitude tent is not a simple pop-up pup tent. The altitude tent is cumbersome to move and without a substantial amount of effort, it would not be feasible to travel with it. Some are made with an air conditioning unit, many are not. Without the cooling unit in the tent, athletes complain of a hot and humid environment, in which water droplets form on the panels of the tent and consequently drop onto them.

Some athletes also don’t like the quality of sleep in this environment. The decreased amount of oxygen seems to make sleep more difficult, this is a similar finding to persons traveling to altitude. A randomly assigned cross-over design by Martin and colleagues (2005) looked into whether sleeping in a moderate hypoxic environment would alter cyclists’ ability to perform high-intensity training over a period of a week. Cyclists performed high intensity interval workouts 2 times per day at 90 minutes each. Martin found no decrements in their ability to perform a weeks worth of high intensity training while sleeping at moderate altitude in an altitude tent, as compared to the participants ability to complete the same workout regime for a week while sleeping in normoxia.

The tents are commercially available. It is well known that many professional and elite level athletes utilize these apparatuses. Despite the possibilities that may come
from the use of the tents, it is the price that precludes most athletes from owning one, as the cheapest model starts at about $10,000. Although less common, nitrogen dilution can also be utilized for a larger area than a tent. A bedroom can be converted into a similar environment for about $25,000. Or, entire houses for $100,000.

**Summary**

To athletes, the numerous inconveniences of the altitude tent seem to be outweighed by the conveniences. Altitude tents have revealed similar gains in improvement as seen with living high and training low. Compared to terrestrial altitude practices, the altitude tent is a more cost-effective method. It requires no travel or separation from the comfort of home. Elite endurance athletes typically must sacrifice a great deal in effort to maintain rigorous training and competition schedules. In the past this included exposure to moderate altitude for weeks at a time, prior to competition. For those who had to travel long distances, spend weeks from home, and compromise their schedules in an effort to live high and train low; the altitude tent provides a welcome convenience by facilitating the acclimatization process.

**Nitrogen Diluted Mask Drawn Air**

A “hypoxic pump” dilutes the amount of oxygen found in room air (21%) and feeds this nitrogen diluted concentration through a sample line to a mask, where the gas concentration is consumed. Nitrogen-diluted air drawn through a mask for 5-7 min alternating with similar periods of room air for a total of 1-2 hours per day for several weeks simulates high altitudes (3000-6500 m). This method originated in the former
Soviet Union, as interval hypoxic training. This method of training was developed for pilots prior to the pressurized cockpit and prepared them for conditions of high altitude. Since individuals react differently to altitude this was useful in determining individual symptoms associated with altitude and proved to be an effective conditioning tool for the pilot.

Studies examining benefits on performance with this approach are lacking as most research efforts have focused upon ventilatory adaptations to hypoxia. Performance benefits have been reported (Serebrovskaya, 2002); while, others have found little or no benefit (Clark et al., 1999).

These devices are commercially available and allow several people to receive simulated altitude at the same time. Due to the cost ($15,000- $25,000) the procedure is usually offered in flight schools, research laboratories, or elite athletic facilities but again would be beyond the resources of many if not all athletes.

**Summary**

Nitrogen diluted air drawn through a mask allows precise controlled exposure to high altitude conditions for a short period of time. This practice is not possible in the natural environment. The premise of this device is that short exposure to high altitude will allow for similar performance adaptations as seen in longer exposures to moderate altitude. Unfortunately, to our knowledge, adequate research on performance adaptations does not exist.
Re-breathing Devices

Re-breathing devices have also been used to produce nitrogen-diluted air. The re-breathing device employs a chemical absorbent (soda-lime) to prevent accumulation of expired carbon dioxide, which would stimulate ventilation and prevent the development of a hypoxic condition. The subject breathes through a mouthpiece joined to a container of soda lime, attached to the soda lime container is another container with a sponge insert which creates a decrease in the amount of oxygen drawn into the device. In order to create conditions of greater hypoxia, more sponge-filled containers are added to the unit. Hypoxia is measured by the relative decline in blood oxygen values, as higher levels of altitude will elicit a drop in blood oxygen as observed by the use of a pulse oximeter. These are reliable medical devices commonly used in monitoring oxygen saturation in medical and non-medical settings.

Research with re-breathing has primarily been related to studies on ventilatory adaptations to hypoxia (Piehl et al., 1998). More recently, the effects of re-breathing on exercise performance have been explored in professional soccer and hockey players, demonstrating a significant increase in performance of running types of field tests which mimic typical conditions in these sports (Woods et al., 2005).

Re-breathing devices are commercially available for $700 to $1,500. Distribution of this device has mainly been confined to Australia and New Zealand, where the commercial producers reside. More recently, the device has become available in the United States. The product is quite popular among endurance athletes despite the lack of scientific evidence associated with performance adaptations.
Convenience

There is substantial convenience related to this device compared to other types of simulated altitude. It costs much less, it is very small and easily portable, it requires less time “spent at altitude” and there are reports of improved sleep and wellbeing associated with using this device. Moreover, if it can achieve similar results to some of the other techniques the cost advantage would be enormous.

Summary

The re-breathing form of simulated altitude can create conditions comparable to high levels of altitude, which the athlete is exposed for a short period of time. This form of simulated altitude appears to offer many benefits (less cost, less cumbersome, less time to use, less side-effects) compared to other forms of simulated altitude. Unfortunately, it lacks adequate research to substantiate its usefulness in performance enhancement.

INTERMITTENT HYPOXIA

Many studies of altitude exposure have examined athletes who lived at moderate altitude or simulated moderate altitude for 2 to 4 weeks at a time. More recent investigations have utilized simulated altitude to examine and compare the effects of shorter intermittent bouts of time spent at altitude.

Hypobaric Chamber

Casas and colleagues (2000) have examined the effectiveness of 3 short intermittent simulated altitude protocols for eliciting hematological enhancement using a
hypobaric chamber. Three protocols of different durations (days) and total exposure (hours) at a simulated altitude of 4000-5500m were studied (A: 17 days, 60 hours, B: 9 days, 31 hours, and C: 21 days, 14 hours). All protocols were effective in eliciting an increase in packed cell volume (mean increase = 7% to 13%), hemoglobin concentration (mean increase = 15% to 19%), red blood cell count (mean increase = 8% to 14%) and reticulocyte counts (120% to 180%).

In terms of hematological adaptation, Protocol A was the most effective for eliciting improvements in each of the parameters. However, the long duration of Protocol A resulted in a less efficient adaptation (i.e. less increase per day). There was small variability between the results of Protocols A and B, despite a nearly double exposure difference. This suggests that values approached maximal limitations and nearly the same adaptation could be achieved in half the time. Protocol B, with only 9 days of exposure was the most efficient protocol at eliciting a hematological adaptation per day. Protocol C was most effective in terms of the degree of adaptation per hour of exposure, with only 1.5 hours of exposure per session, compared to longer durations of Protocol A and B. This data indicates that various protocols of intermittent hypoxia elicit hematological response, even with limited exposure. A greater erythropoietic response may be achieved by prolonged and more frequent exposures.

Rodriguez and colleagues examined the effect of simulated altitude exposure on erythropoietic response and aerobic performance capacity at sea level. The effects of hypobaric hypoxia alone and hypobaric hypoxia combined with low-intensity exercise were compared. Results revealed no significant differences in any of the parameters, indicating that hypoxia alone was responsible for changes incurred. After the
acclimatization period, a significant increase in exercise time (mean difference: +3.9%; P < 0.01) was seen during the maximal incremental test at sea-level. Individual lactate-velocity curves significantly shifted to the right (p < 0.05), revealing an improvement of aerobic endurance. A significant increase was found in RBC count (5.16 to 5.79; P < 0.0001), reticulocytes (0.5 to 1.1%; p < 0.0001) and hemoglobin (Hb) concentration (14.2 to 16.7 g·dL⁻¹; p < 0.002). It was concluded that short-term hypobaric hypoxia can activate the erythropoietic response and improve the aerobic performance capacity in healthy subjects (Rodriguez et al., 1999).

Intermittent hypoxia has shown to improve endurance performance and submaximal exercise efficiency (Katayama et al., 2003). Subjects were exposed to a simulated altitude of 4500 m for 90 min, three times a week for 3 weeks. The measurements of 3000 m running time, running time to exhaustion, and cardiorespiratory parameters during maximal exercise test and hematological status were performed before (Pre) and after 3 weeks of intermittent hypoxic exposure (Post). These measurements were repeated after the cessation of intermittent hypoxia for 3 weeks (Re). In the hypoxic group, the 3000 m running time and running time to exhaustion during maximal exercise test improved. Neither cardiorespiratory parameters to maximal exercise nor resting hematological parameters were changed in either group at Post, whereas oxygen uptake during submaximal exercise decreased significantly in the hypoxic group. After cessation of intermittent hypoxia for 3 weeks, the improved 3000 m running time and running time to exhaustion tended to decline, and the decreased VO2 during submaximal exercise returned to Pre level. Results seem to imply that intermittent hypoxia at rest could improve endurance performance and submaximal exercise efficiency at sea level in
trained endurance athletes, but these improvements are not maintained after the cessation of intermittent hypoxia for 3 weeks.

**Re-breathing Techniques**

Hamlin and Hellmans (2004) propose intermittent hypoxic training to bring forth changes in hematological indices, which indicates an acceleration of erythropoiesis. Utilizing re-breathing methods, subjects inhaled reduced oxygen gas mixtures in 5-min intervals interspersed with 5-min recovery periods of ambient room air for a total of 90 min per day, 5 days per week for 3 weeks. The hypoxic gas was adjusted from a simulated altitude of 4000 meters (equivalent to an oxygen saturation of 88%) at the beginning of week 1 to 6000 meters (equivalent to an oxygen saturation of 77%) by the end of week 3.

Venous blood samples were taken before, 2 and 12 days after the simulated altitude exposure. The results are described as mean change between groups as a percentage ± 95% confidence limit. Substantial increases were unlikely for hemoglobin at day 2 (0.2 ± 3.2%) but possible by day 12 (2.5 ± 4.2) after exposure. Increases in hematocrit (1.5 ± 3.1 day 2 and 3.6 ± 4.1 day 12) and reticulocytes (23.5 ± 21.1 day 2 and 14.6 ± 21.7 day 12) were also found. Effects on mean cell volume and mean cell hemoglobin were trivial. These findings may be associated with an improvement in aerobic performance. Although not measured in this investigation, gains in endurance events have been associated with improved red blood cell indices.
NEW RESEARCH INVESTIGATES ANAEROBIC CHANGES

The majority of research related to altitude exposure examines endurance performance. This is to be expected, as physiological adaptations for altitude exposure are presumed to primarily affect aerobic power. More recently a few researchers have examined the effects on short-term high-intensity performance that requires major contribution from anaerobic systems.

Nummela and Rusko have claimed elite triathletes’ exhibit increased power performance in both aerobic and anaerobic tests after intermittent exposure to altitude (2h/d) for 10 days in a hypobaric chamber (2000). In a pilot study by Woods, professional athletes (hockey and soccer players) have enhanced performance in repeated sprints and shuttle runs following exposure to simulated altitude via re-breathing (Woods et al., 2006).

Woods performance measures may be criticized for being field tests, rather than well controlled assessments. Did athletes in his study perform better because of a competitive-nature between teammates? Were the courses set up the same each time? Were conditions the same for each test? On the other hand, the field test is a beneficial way to begin to look at real world performances. Not many studies have examined altitude in relation to anaerobic power, so the concerns with Woods study are left unanswered. Additional research is needed to clarify possible anaerobic adaptation following hypoxia via re-breathing.
Critiquing research is not uncommon, and it generally serves to improve investigated endeavours. Altitude and performance research has been popular for over 40 years, in this time quite a few criticisms have arisen, as discussed below. Taking these into consideration is important for designing better studies.

CRITICISM OF ALTITUDE RESEARCH

With so much altitude research, it may not come as a surprise that there are often serious criticisms associated with some of it. The small gains in improvements, the lack of the identification of a definitive mechanism, and inconsistencies have led to some serious critiques, which should be considered prior to undertaking a research investigation in this area.

Control Group

At the top of the critique list, is altitude research that lacks a control group or in some instances, an adequate control group. Studies involving altitude exposure have received heavy criticism for lack of control groups. In experimental study, it is the quest of the researcher to control variables which may influence the dependent variables. It is no small feat to design studies in this way, and often they fall short of expectations. It is worthy therefore to have both a treatment and a control group who are exposed to the same conditions, except those which are under investigation (i.e. the dependent variable of altitude exposure). This ensures that changes in the dependent variable are attributable to the treatment not extraneous variables which have not been adequately accounted for and/or controlled. There are plenty of altitude studies that show an increase in
performance and suggest that this change came from altitude exposure. Can we be sure it was altitude that was responsible for this change?

Or, what about the control group that stays at sea level while the treatment group travels to the top of Pike’s Peak for a month’s time? Is this an adequate control? It is, quite obviously, not.

Another concern is awareness of being in a study and that awareness affecting either control or experimental performance (the so-called Hawthorne effect and the notion subject expectancies). In many studies, participants are well aware of who is and who is not receiving altitude exposure. In such instances having control groups can be quite a challenge. How do researchers insure both groups in the study feel like they are getting the same treatment? With small changes in performance gains, we do not wish to mistakenly infer a causal effect of altitude, to a change which could be attributed to subject expectancies or attitudes of the control group.

**Training Camp Phenomenon**

It may not be surprising that when a group of athlete’s live and train together for weeks at a time, performances may improve. The competitive nature of athletes and the close proximity could likely spur high efforts in training. This phenomenon enforces the need for an adequate control group that would permit reasonable inferences that changes in performance arise from altitude exposure rather than being due to better training practices. The latter is simply being attributed to a manifestation of being paired with competition.
Measurement

A 1-3% gain in performance is substantial to the athlete, as it can be the margin between victory and defeat. To the researcher, 1-3% performance gains mean something totally different, precision of measurement. Measurement error should be of the utmost concern. Reproducible methods need to be utilized. Adequate research should be available that attests to the quality of the methods utilized for measurement.

Sample Size

A power analysis must be used to determine the appropriate number of subjects for investigation. Altitude studies may fall short in this category, resulting in non-viable research. It is necessary to have an appropriate sample size to insure statistical significance and power related to any observed changes. While replicating investigations often reinforce findings, sometimes do not which is difficult to explain. Unfortunately many attempts to elucidate mechanisms underlying changes fall into this category. As a consequence many improvements seen with altitude training have no clear mechanistic explanation.

CHAPTER SUMMARY

While there are some criticisms of altitude research, living at altitude while training at sea-level has shown to be an effective method for improving endurance performance. Investigation of cycling performance and efficiency has shown an increase in functioning while decreasing the accumulation of lactate in subjects (Gore et al.,
Exposure to simulated altitude while living and training at sea-level has exhibited similar effects in cyclists (Rodriquez, et al. 1999).

Anaerobic adaptations to acclimatization have been less investigated, as physiological adaptations related to altitude exposure have been largely associated with enhancements of aerobic power. A recent study by Woods et al., suggests improvements in anaerobic type field tests in team sport athletes following a 15 day exposure to simulated altitude via re-breathing (2006). Their findings provide impetus for exploration into a new and less investigated area of altitude research.

It remains; the effect of intermittent simulated altitude exposure via re-breathing on aerobic or anaerobic performance has not been well-established. This form of altitude simulation could serve as a valuable tool for many athletes. The re-breathing device is cost-effective, time-efficient, and can be easily transported. These qualities are lacking in other forms of altitude, real or simulated. As a result, the goal of this research is to determine the effectiveness of a simulated altitude re-breathing device on cycling performance. Mechanisms which may be associated with a performance adaptation will also be investigated.
CHAPTER 3

Methodology

Do re-breathing devices actually work? It is has been demonstrated that spending large quantities of time at altitude, either terrestrial or simulated, while training at lower altitude, can improve performance. The re-breathing method proposes spending a much shorter period of time in hypoxia (about 1hr/day for 15 days) while maintaining sea level training. Will this methodology bring about performance adaptation? This investigation sought to answer this question by examining athletic performance and mechanistic properties in well-trained cyclists prior to and after exposure to simulated altitude via re-breathing.

EXPERIMENTAL DESIGN

This study was a randomized controlled trial in which 18 subjects were exposed to simulated altitude via a re-breathing device. In this single-blind study, subjects were randomly assigned to either the constant or progressive simulated altitude group. The constant treatment (CON) was comparable to low altitude (150m). The TRT protocol was consistent with manufacturer instructions (Pharma Pacific). It was a progressive treatment protocol (TRT) comparable to exposure of a moderate altitude graduating to high altitude; (3600m – 6300m) over a period of 15 consecutive days. It is noteworthy to
mention here, these “high” altitudes have been previously studied without deleterious effects.

Pilot data and one published study (Woods et al., 2006) have utilized this protocol with effective results. These works do not describe outcomes which may be expected for the typical athlete who utilizes altitude. That is, competitive endurance athletes such as cyclists, runners, swimmers, or cross country skiers. Woods study consisted of field tests with athletes in team sports. Such athletes are not the “typical altitude study participant” given that a majority of work in these events are associated with anaerobic power. Field testing also brings about concerns associated with measurement issues and lack of a controlled setting.

The manufacturer, Pharma Pacific, has collected a variety of pilot data from individual athletes, but these measures were collected without appropriate controls. The study described here uses the protocol suggested by the manufacturer in a controlled environment in an effort to provide benchmark results for endurance athletes.

Subjects were given specific instructions and monitored for factors which may influence performance; detailed records of training, diet, overall health, and well-being were recorded on a daily basis. Subjects performed exercise performance tests on three occasions: a familiarization trial (FAM), a baseline trial before the simulated altitude sessions (PRE) and 5 days after the completion of the altitude exposures (POST). Hematological measurements were performed at PRE and at POST. Performance testing and blood draws were specifically timed to ensure adequate physiological adaptation (red blood cell production) to the altitude stimulus. Due to the continual recycling of blood, it was anticipated that all effects would dissipate in the time of 120 days.
The measures collected in this study fall into 3 categories: performance, physiological and hematological measures. The study design and dependent variables are seen below. Table 3.1 depicts the repeated measures design used in this investigation while Table 3.2 specifies when each dependent variable was measured.

**Independent Variables**

Within-subject factor: Time, with three levels (FAM, PRE, and POST)

Between-subject factor: Group, with two levels (TRT, and CON).

**Dependent Variables**

Performance measures (15m TT, 3m TT, and 60m TT)

Physiological measures (VO2, HR, and Lactate)

Hematological measures (HTC, RTC, and Fe)

<table>
<thead>
<tr>
<th>Factor B (between-subject)</th>
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<th>Factor A (within-subject)</th>
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</thead>
<tbody>
<tr>
<td>TRT group (n=9)</td>
<td></td>
<td>FAM</td>
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<td>S9</td>
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<tr>
<td>CON group (n=9)</td>
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Table 3.1 Repeated Measures Design
### Table 3.2 Repeated measures variables.

<table>
<thead>
<tr>
<th>Repeated Measures</th>
<th>CON</th>
<th>TRT</th>
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</thead>
<tbody>
<tr>
<td><strong>GROUP</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Training (time &amp; intensity)</strong></td>
<td>Wk 1</td>
<td>Wk 2</td>
</tr>
<tr>
<td><strong>15 min TT Power (watt&lt;sub&gt;avg&lt;/sub&gt;)</strong></td>
<td>FAM PRE</td>
<td>POST FAM PRE POST</td>
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<tr>
<td><strong>3 min TT Power (watt&lt;sub&gt;avg&lt;/sub&gt;)</strong></td>
<td>FAM PRE</td>
<td>POST FAM PRE POST</td>
</tr>
<tr>
<td><strong>60 min TT Power (watt&lt;sub&gt;avg&lt;/sub&gt;)</strong></td>
<td>FAM PRE</td>
<td>POST FAM PRE POST</td>
</tr>
<tr>
<td><strong>VO2 Index (ml/kg/min&lt;sub&gt;avg&lt;/sub&gt;/watt&lt;sub&gt;avg&lt;/sub&gt;)</strong></td>
<td>PRE POST FAM PRE POST</td>
<td></td>
</tr>
<tr>
<td><strong>HR Index (HR&lt;sub&gt;avg&lt;/sub&gt;/watt&lt;sub&gt;avg&lt;/sub&gt;)</strong></td>
<td>PRE POST FAM PRE POST</td>
<td></td>
</tr>
<tr>
<td><strong>Lactate Index (area/watt&lt;sub&gt;avg&lt;/sub&gt;)</strong></td>
<td>PRE POST PRE POST</td>
<td></td>
</tr>
<tr>
<td><strong>HTC (%)</strong></td>
<td>PRE POST</td>
<td></td>
</tr>
<tr>
<td><strong>RTC (M/uL)</strong></td>
<td>PRE POST</td>
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</tbody>
</table>

**SAMPLE**

Although the body of work examining the effects of altitude exposure is quite large and simulated altitude exposure has been studied as well, this research project may be described as pilot work or as being more exploratory in nature. The nature of the subject population, the attempt to discern underlying hematological parameters and the limited application of the findings (external validity) all contribute to the exploratory nature of this study. In this regard while the re-breathing form of simulated altitude training has been inspected for changes in blood characteristics, it is only recently that performance effects been reported in the literature (Woods, et al., 2006). The results
from this study report improved anaerobic performances in team sport athletes. This is an unexpected finding, as the majority of altitude research investigates aerobic adaptation. The goal of the current investigation was to determine the effect of simulated altitude via re-breathing on both endurance and high-intensity anaerobic efforts in cyclists. As such, eighteen well-trained male cyclists were recruited and randomly assigned to either a treatment or a control condition.

**Recruitment**

Two African-American men were recruited for participation in this study. Other, minorities were recruited and accepted, if the study inclusionary criteria were met. It is noteworthy to indicate; the number of eligible candidates to fit the criteria for involvement was seen as being very low, even before starting the endeavor. As an example, The Ohio State University Cycling team has what is considered to be a very large men’s team. Yet, only 1 male minority met the study criteria of “well-trained” status.

Furthermore, it is appropriate to explain why females were not suitable for the proposed study. Female subjects were not recruited due to lack of availability, iron stores, hematological and performance related differences.

There exists a limited availability of “well-trained” female cyclist’s in the Central Ohio area. The Ohio State University Cycling team also has what is considered to be a large women’s team. Still only 2 females met the study criteria of “well-trained cyclist”. Of these subjects, neither was eligible to participate in the proposed study due to further exclusionary criteria (i.e., age, time commitment).
It has been previously addressed, that the maintenance of iron stores is necessary to allow for appropriate erythropoetic responses. Karamizarak and colleagues (1996) established that physical training can reduce iron stores (Ferritin) and create a negative iron balance, especially in female athletes when compared to male athletes. The incidence of iron depletion is reported to be between 30 - 50 %, particularly among female athletes (Volpe, 1999).

The length of time between performance measurements is 21 days. For the majority of females, the menstrual cycle is likely to occur every 28 days. This timeline makes it impossible to test females during the same phase of their menstrual cycle. Previous research has shown females exercising at workloads corresponding to 80% VO2max exhibit varying levels of oxygen consumption dependant upon the stage of the menstruation cycle (Williams & Krahenbuhl, 1997). Thus, females were not utilized in this pilot investigation.

**SUBJECT RECRUITMENT PROCEDURES**

Local subjects were recruited by contact with coaches. Due to a high number of subject visits, it was desirable that subjects lived in a close proximity to the university and the testing facility. The primary focus for subjects was the OSU Cycling team. Nevertheless, all males 18-35 who met study criteria and were willing to adhere to study requirements were eligible to participate. Subjects consisted of 18 well-trained endurance cyclists recruited as described above, with well-trained endurance cyclist being defined as no less than 2 years experience in competitive cycling, having competed in at least 6 road races or criteriums in the previous 12 months, and a current training program that consists
of at least 6 hours per week of moderate to high intensity cycling. Given the highly special characteristics and pre-determined conditions of the sample, achieving the required sample size or an adequate sample was challenging part of the research.

**SELECTION CRITERIA FOR STUDY PARTICIPANTS**

Subjects completed preliminary study screening questionnaire (to determine if subject met the “well-trained” status), AHA/ACSM Health/Fitness Facility Preparation Screening Questionnaire (to determine health risk factors) via self-report. They were risk stratified by a qualified Exercise Physiologist as appropriate according to ACSM Guidelines for Exercise Testing and Prescription. Individuals were pre-screened for use of ergogenic aids and banned substances and if these characteristics were apparent they were not included as subjects. Documentation and obtained information was kept in a secured and locked facility. This material was only accessible by key entry kept by Babcock. Subject inclusion and exclusion criteria are listed below.

**Inclusion Criteria:**

- Male
- Age 18-35
- Well-trained endurance cyclist; defined as subjects with no less than 2 years experience in cycling, having competed in at least 6 road races or criteriums in the previous 12 months, and sustained training practices (moderate to high intensity cycling) of no less than 6 hours per week for the previous month.
- Maintenance of fitness training (in volume and intensity) starting 1 month prior to baseline testing through the last performance test.
- Categorized as Low Risk according to ACSM Risk Stratification (Appendix B, Tables A-D)

**Exclusion Criteria:**

- Inability to meet the above Inclusion Criteria
- Subjects were not considered eligible to participate in the study if they had uncontrolled hypertension, adverse cardiac response to exercise during the stress test (i.e., ischemia, arrhythmias, claudication, etc.), a history of neuropathy, nephropathy, or retinopathy, or musculoskeletal conditions which would make participation in regular exercise difficult or dangerous.
- Categorized as Moderate or High Risk according to ACSM Risk Stratification
- Current or prior use of banned supplements or ergogenic aids as specified by UCI and USA Cycling Federation (Appendix B).
- Acclimatization to altitude in the previous 4 months.
- Track cyclists, who are considered “sprinters” in nature (have not competed in road races or criteriums)

**INCENTIVES TO PARTICIPATE**

Subjects were compensated in the form of an exercise prescription put together from performance measures during exercise testing. Outcomes (e.g. heart rate, oxygen consumption, lactates, power output) were explained and are commonly used as a
beneficial tool for training purposes and benchmarking fitness changes. This is valued at $150/per visit.

Subjects learned of their personal blood characteristics: CBC’s (including: hematocrit, hemoglobin, red blood cell count, white blood cell count, white blood cell differential, red blood cell indices, and platelet count) reticulocyte count, and serum Ferritin. This type of testing is valued at $100/per visit.

Pre- and post-exercise meals were provided and valued at $15/per visit. They consisted of a high-carbohydrate meal replacement beverage. The post-exercise meal was chosen by the participant from a list of meal choices as provided by the GCRC nutrition staff. Subjects also received simulated altitude exposure, which could influence cycling performance. The cost of the simulated altitude unit is valued at $1200.

INFORMED CONSENT

Informed consent was received prior to the subject’s familiarization trial. The form for this purpose was administered by presenting subjects with an objective overview of the study and their responsibilities. The person responsible for initiating the consent process was the principal investigator, C. Babcock. Expectations of the subject were addressed prior to the subject giving his consent. There was no attempt to dissuade subjects who did not wish to participate. Following consent, all subjects were asked if they understood the expectations required to be a participant in the study. Any concerns and/or negative responses were addressed. A list of subjects, the date of consent and any comments or questions raised by any individual subject were documented. Babcock explained aspects of the study until he was satisfied or declined to participate.
WHO ANSWERED SUBJECTS QUESTIONS

Subjects were instructed to direct their study-related concerns to C. Babcock. The subjects were also told that they could contact 1-800-678-6251 in relation to their rights as a participant in this study or to discuss study-related issues that might arise during course of the research. Thus they had the option to speak with Ms. Sandra Meadows in the Office of Responsible Research Practices. Ms. Meadows is not part of the project. If the subject was injured as a result of taking part in the study, he was instructed to immediately contact OSU Sports Medicine at (614)293-3600.

MEASURED PHYSIOLOGICAL PARAMETERS

Measured physiological parameters include: power output, heart rate, oxygen consumption and lactate. Heart rate, oxygen consumption and lactate were used as indicators of physiological efficiency. Data was collected during each of the 3 exercise tests as given below.

Power Output

Performance in cycling is the primary dependent variable of interest in this investigation. Data was collected in each of the 3 exercise tests described later. Subjects completed the exercise test on their personal racing bikes, placed upon a computer regulated and calibrated stationary trainer (Computrainer). Computrainer has been studied in relation to the Monark cycle ergometer (Ergomatic 818-E, Denmark). The results of this investigation show the Computrainer allows for valid and reliable measures
of heart rate, oxygen consumption, and carbon dioxide production among other physiological variables.

Power output was measured in watts on a continual basis and averaged over the length of the TT effort, either 15 minutes (15m) or 3 minutes (3m) in length. Meeuwsen et al. (2001) has previously established power output in TT efforts of this nature to be highly reproducible. Power was displayed on a computer screen that was placed behind the subject and out of view. Subjects were prohibited from using power meters as a means of monitoring performance during testing.

**Oxygen Consumption**

A mouthpiece and nose clips were worn by the subject, which were adjoined to a laboratory metabolic cart (Med Graphics) used to analyze expired gases; oxygen consumption \( (VO_2) \) was ascertained on a breath by breath basis. Oxygen consumption rises linearly with increasing workloads (watts). As an indicator of \( VO_2 \) efficiency, the average amount of oxygen consumed (ml/kg/min) per watt\(_{avg} \) was examined at PRE and POST. It was termed \( VO_2 \) index.

**Lactates**

Increased measures of blood lactate are indicative of a rise in the amount of anaerobic metabolism. In efforts to measure the amount of lactate at PRE and POST, the index finger of the subject's left hand was used as the sample site for measurement. The skin was punctured with a sterile lancet, the first drop of blood was wiped away and the next drop of blood was drawn into an automatic handheld lactate analyzer (Accusport).
The Accusport analyzer has been examined for reliability in comparison to a fully enzymatic photometric method, with findings indicating an R=0.969, n=418, over a range of .8 to 18 mmol/l (Accusport, Sports Resource Group).

A single drop of blood was necessary for lactate analysis, which means minimal disturbance to the subject during testing. Data were collected serially at 3, 6, 9, 12, and 15 minutes of the 15m TT. Multiple samples were collected over time to determine the blood lactate accumulation, a marker of anaerobic metabolism, during the TT. Lactate values versus time were plotted and quantified as a summary value, which accounts for the total area under the curve. To examine lactate efficiency the area under the curve is divided by the average watt achieved. This manipulation allows comparison of lactate accumulation for specific workloads.

**Heart rate**

Heart rate was continuously monitored and recorded using a 12-lead electrocardiograph. Heart rate has been shown to rise linearly with workload and be and extremely reproducible in adequately controlled conditions (Taylor et al., 1963). Heart rate was divided by power output (watt_{avg}) to examine efficiency; which is called heart rate index.

**EXERCISE PERFORMANCE TESTING**

Measurements of performance were completed, in a regulated laboratory facility, 3 times for each subject: a familiarization trial, pre-treatment and post-treatment. Testing occurred at approximately the same time of day for each subject and they were instructed
to eat high carbohydrate meals on the evening before and on the day of each test. The familiarization trial was included to deter performance improvements due to a learning effect. It was expected that the 2 initial performances would elicit similar results. If an adaptation occurred at post-test in the treatment group, the presence of the familiarization trial would provide evidence of its authenticity. Pre-treatment represents a baseline measurement, and was administered on the day prior to treatment. Post-treatment testing was administered 5 days post-treatment to allow for possible physiological adaptation to the altitude stimulus. Each subject was instructed to perform to the best of their ability.

Competitive cycling is a unique and challenging sport. In road racing; the course, conditions and competition varies dramatically from event to event. Races are a highly aerobic event; but also commonly require cyclists to put forth multiple, short-duration, extreme-intensity efforts utilizing anaerobic contributions. Whether it’s an attack, chasing down a break-away, climbing an ascent, or in training; the durations of these efforts vary greatly depending upon variables pertaining to the specific competition and environment. It is highly desirable to utilize a testing protocol that may simulate familiar racing experiences; as well as provide a prediction for actual cycling performance.

Previous examination of cyclists shows actual cycling performance, for a 40k TT on the road, to be highly correlated with average power elicited over 60 minutes (Coyle et al., 1991). The Critical Power Cycling Protocol can successfully estimate average aerobic intermittent power for a period of 60 minutes by performing bouts of work that have highly anaerobic contributions (Jenkins & Quigley, 1990; Jenkins & Quigley, 1993). Jenkins and Quigley (1993) indicated the Critical Power function closely reflects
the ability to perform supra-maximal exercise. Given the altering nature of power output in racing, the Critical Power Protocol has been chosen to examine the various metabolic components of cycling. Specifically, the Critical Power Test is expected to: 1) accommodate and match the type of efforts commonly associated with training and racing for road cyclists, 2) examine average power over different durations of time; which align to varying degrees of contribution from anaerobic and aerobic energy systems, and 3) determine the potential effects of the experiment on actual cycling performance by estimating average power output over 60 minutes.

Subjects were pre-screened for exercise testing risk stratification. Only subjects who qualified as Low Risk according to ACSM Risk Stratification (Appendix B: Tables A-B) were eligible to be a part of the study. According to ACSM, a male is categorized as “Low Risk” if he meets the following criteria: is less than 45 years of age, is asymptomatic and has no more than one risk factor (i.e., family history, cigarette smoking, hypertension, dislipidemia, impaired fasting glucose, obesity, or sedentary lifestyle). Under this condition, a physician is not necessary during exercise, nor is physician clearance necessary to participate in strenuous activity.

Exercise testing was administered by Babcock. She is certified by the American College of Sports Medicine as an Exercise Specialist and the American Heart Association to provide Advanced Cardiac Life Support and has extensive experience performing exercise testing at The Ohio State University Medical Center, including Nuclear Medicine, Cardiology, Pulmonary, and the General Clinical Research Center. She has been employed by The Ohio State University as the Program Manager in Exercise Science for the past 7 years.
Each testing session consisted of a 15 min warm-up, a maximal sustained 15 min effort, an active recovery period of 15 min, a maximal sustained effort for 3 min effort, and an active recovery period of 10 minutes. The warm-up and cool-down period are based on general guidelines suggested for strenuous exercise bouts. The sustained 15 minute and 3 minute testing periods are part of the critical power protocol, previously described. The workload for the both the 15 minute and 3 minute maximal sustained effort was directly controlled by each cyclist. Each subject was free to adjust his workload to optimize his performance over each of the performance trials. The intent was to closely mimic a TT effort. Cycling speed, cadence, average power, and time were continually recorded. The average watts (W) over 60 minutes were calculated from the Critical Power function.

FACTORs THAT CAN INFLUENCE EXERCISE PERFORMANCE

Diet

Subjects in this study were endurance athletes who performed strenuous bouts of exercise for multiple hours a day on a routine basis. To over or under feed subjects may cause an undesired effect on subject performance. Therefore, participants were asked to maintain a diet that is consistent with their training practices and typical for their routine.

Subjects’ were guided by a Registered Dietician (RD) on how to perform proper recordings of dietary intake using standardized food models. They were also questioned about their food intake by an RD utilizing the multiple pass method. This method gives subjects examples of food size and quantities. The dietician then inquires about consumed foodstuffs in a progressive and then repetitive nature. This type of 24-hour
dietary recall has shown to be more accurate than other dietary methods and to produce true results of consumed foodstuffs, including accurate quantities of carbohydrate, proteins and fats (Jonnalagadda, Mitchell, Smicikas-Wright, et al., 2000). In addition, the RD looked at the intake of supplements, herbals, and other alternatives.

To ensure proper carbohydrate loading and equivalent nutritional status prior to exercise, all subjects ingest a high-carbohydrate meal replacement beverage (Gatorade Nutrition Shake, GSSI) 2 hours before exercise testing. They received 6 kcal per kg of body weight of meal replacement beverage. The appropriate amount of beverage (per individual body weight) was delivered to each subject on that day by the principal investigator or an appointed individual.

Measurement of Training and Subjective Ratings

Subjects were asked to perform maintenance training (i.e., current training regimen) during the study period. It is understood that with physical fitness training, both duration and intensity, factor into fitness. That is, some days may be at a lower intensity but higher duration and others consist of high intensity and low duration. Recall, that 6 hours was the minimum required training per week, but it is not uncommon for some cyclist’s to train around 20 hours per week. The Borg RPE scale was used to measure intensity. This scale ranges from 6 to 20. Given the similar ranges of duration per week and reported intensity (6-20), a Training Index was created by adding the average duration to the average intensity score. That is, if a subject trained an average 12 hours on the bike per week, and averaged 10 on the RPE for intensity in that week, his Training
Index score would be 22. Similarly, if one trained 8 hours per week and averaged a 14 RPE, his Training Index score would also be 22.

Each subject received a simple standard questionnaire and to the extent possible, they recorded their daily training information as well as any comments in regards to stress, fatigue, quality of sleep and training performance throughout the duration of the investigation. Participants were reminded to refrain from strenuous physical activity 24 hours prior to each performance test.

**MEASURED HEMATOLOGICAL PARAMETERS**

Measured haematological parameters include: hematocrit (HTC), red blood cell volume (RBC), white blood cell volume (WBC), serum Ferritin, and reticulocytes. Blood samples were collected pre-treatment and post-treatment. The pre-treatment sample was taken 1 day prior to the altitude treatment and the post-treatment draw was taken 5 days following the treatment. Five days post-altitude treatment was allowed for full physiological adaptation to altitude stimulus.

Prior to the exercise testing blood was taken by venous draw. The minimum requirements for the blood draw are: CBC (.5ml), reticulocyte count (.5ml), and serum Ferritin (.6ml). CBC’s and reticulocytes samples were placed into tube or microcontainer containing EDTA. Serum Ferretin sample was placed in a microcontainer with lithium heparin. Blood draws were done by the GCRC nursing staff and immediately sent to The OSU Hospital Clinical Lab for analysis.
SIMULATED ALTITUDE TREATMENT

Altitude was simulated by exposing a subject to a decreased concentration of oxygen than what is found in normoxive air (20.99%). This was accomplished by the use of a device consisting of a breathing tube attached to an open-ended silo containing soda-lime to absorb carbon dioxide (CO$_2$). Additional foam-filled silos were added to increase respiratory dead space and thereby increase the altitude stimulus. Subjects wore a nose clip to prevent nasal breathing. As previously administered by Woods and colleagues (2006) individuals in this study, alternated 6 min of breathing through the simulated altitude device with 4 min of breathing room air, six times, for a total of 56 minutes. Peripheral oxygen saturation was continuously monitored using a pulse oximeter.

In the CON Group (control) saturation is held at 98% for 15 days of treatment; this saturation occurs with adaptation to altitudes of approximately 150 m (Hackett & Roach, 1995). This short duration of exposure to mild altitude was not expected to lead to significant differences in measured physiological or hematological parameters. The low level stimulus was chosen in effort to blind the subjects from the actual altitude treatment, such that the subject was aware of receiving an altitude treatment but blind to the gradation. In the TRT Group saturation was progressively reduced, starting at 90% on the first day and finishing at 76% on the last day; these saturations occur with adaptation to altitudes of approximately 3600 and 6300 m (Hackett & Roach, 1995) and were chosen to imitate altitude levels as demonstrated in other studies that have shown physiological adaptation (Rodriguez et al., 1999; Woods et al., 2006). Rodriguez (1999) and Woods (2006) both utilized control groups, and demonstrated acclimatization to high
simulated altitudes for relatively short durations. These were associated with improved athletic performances,

During the re-breathing procedure, subjects were separated by a screen from the oxygen saturation device. Subjects were continuously monitored during treatment. If oxygen saturation fell below the targeted value, the subject was instructed to disengage from the mouthpiece and breathe room air. This methodology of exposure was beneficial in that exposure to the altitude stimulus could be immediately sustained. By exposing the subject to normoxic air, symptoms (e.g., dizziness, light headedness, disorientation) related to altitude stimulus were promptly dissipated. Subjects were observed for adverse reactions. In the event of an adverse reaction; participants would be monitored for heart rate, resting blood pressure, oxygen saturation, rating of perceived exertion, and sense of well-being. Although not necessary in this investigation, standard laboratory emergency procedures are followed by qualified and certified (American College of Sports Medicine) staffing who oversees all treatment and testing procedures.

FACILITY USE

The simulated altitude re-breathing visits were performed in the Exercise Science Laboratory, 300 Cunz Hall, at The Ohio State University. All other visits were made to the General Clinical Research Center at The Ohio State University (GCRC). The GCRC General Advisory Committee approved this study in a process similar in nature to the IRB approval process. The mission of the GCRC is to support clinical investigators with their research efforts, using various resources provided by the National Institutes of Health (NIH).
The GCRC is a unique atmosphere ideal for this research study. The readily available professional staffing (physicians, exercise physiologists, nurses, and registered dieticians) to provide exercise, hematological and nutritional assessments was valuable for this investigation. This type of facility provided convenience to the subject and researcher. Without its support, certain aspects of this study would have been omitted which in turn, would compromise the comprehensiveness of the investigation.

**Physician Coverage**

The GCRC required each study to have a sponsoring physician. Kelley Clem, MD at OSU Sports Medicine practice fulfilled this role. In the case of an emergency or any medical concern related to this study, Clem was responsible for subjects’ well-being. Due to the low risk nature of this protocol, it was expected that physician involvement would be minimal in necessary at all.

**PROCEDURES TIMELINE**

As noted previously, exercise testing was completed 3 times for each subject: a familiarization trial (FAM), pre-treatment (PRE), and post-treatment (POST). Hematological testing was performed PRE and POST. The Simulated Altitude Treatment (ALTITUDE) was performed for 15 days on each subject. The procedures are depicted in Figure 3.1. Previously explained events are then described as they occur for each subject visit.
Recruitment of subjects was initiated prior to FAM, and all subjects received study inclusionary criteria, the informed consent and AHA/ACSM Health/Fitness Facility Preparation Screening Questionnaire. Subjects were screened for participation requirements, including pre-existing medical conditions, history of banned supplement or ergogenic aid use, and acclimatization to altitude in the previous 4 months.

They were provided an explanation of the testing and simulated altitude procedures, questions were answered, and the informed consent was administered. Lastly, a time-frame for their participation in the study was determined.

**FAM (Visit 2)**

Following the successful completion of screening procedures, subjects reported to the GCRC for visit 2. Subjects had anthropometric characteristics measured. Anthropometrics were assessed by the measurement of height and weight. Body composition was assessed via skinfolds measurement.

---

**Figure 3.1 Procedures Timeline**

<table>
<thead>
<tr>
<th>Screening Visit 1</th>
<th>FAM Visit 2</th>
<th>PRE Visit 3</th>
<th>ALTITUDE Visit 4-18</th>
<th>POST Visit 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Screening Questionnaires</td>
<td>Exercise Performance Familiarization Trial</td>
<td>Exercise Performance Pre-treatment Measurement</td>
<td>Simulated Altitude Treatment</td>
<td>Exercise Performance Post-treatment Measurement</td>
</tr>
<tr>
<td>Informed Consent</td>
<td>Hematological Pre-test</td>
<td>Hematological Pre-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hematological Post-test</td>
<td>Hematological Post-test</td>
<td>Hematological Post-test</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
An initial blood draw was taken to determine hematocrit, hemoglobin, red cell volume, white cell volume and serum Ferritin. Individuals with low Ferritin concentrations (25µg.L\(^{-1}\)) were not eligible for participation in this study, as proper iron stores are necessary to facilitate erythropoiesis (Berglund, 1992).

All subjects ingested a high-carbohydrate meal replacement drink 2 hours prior to the scheduled exercise testing. The participant’s were tested on their personal bike which is placed upon a computrainer. Electrocardiograph was used to monitor each subject during this procedure. Oxygen consumption, lactates, heart rate and power outputs were monitored on a continual basis. Each subject was directed to perform the exercise test as described in exercise performance testing. Contraindications to testing and test termination followed guidelines set forth in ACSM’s Guidelines for Exercise Testing and Prescription. This testing served as a familiarization trial for the subjects.

**PRE (Visit 3)**

The data collected from visit 3 served as baseline performance data. Subjects had ingested a high-carbohydrate meal replacement drink 2 hours prior to the scheduled exercise testing and performed an exercise test using a Computrainer®. Electrocardiograph, oxygen consumption, heart rate and power outputs, as discussed, were monitored on an on-going basis. Additionally, lactates were monitored serially during performance testing.
ALTITUDE (Visits 4-18)

Visit 4 through visit 18 corresponds to the 15 days of simulated altitude treatment, which took place in the Exercise Science Laboratory in Cunz Hall at The Ohio State University. Subjects were exposed to intermittent simulated altitude for 1 hour per day, remained passive (in a sitting position) during exposure and were blind to their assigned group. One group received low constant low exposure (CON) while the other group received a progressively increased exposure (TRT). They were supervised by the researcher or other trained exercise physiologist. During this time, all subjects received the recommended daily allowance of vitamin E, about 23 international units per day. As some studies advocate, Vitamin E taken during a prolonged stay at high altitude may prevent a "deterioration" of blood flow and subsequent decrease in physical performance associated with free radical damage to cellular antioxidant defense systems (Askew 1995, Simon-Schnass 1996). Participants were also given a standard daily iron supplement, every other day, to insure adequate serum Ferritin stores.

POST (Visit 19)

During visit 19, subjects make their third and final visit to the GCRC, which occurs 5 days following the simulated altitude exposure. Subjects had their anthropometric characteristics re-measured and received post-treatment testing for hematological characteristics and performance measures as given earlier. Five days post-simulated altitude treatment was allotted to afford full physiological adaptation(s) if any to the treatment.
STATISTICAL ANALYSES

Sample Size

Based upon previous research by Hodges et al. (2003) it was estimated that a sample size of 8 would be required to detect significant F-ratios with adequate power (power = 0.8) in efforts to detect change in a steady state performance test with exercise. This analysis was performed by calculating the change in VO$_2$ during steady-state cycling. Meeuwsen et al. (2001) shows a subject size of 8 cyclists to exhibit adequate power when investigating cycling TT performances after intermittent hypobaric hypoxia. Analysis measured change in both watts and maximal oxygen consumption.

Statistical Analysis

Descriptive statistics describe: subject characteristics, training characteristics, dietary characteristics, performance variables, and hematological features described as means ± S.D. Subject characteristics include: age, height, weight, and body composition. Training characteristics portray time spent riding per week, intensity described as rating of perceived exertion, and training index. Dietary characteristics recount the subject’s kilocalories, carbohydrate, protein, and fat intake and then average values for a summary daily intake. Performance variables indicate average power output elicited during time trials, lactate index, HR index, and VO$_2$ index. Hematological features identify HTC, reticulocytes, serum Ferritin values.

Diet characteristics between groups were compared using MANOVA. There was an effort to have subject’s maintain training (time and intensity) over the duration of the
Repeated Measures MANOVA was used to examine the effects of re-breathing simulated altitude on cycling performance, hematological and physiological variables in subjects that had been randomly assigned to a treatment or a control group. The subjects in the treatment and control group performed 3 testing sessions (FAM, PRE and POST) as shown previously in Table 3.1. At each of these testing sessions subjects were measured on: 15m TT, 3m TT, and Estimated 60m TT performance. At PRE and POST subjects were measured on the above parameters as well as: VO2, HR, Lactate, HTC, RTC, and Fe. The repeated measures for the dependent variables were shown earlier in Table 3.2. Multivariate subset tests were also examined in an effort to determine the effect of a specific dependent variable in the model. Assumptions for data (i.e., distribution) were checked. Alpha level was set a priori at $p < 0.05$.

**DATA MANAGEMENT PLAN**

Data was collected and kept under the supervision of Dr. Timothy E. Kirby, a co-principal investigator. Information was collected in a discreet fashion, and subject results remain confidential as prescribed by the HIPAA Act and Informed Consent. Statistical software SPSS for Windows 14.0 was used to run analyses.

**SOURCES OF RESEARCH MATERIAL**

All research material was collected with the sole intention of research purposes. We did not make additional use of existing specimens, records or data. All data collected
was kept confidential. Only those who received subject approval had access to the data collected in this research study.

**DATA AND SAFETY MONITORING PLAN**

Dr. Kirby monitored all aspects of the protocol, while meeting with Babcock to discuss the performance of study participants with respect to their responsibilities and expectations during the study. Babcock was responsible for the collection and downloading of data for the study under the close supervision of the PI. Subjects were encouraged to report any feelings of discomfort during the study and when concerns were experienced they were brought to the PI’s attention immediately, and appropriate action was taken to relieve the reported discomfort (even if it entailed discontinuation of the treatment). No subjects were influenced by any inappropriate means to partake in simulated altitude treatment while experiencing discomfort of any kind.

**SUMMARY**

Subjects were well-trained cyclists who were randomly assigned to a low constant exposure group, designated as a placebo or to a progressively increased exposure group, set as the treatment. Subjects maintained current diet and training practices and were monitored for such. Subjects were tested for performance, physiological and hematological characteristics prior to and after 15 days of simulated altitude via re-breathing.
CHAPTER 4

Results

The results of this investigation are presented below. Descriptive data afford a description of the subject’s characteristics, dietary practices, training efforts, performance values, blood characteristics and measures of efficiency. Repeated measures MANOVA were used to analyze the dependent variables in an effort to address the primary questions of the research.

The chief concern was the matter of cycling performance. Does performance in the treatment group comparatively improve, following the use of the re-breathing device? More specifically, are aerobic power and/or anaerobic power enhanced? Secondary issues addressed mechanistic properties which may be responsible for improvement effects. Blood characteristics and physiological efficiency measures were examined for this purpose.

SUBJECT TRAITS

The study subjects were on average, approximately 23.5 years, 71 inches in height, 171.5 lbs, and 8.7% fat. The age range was 18-35 years as mentioned previously. Given that a majority of the recruiting was done on a college campus, it was not surprising that the average age was closer to 18 than 35. A majority of the subjects came from the Ohio State University Cycling Team, while others were recruited from the surrounding
community. The demanding nature of cycling and numerous hours spent on the bike is evidenced by relatively low weight compared to stature. A body composition of less than 10% fat for this age range is considered excellent. The overall features of the groups can be described as typical of what would be expected for competitive cyclists.

<table>
<thead>
<tr>
<th></th>
<th>TRT (n=8)</th>
<th>CON (n =9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.25 ± 1.165</td>
<td>25.67 ± .412</td>
</tr>
<tr>
<td>Height (in)</td>
<td>71.75 ± 3.105</td>
<td>70.56 ± 2.698</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>169.88 ± 8.149</td>
<td>173.56 ± 17.608</td>
</tr>
<tr>
<td>Percent fat (%)</td>
<td>8.725 ± 4.378</td>
<td>8.744 ± 2.984</td>
</tr>
</tbody>
</table>

Table 4.1 Characteristics of the subjects, values are means ± S.D.

Descriptive data depicting subject characteristics for each group are presented in Table 4.1. Independent sample t-tests were used to examine differences between the TRT and CON groups on basic traits. Equal variances were not assumed for the variable “age” due to a significant (p = .016) Levene’s Equality of Variances test. No significant differences in subject traits were found between the groups regardless of assuming equal variances (Table 4.2).

Subjects were randomly assigned to groups. Both random assignment and the highly competitive nature of cyclists’ contribute to the similarity of attributes between the groups. Road racing is an endurance event that requires a high level of aerobic fitness, which exists to a greater degree in the younger versus the older athlete. Cyclists’ endurance abilities can be maintained into their 30’s. For this reason, the age limit was set at 35. The athlete’s in this study were generally much younger. Two athletes in the
control group, both professional cyclists, were in their early 30’s, which raised the mean of the CON group. Ages between groups were not significantly different. If they had been, it is not expected to have influenced the findings to any great degree. The purpose of the upper limit in the age range was to exclude those who may have detriments in their endurance capacity. This was not the case in this study.

<table>
<thead>
<tr>
<th></th>
<th>t-test for Equality of Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
</tr>
<tr>
<td>Age</td>
<td>Equal variances not assumed</td>
</tr>
<tr>
<td>Height</td>
<td>Equal variances not assumed</td>
</tr>
<tr>
<td>Weight</td>
<td>Equal variances not assumed</td>
</tr>
<tr>
<td>Body Fat</td>
<td>Equal variances not assumed</td>
</tr>
</tbody>
</table>

Table 4.2 Independent sample t-tests for subject characteristics.

The similarity in age (TRT = 22.5 ± 1.7 yrs; CON = 25.7 ± 0.4 yrs), height (TRT = 71.8 ± 1.1 in; CON = 70.6 ± 0.9 in), weight (TRT = 169.9 ± 2.9 lbs; CON = 173.6 ± 5.9 lbs), and body composition (TRT = 8.7 ± 4.4 % fat; CON = 8.7 ± 3.0 % fat) between groups indicates that in terms of these variables the two groups were quite alike. This finding gives assurance that groups were similar in regard to subject characteristics and that adaptations in performance based on the experimental treatment can be reasonably attributed in this experiment.
MEASUREMENTS OF DIET AND TRAINING

Diet

Dietary data (kilocalories, % carbohydrates, % fats, and % protein) are depicted as means ± S.D in Table 4.3. Kilocalories (TRT = 3392.6 ± 739.8; CON = 2765.0 ± 666.8), % carbohydrates (TRT = 48.3 ± 14.1; CON = 37.9 ± 8.3), and % fats (TRT = 44.4 ± 8.7; CON = 35.6 ± 12.5) are higher in the TRT group compared to the CON group. The % protein (TRT = 16.1 ± 4.0; CON = 17.7 ± 3.8) is lower in TRT compared to CON. This finding may be associated with the observation of a greater amount of training in the TRT group compared to the CON group as is discussed in the next section.

<table>
<thead>
<tr>
<th></th>
<th>TRT (n=8)</th>
<th>CON (n =9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilocalories</td>
<td>3392.629 ± 739.750</td>
<td>2765.062 ± 666.826</td>
</tr>
<tr>
<td>% Carbohydrate</td>
<td>48.302 ± 14.144</td>
<td>37.921 ± 8.257</td>
</tr>
<tr>
<td>% Fat</td>
<td>35.558 ± 12.477</td>
<td>44.367 ± 8.735</td>
</tr>
<tr>
<td>% Protein</td>
<td>16.140 ± 3.970</td>
<td>17.712 ± 3.769</td>
</tr>
</tbody>
</table>

Table 4.3 Dietary intake characteristics, values are means ± S.D.

The food intake was examined using a two group MANOVA. Although the TRT group had less protein and a greater amount of calories, carbohydrate, and fat; overall there was no significance between groups in pattern of eating, as given in Table 4.4
Further examination confirms a lack of difference between the TRT and CON group in regard to diet (Table 4.5). Subjects were asked to maintain a diet that was consistent with their training load. It appeared that they complied accordingly with the nutritional requests. A similar diet between groups is a desirable finding when examining performance adaptations. Being such it can be expected that nutritional stores would not account for differences in performances among groups.

<table>
<thead>
<tr>
<th>Source</th>
<th>Dependent Variable</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Kcals</td>
<td>1668032.762</td>
<td>1</td>
<td>3.387</td>
<td>.086</td>
</tr>
<tr>
<td></td>
<td>CHO</td>
<td>456.396</td>
<td>1</td>
<td>3.518</td>
<td>.080</td>
</tr>
<tr>
<td></td>
<td>PRO</td>
<td>10.468</td>
<td>1</td>
<td>.701</td>
<td>.416</td>
</tr>
<tr>
<td></td>
<td>FAT</td>
<td>328.572</td>
<td>1</td>
<td>2.899</td>
<td>.109</td>
</tr>
<tr>
<td>Error</td>
<td>Kcals</td>
<td>7387859.310</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHO</td>
<td>1945.847</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PRO</td>
<td>224.022</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FAT</td>
<td>1700.212</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.5 Tests of between-subjects effects (dietary characteristics).

Training

Training volumes (hours/week) and intensities (RPE_{avg}/week) over the four week duration of the study are presented by week, in Table 4.6. One subject was removed
from the study due to failure to comply with training requirements, resulting in n=8 for
the TRT group. As explained in Chapter 3, subjects were required to complete a
minimum of 6 hours per week training and they were also asked to keep training
consistent in regards to duration and intensity.

<table>
<thead>
<tr>
<th></th>
<th>TRT (n=8)</th>
<th>CON (n =9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Hours</td>
<td>11.950 ± 1.827</td>
</tr>
<tr>
<td></td>
<td>Intensity</td>
<td>13.750 ± 1.035</td>
</tr>
<tr>
<td>Week 2</td>
<td>Hours</td>
<td>12.000 ± 2.712</td>
</tr>
<tr>
<td></td>
<td>Intensity</td>
<td>14.125 ± 1.126</td>
</tr>
<tr>
<td>Week 3</td>
<td>Hours</td>
<td>10.863 ± 2.370</td>
</tr>
<tr>
<td></td>
<td>Intensity</td>
<td>14.875 ± 2.417</td>
</tr>
<tr>
<td>Week 4</td>
<td>Hours</td>
<td>11.438 ± 2.091</td>
</tr>
<tr>
<td></td>
<td>Intensity</td>
<td>14.250 ± 1.389</td>
</tr>
</tbody>
</table>

Table 4.6 Training time (hours) and intensity (RPE) for the duration of the study. Values are means ± S.D.

Training volume and intensity were combined to create a Training Index for each
subject. Group means and S.D are provided in Table 4.7. TRT scores consistently rank
higher than CON scores. But more importantly, training appears to be consistent from
week to week within the groups. MANOVA repeated measures were used to analyze
training over the four week duration of the study. There was no significant effect of
Time (week to week) in respect to training practices, nor was there any significance
related to the interaction of Time and Group. In other words, training did not change
from week to week depending upon whether one was in the TRT of CON group (Table 4.8).

<table>
<thead>
<tr>
<th></th>
<th>TRT (n=8)</th>
<th>CON (n =9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1 Training Index</td>
<td>25.70 ± 1.900</td>
<td>22.11 ± 4.045</td>
</tr>
<tr>
<td>Week 2 Training Index</td>
<td>26.13 ± 2.656</td>
<td>22.00 ± 3.031</td>
</tr>
<tr>
<td>Week 3 Training Index</td>
<td>25.74 ± 3.785</td>
<td>22.33 ± 4.548</td>
</tr>
<tr>
<td>Week 4 Training Index</td>
<td>25.69 ± 2.304</td>
<td>20.94 ± 3.592</td>
</tr>
</tbody>
</table>

Table 4.7 Training index for the duration of the study, values are means ± S.D.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td>.095</td>
<td>.456</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Time * Group</td>
<td></td>
<td>.055</td>
<td>.251</td>
<td>3</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 4.8 Multivariate test for training index variable.

Tests of sphericity were met prior to further analysis. There was no significant difference in training from week to week as a result of Time (week 1, week 2, week 3, week 4) or Time interaction with Group (Table 4.9). These findings indicate the training index was held constant within both groups (TRT: 25.7 ± 1.9 wk 1, 26.1 ± 2.7 wk 2, 25.7 ± 3.8 wk 3, 25.7 ± 2.3 wk 4; CON = 22.1 ± 4.0 wk 1, 22.0 ± 3.0 wk 2, 22.3 ± 4.5 wk 3, 20.9 ± 3.6 wk 4), an important objective when examining performance adaptations.
As is well established, that variation in training practices could have an effect on one’s working capacity. Subjects were asked to maintain a consistent training schedule throughout the duration of the study and record values of duration and intensity on a daily basis. All but one of the records submitted by subjects suggests that this was the case but that record indicated a variation in training. Due to this, the data of the subject was discarded. In addition, because of personal reasons, this individual did not ride his bike at all during the final 2 weeks of the study. His last testing session revealed a final test score which was greatly lower than his initial 2 test scores.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>6.204</td>
<td>3</td>
<td>.403</td>
<td>.751</td>
</tr>
<tr>
<td>Time * Group</td>
<td>4.604</td>
<td>3</td>
<td>.299</td>
<td>.826</td>
</tr>
<tr>
<td>Error (Time)</td>
<td>230.806</td>
<td>45</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.9 Tests of within-subjects effects (Training Index).

Although, training within groups did not change, there was a significant difference (p = .010) in training between groups (Table 4.10). The TRT group reported training more and at a higher intensity when compared to the CON group (see Figure 4.1). This is not a detrimental finding as will be explained in greater detail a bit later and merely points to the fact that the TRT group rode about 2 hours more per week and at a little higher intensity than the CON group. Both groups met the minimum criteria for training and maintained it consistently over the duration of the study.
It is expected that the difference in training may be attributed to the timing of data collection. Due to the large number of subject visits and time associated with each condition, it was not possible to collect all of the data in the same season. Collection went from the spring until the winter months. Although randomly assigned, more TRT subjects were tested in the spring and summer months compared to a greater number of CON subjects being tested in the autumn and winter. It is expected that subjects rode more and at a higher intensity during the warmer months, as they correspond to the racing season.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>266.373</td>
<td>1</td>
<td>8.793</td>
<td>.010</td>
</tr>
<tr>
<td>Error</td>
<td>454.387</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.10 Tests of between-subjects effects (training index).
Figure 4.1 Training (hours) and intensity (RPE) for each week of the study.

**PERFORMANCE VARIABLES**

Power outputs for the 15m, 3m and estimated 60m TT are presented in Table 4.11. Following the FAM trial, one TRT subject announced he had misunderstood the exercise testing directions and had not performed to the best of his ability (i.e., he didn’t give his best effort because he believed he had to make multiple repeated performance efforts). Unlike other subject results, his score for the FAM trial was not similar to his score at PRE. Given this circumstance, his FAM data was deleted from analysis,
resulting in a varying n for the 15m TT. The FAM 15m TT score was also used to estimate FAM 60m TT, so there is also a decline in the number of subjects available for this variable.

<table>
<thead>
<tr>
<th></th>
<th>TRT (n=8)</th>
<th>CON (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15m TT (watts)</td>
<td>FAM 322.6 ± 35.0 (n=7)</td>
<td>295.7 ± 30.1</td>
</tr>
<tr>
<td></td>
<td>PRE 325.0 ± 34.4</td>
<td>295.9 ± 23.3</td>
</tr>
<tr>
<td></td>
<td>POST 335.0 ± 33.6</td>
<td>289.9 ± 30.5</td>
</tr>
<tr>
<td>3m TT (watts)</td>
<td>FAM 395.5 ± 45.1</td>
<td>362.0 ± 31.1</td>
</tr>
<tr>
<td></td>
<td>PRE 409.0 ± 43.9</td>
<td>360.0 ± 20.4</td>
</tr>
<tr>
<td></td>
<td>POST 402.5 ± 29.6</td>
<td>346.3 ± 40.4</td>
</tr>
<tr>
<td>60m TT (watts)</td>
<td>FAM 307.9 ± 35.5 (n=7)</td>
<td>283.2 ± 31.4</td>
</tr>
<tr>
<td></td>
<td>PRE 300.1 ± 28.4</td>
<td>275.2 ± 29.1</td>
</tr>
<tr>
<td></td>
<td>POST 322.4 ± 36.1</td>
<td>279.4 ± 29.9</td>
</tr>
</tbody>
</table>

Table 4.11 Exercise performance test results, values are means ± S.D.

Repeated Measures MANOVA was performed to examine the relationships among and within the TT efforts (Table 4.12). There was a significance (p=.005) found with Time (FAM to PRE to POST) and Group (TRT or CON) interaction and also between Groups (p=.038). Figures 4.2 depicts the mean group scores for each performance test, the Time and Group interaction can be noticed when examining the slope of the line. The improvement in the 15 and 60m TT at POST is noted in the TRT group, but not in the CON group. As previously noted in regard to training, the difference between group TT efforts is likely due to the timing of performance testing. More TRT subjects were tested in the warmer months, which would likely reflect a higher level of fitness.
We do not believe the observed between Group difference in regard to training practices will impact performance results over Time (FAM to PRE to POST). The important variable is the degree of change influenced by the simulated altitude which should not be impacted by the initial level of training. The dependent variables used to examine performance (watts, VO₂, HR, lactate) are reliable physiological measures. If subjects maintained a consistent training program, which they reported to be the case, then differences detected as a consequence of the simulated altitude exposure should not be affected, despite the total training load or intensity of training.
The physiological variable HR provides a good example of this premise. The HR Index was used to examine heart rate in relation to the amount of power output achieved. The Index remained consistent across the CON group, indicating that there was no de-conditioning during the testing period. The higher levels of HR Index observed in the CON group, points toward the fact that the TRT group was more fit. This is confirmed by higher preliminary performance scores in the TRT group.

Of more importance is that fitness was maintained within all subjects. This finding was verified by within-subject scores that were not significantly different when only Time was considered as a factor. That is, scores did not change significantly within the subjects from FAM to PRE to POST. The interaction of Time and Group (TRT or CON) was significant, indicating the re-breathing simulated altitude treatment as the possible causal factor. As seen in Table 4.11, the TRT group scores increase in endurance type events (15mTT and 60mTT) following the treatment. In comparison, the scores for the CON group show very small to no improvement.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Group</th>
<th>Pillai's Trace</th>
<th>Value</th>
<th>F</th>
<th>df</th>
<th>Error df</th>
<th>Sig</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td>Group</td>
<td></td>
<td>.492</td>
<td>3.87</td>
<td>3.0</td>
<td>12.0</td>
<td>.038</td>
<td>.677</td>
</tr>
<tr>
<td>Within Subjects</td>
<td>Time</td>
<td>Pillai's Trace</td>
<td>.640</td>
<td>2.67</td>
<td>6.0</td>
<td>9.0</td>
<td>.090</td>
<td>.568</td>
</tr>
<tr>
<td>Time * Group</td>
<td>Pillai's Trace</td>
<td></td>
<td>.824</td>
<td>7.01</td>
<td>6.0</td>
<td>9.0</td>
<td>.005</td>
<td>.957</td>
</tr>
</tbody>
</table>

Table 4.12 Multivariate tests for performance measures.
Mauchly’s test of sphericity was used to test the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables was proportional to an identity matrix (Table 4.13). Both the 15m TT and Estimated 60m TT were found to meet tests of sphericity. The 3mTT effort was significant (p=.005) therefore the degrees of freedom were adjusted when examining tests in this variable.

<table>
<thead>
<tr>
<th>Within</th>
<th>Measure</th>
<th>Mauchly’s W</th>
<th>Approx. Chi Square</th>
<th>df</th>
<th>Sig.</th>
<th>Greenhouse-Geisser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>15m TT</td>
<td>.782</td>
<td>3.188</td>
<td>2.0</td>
<td>.203</td>
<td>.821</td>
</tr>
<tr>
<td></td>
<td>3m TT</td>
<td>.440</td>
<td>10.682</td>
<td>2.0</td>
<td>.005</td>
<td>.641</td>
</tr>
<tr>
<td></td>
<td>60m TT</td>
<td>.832</td>
<td>2.398</td>
<td>2.0</td>
<td>.301</td>
<td>.856</td>
</tr>
</tbody>
</table>

Table 4.13 Mauchly’s test of sphericity.

15 Minute Time Trial

In Figure 4.3 the 15m TT’s are shown for both groups in terms of boxplots which specify medians, interquartile ranges and outlier data. The CON group data for FAM, PRE and POST appears to change little between trials, whereas, the TRT group data appears to increase at POST when compared to FAM and PRE scores.

As expected, the FAM and PRE scores were similar within groups (TRT: FAM = 322.6 ± 35.0 watts and PRE = 325.0 ± 34.4 watts; CON: FAM = 295.7 ± 30.1 watts and PRE = 295.9 ± 23.3 watts). This finding indicates the 15m TT performance was likely to be reproducible among subjects. Although this does not constitute a full measure of reproducibility, it does provide an indication of same. At POST the TRT group improved
performance (PRE = 325.0 ± 34.4 watts, POST = 335.0 ± 33.4 watts) and there was a decrease performance in the CON group (PRE = 295.9 ± 23.3 watts, POST = 289.9 ± 30.5 watts).

Figure 4.3 Fifteen minute time trial performance, * denotes a significant within subjects effect p<0.05.
The 6 watt decline in power from the CON group at POST is not easily explained. The 2 initial scores of performance were spaced 2 weeks apart and were extremely close in proximity. Training and diet practices have been previously cited and would not be expected to account for this result. It could be posited that motivation may explain the decrease if CON subjects recognized they were in a placebo group. But, this too is thought to be unlikely. At the completion of the study participants were asked to report if they felt they were “treatment” or “control” subjects in this investigation. Eight of the 9 CON subjects reported expecting to have been treatment subjects.

Another known contributor relating to performance is stress. Being able to control this variable was beyond this study so it was not assessed. However, the timing of data collection could have a relationship to subject stress levels. More CON subjects were tested in colder months as compared to the treatment group. Given that most of the subjects in the study are college students, the stress of academic life may have been a factor to a greater degree in the CON group than in the TRT group. Two of the subjects in the CON group were not college students. Despite the fact that their level of stress was not quantified, both were currently involved in what may be labeled as a stressful event/time. One subject was expecting his first child, and another had recently separated from a spouse. For the reasons explained above, it is possible the CON group experienced more stress as compared to the TRT group, which has the potential to have influenced testing results at POST.

Also, it is possible that Seasonal Affective Disorder may also have been a contributor to greater amounts of stress for the controls. Yet, aside from these
speculations it remains unclear as to why there was a decrease at POST in the CON group.

Based upon within-subject analysis there was a significant interaction (p = .004) between Time and Group as seen in Table 4.14. The average 3% improvement in power output, in the 15m TT performance in the TRT group may be attributed to the progressive re-breathing simulated altitude treatment. This finding suggests that the treatment may significantly improve performance in an event at sea level which relies heavily upon aerobic power.

<table>
<thead>
<tr>
<th>Source</th>
<th>Measure</th>
<th>df</th>
<th>Type III Sum of Squares</th>
<th>F</th>
<th>Sig.</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
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<td>353.725</td>
<td>1.965</td>
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<td>.372</td>
</tr>
<tr>
<td></td>
<td>3m TT</td>
<td>1.28</td>
<td>955.435</td>
<td>.921</td>
<td>.375</td>
<td>.193</td>
</tr>
<tr>
<td></td>
<td>60m TT</td>
<td>2.0</td>
<td>1578.850</td>
<td>4.835</td>
<td>.016</td>
<td>.754</td>
</tr>
<tr>
<td>Time * Group</td>
<td>15m TT</td>
<td>2.0</td>
<td>1230.982</td>
<td>6.837</td>
<td>.004</td>
<td>.890</td>
</tr>
<tr>
<td></td>
<td>3m TT</td>
<td>2.0</td>
<td>1030.935</td>
<td>.994</td>
<td>.383</td>
<td>.205</td>
</tr>
<tr>
<td></td>
<td>60m TT</td>
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<td>1346.517</td>
<td>4.124</td>
<td>.027</td>
<td>.681</td>
</tr>
<tr>
<td>Error (Time)</td>
<td>15m TT</td>
<td>28.0</td>
<td>2519.608</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3m TT</td>
<td>17.9</td>
<td>14520.190</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60m TT</td>
<td>28.0</td>
<td>4571.608</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.14 Tests of within-subjects effects (performances).

**3 Minute Time Trial**

In Figure 4.4, observe the similarity of scores within the TRT and CON group for the 3m TT. The TRT group consistently scores higher than the CON group, as noted between groups. Between group analysis shows there was a significant difference (p =
0.002) for 3m TT performance (Table 4.15) confirming that the TRT group achieved significantly higher outputs compared to the control group.

Figure 4.4 Three minute time trial performance.

On the other hand, the key concern, as with all the performance trials, was the within-subjects effect. As provided in Table 4.15, there was no significant effect as a result of Time or interaction of Time and Group. In our sample of well-trained cyclists,
18-35 years, findings indicate the re-breathing form of simulated altitude does not significantly affect performance in an event at sea level which relies heavily upon anaerobic power. This 3m TT effort is an appropriate measure of anaerobic power as the majority of energy metabolism to support this maximal type effort is generated via anaerobic means.

60 Minute Time Trial

Similar to the 15 and 3m TT, TRT scores are regularly higher than CON scores in the estimated 60m TT, as shown in Figure 4.5. TRT scores appear noticeably higher at POST compared to CON scores which remain relatively steady over time.

Subsequent analysis confirms there was a significant difference (p = .035) between CON (FAM = 283.2 ± 31.4 watts; PRE = 275.2 ± 29.1 watts; POST = 279.4 ± 29.9 watts) and TRT (FAM = 307.9 ± 35.5 (n=7) watts; PRE = 300.1 ± 10.0 watts; POST = 322.4 ± 12.8 watts) scores (Table 4.14). There was a significant (p = .002) within-subjects effect of Time. That is, all of the subject’s performances, regardless of group, were affected by the time of the measurement. Both the CON and the TRT group scores declined at PRE (CON = -2.8%; TRT = -2.5%), and then improved at POST, although it is noted that the CON group did not score higher than at FAM. There was also a significant effect (p = .023) of Time interaction with Group (CON or TRT). These findings are reported in Table 4.14.
As seen in Table 4.15, subjects in the TRT and CON group performed differently. The CON group did not improve performance at POST in contrast to the quite large increase in the TRT group. From the best preliminary performance, the CON group was an average 1.3% lower at POST whereas the TRT group improved an average 4.5%. The implication is that the re-breathing form of simulated altitude has a significant improvement on longer aerobic events at sea level. CON boredom with the study is also not a likely cause since they did not report recognition of being in the placebo condition.
Table 4.15 Tests of between-subjects effects (performances).

HEMATOLOGICAL VARIABLES

Subjects’ blood characteristics (HTC, RTC, Fe) at PRE and POST are presented in Table 4.16. Due to a processing error in the laboratory, one subject’s data was excluded from RTC analysis. Repeated measures MANOVA were used to examine the hematological variables. There were not any significant differences in the blood characteristics between or within subjects as shown in Table 4.17.

Table 4.16 Haematological measurements, values are means ± S.D.
Tests of sphericity were checked and analysis of the hematological variables was performed. No significant differences were found within-subjects for individual variables of HTC, RTC or Fe (Table 4.18). The lack of difference from PRE to POST can be noted in measures of HTC seen in Figure 4.6. A between-subjects difference was noted for the variable RTC (Table 4.19). As seen in Figure 4.6, the CON group RTC values were slightly higher at PRE and POST compared to the TRT group. This is inconsequential, since both groups were in the normal range of reticulocyte volumes. Serum Fe levels were maintained in both groups over the period of the investigation. This confirms that the lack of red cell growth was not due to a lack of necessary iron in the blood. It appears the re-breathing form of simulated altitude has little to no effect on blood parameters after 15 days of exposure.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects Group</td>
<td>Pillai’s Trace</td>
<td>.343</td>
<td>2.089</td>
<td>3.0</td>
<td>12.0</td>
<td>.155</td>
</tr>
<tr>
<td>Within Subjects Time</td>
<td>Pillai’s Trace</td>
<td>.179</td>
<td>.873</td>
<td>3.0</td>
<td>12.0</td>
<td>.482</td>
</tr>
<tr>
<td>Time * Group</td>
<td>Pillai’s Trace</td>
<td>.033</td>
<td>.136</td>
<td>3.0</td>
<td>12.0</td>
<td>.937</td>
</tr>
</tbody>
</table>

Table 4.17 Multivariate tests of hematological characteristics.
Figure 4.6 Hematocrit values.
Figure 4.7 Reticulocyte values.
<table>
<thead>
<tr>
<th>Source</th>
<th>Measure</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>HTC</td>
<td>.842</td>
<td>1</td>
<td>.381</td>
<td>.547</td>
<td>.089</td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>.000</td>
<td>1</td>
<td>1.147</td>
<td>.302</td>
<td>.170</td>
</tr>
<tr>
<td></td>
<td>FE</td>
<td>39.727</td>
<td>1</td>
<td>.134</td>
<td>.720</td>
<td>.063</td>
</tr>
<tr>
<td>Time * Group</td>
<td>HTC</td>
<td>.267</td>
<td>1</td>
<td>.121</td>
<td>.733</td>
<td>.062</td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>2.47E-005</td>
<td>1</td>
<td>.079</td>
<td>.783</td>
<td>.058</td>
</tr>
<tr>
<td></td>
<td>FE</td>
<td>98.227</td>
<td>1</td>
<td>.330</td>
<td>.575</td>
<td>.084</td>
</tr>
<tr>
<td>Error (Time)</td>
<td>HTC</td>
<td>30.943</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>.004</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FE</td>
<td>4163.492</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.18 Tests of within-subjects effects (hematological characteristics).

<table>
<thead>
<tr>
<th>Source</th>
<th>Measure</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>HTC</td>
<td>2.135</td>
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<td>.641</td>
<td>.437</td>
<td>.116</td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>.001</td>
<td>1</td>
<td>5.545</td>
<td>.034</td>
<td>.592</td>
</tr>
<tr>
<td></td>
<td>FE</td>
<td>54053.929</td>
<td>1</td>
<td>2.475</td>
<td>.138</td>
<td>.311</td>
</tr>
<tr>
<td>Error</td>
<td>HTC</td>
<td>46.615</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>.003</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FE</td>
<td>305790.540</td>
<td>14</td>
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<td></td>
</tr>
</tbody>
</table>

Table 4.19 Tests of between-subjects effects (hematological characteristics).

**EFFICIENCY VARIABLES**

Means and S.D.’s of VO₂ Index, Lactate Index, and HR Index are presented in Table 4.20. MANOVA Repeated Measures was used to examine these variables. There was a significant difference (p=.012) in these variables between groups (Table 4.21).
This finding is probably linked to the previous findings between groups, that is, a higher level of fitness in the TRT group as compared to the CON. Higher levels of fitness correspond to lower sub-maximal levels in these physiological measures. There was not a significant effect of Time within subjects, but Time (PRE to POST) combined with Group neared significance at p = .075.

<table>
<thead>
<tr>
<th></th>
<th>TRT (n=8)</th>
<th>CON (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VO₂ Index</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAM</td>
<td>0.176 ± 0.032</td>
<td>0.159 ± 0.017</td>
</tr>
<tr>
<td>PRE</td>
<td>0.165 ± 0.016</td>
<td>0.163 ± 0.022</td>
</tr>
<tr>
<td>POST</td>
<td>0.152 ± 0.023</td>
<td>0.170 ± 0.021</td>
</tr>
<tr>
<td><strong>Lactate Index</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE</td>
<td>0.346 ± 0.039</td>
<td>0.433 ± 0.146 (n=9)</td>
</tr>
<tr>
<td>POST</td>
<td>0.406 ± 0.030</td>
<td>0.433 ± 0.146 (n=9)</td>
</tr>
<tr>
<td><strong>HR Index</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAM</td>
<td>0.584 ± 0.072</td>
<td>0.635 ± 0.094</td>
</tr>
<tr>
<td>PRE</td>
<td>0.564 ± 0.044</td>
<td>0.631 ± 0.094</td>
</tr>
<tr>
<td>POST</td>
<td>0.544 ± 0.053</td>
<td>0.646 ± 0.091</td>
</tr>
</tbody>
</table>

Table 4.20 Physiological efficiency variables, values are means ± S.D.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis Trace</th>
<th>Error df</th>
<th>Sig.</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td>Group</td>
<td>Pillai's Trace</td>
<td>.585</td>
<td>5.639</td>
<td>3.0</td>
<td>.012</td>
</tr>
<tr>
<td>Time * Group</td>
<td>Time</td>
<td>Pillai's Trace</td>
<td>.093</td>
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<td>.750</td>
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<tr>
<td></td>
<td></td>
<td>Pillai's Trace</td>
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<td>.075</td>
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</table>

Table 4.21 Multivariate tests for physiological variables.

Tests of sphericity were confirmed and multivariate subset analysis was completed (Tables 4.22 and 4.23). There were no significant effects for the variable
Lactate within or between subjects. There was a significant effect (p=.026) of Time interaction and Group in HR index within subjects and also a significant between subjects effect (p=.014). The notable difference exhibited in VO₂ Index does not quite reach significance (p = .075). The discovery of an improved efficiency is noticeable when examining the decline in the HR and VO₂ boxplots in the TRT compared to CON group in Figure 4.8.

### Table 4.22 Tests of within-subjects effects (physiological variables).

<table>
<thead>
<tr>
<th>Source</th>
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<th>Type III Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
<th>Observed Power</th>
</tr>
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<tbody>
<tr>
<td>Time</td>
<td>VO₂</td>
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<td>.652</td>
<td>.071</td>
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<tr>
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<td>.167</td>
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<td>Lactate</td>
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<td>3.699</td>
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<td>1.555</td>
<td>.233</td>
<td>.641</td>
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<td></td>
</tr>
<tr>
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<td>HR</td>
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<td>14.0</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Lactate</td>
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### Table 4.23 Tests of between-subjects effects (physiological variables).

<table>
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<th>Type III Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
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<td>Group</td>
<td>VO₂</td>
<td>.000</td>
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<td>.402</td>
<td>.537</td>
<td>.091</td>
</tr>
<tr>
<td></td>
<td>HR</td>
<td>.062</td>
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<td>7.804</td>
<td>.014</td>
<td>.161</td>
</tr>
<tr>
<td></td>
<td>Lactate</td>
<td>.030</td>
<td>1.0</td>
<td>1.068</td>
<td>.319</td>
<td>.738</td>
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<tr>
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<td>VO₂</td>
<td>.009</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HR</td>
<td>.111</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lactate</td>
<td>.398</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.22 Tests of within-subjects effects (physiological variables).

Table 4.23 Tests of between-subjects effects (physiological variables).
Figure 4.8 Physiological variables (lactate Index, VO\textsubscript{2} Index, and HR Index), * denotes a significant within subjects effect p<0.05.

An improved HR efficiency, or a lower HR at the same level of work, is apparent in the TRT group following 15 days of re-breathing simulated altitude treatment (Table 4.22, p =.026) as a result of interaction of Time (FAM, PRE, POST) and Group (TRT and CON). There also appears to be a decline in oxygen consumption in the TRT group following 15 days of the re-breathing treatment. These findings may shed some light on the possible or contributing mechanisms for improved performances.
It is known that steady state measurement of these variables produce reliable quantification of physiological processes. A reduction in HR and VO₂ given the same workload, leads one to assume a more efficient delivery of oxygen. Direct measures of this phenomenon were not made in this investigation. On the other hand, there are other potential explanations. A variety of possible scenarios which may have attributed to the improved physiological efficiencies and the direction for future research will be discussed in the conclusions chapter. The findings of this investigation support improved physiological efficiencies to be a mechanism for improved performance, but not hematological adaptation.

SUMMARY

In the TRT group, aerobic performance measures show a dramatic improvement (3 – 4.5%) in average power output, following the simulated altitude treatment. There was no change in anaerobic performance measures. There were no significant effects on haematological characteristics. The physiological measure, HR Index was found to be significantly more efficient and VO₂ Index exhibited a strong trend toward improved economy at POST in the TRT group. The specific findings for each hypothesis are outlined in the Table 4.24.
<table>
<thead>
<tr>
<th>Grouping</th>
<th>Specific Hypothesis</th>
<th>Results</th>
<th>Significance</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>Cycling performance which relies heavily upon aerobic power (average watts elicited in a 15m TT) will show an advantage for the treatment group but not in the control group</td>
<td>Supported</td>
<td>Significant (p=.004)</td>
<td>.890</td>
</tr>
<tr>
<td></td>
<td>Cycling performance in an event which relies heavily upon anaerobic power (average watts elicited in a 3m TT) will show an advantage for the treatment group but not in the control group</td>
<td>Not Supported</td>
<td>Not Significant (p=.383)</td>
<td>.169</td>
</tr>
<tr>
<td>Category 2</td>
<td>The treatment group will improve in the efficiency of oxygen consumption (VO$_2$ Index) as compared to the control group</td>
<td>Not Supported</td>
<td>Not Significant (p=.075)</td>
<td>.433</td>
</tr>
<tr>
<td></td>
<td>There will be a decrease the amount of lactate build up (Lactate Index) in the treatment group and there will be no effect in the control group</td>
<td>Not Supported</td>
<td>Not Significant (p=.233)</td>
<td>.214</td>
</tr>
<tr>
<td></td>
<td>Submaximal heart rates (HR Index) will decrease in the treatment group with no similar effect on the control group</td>
<td>Supported</td>
<td>Significant (p=.026)</td>
<td>.641</td>
</tr>
<tr>
<td>Category 3</td>
<td>Hematocrit levels (HTC) will improve in the treatment group but not in the control group</td>
<td>Not Supported</td>
<td>Not Significant (p=.733)</td>
<td>.062</td>
</tr>
<tr>
<td></td>
<td>Reticulocyte values (RTC) will improve in the treatment group but not in the control group</td>
<td>Not Supported</td>
<td>Not Significant (p=.783)</td>
<td>.058</td>
</tr>
</tbody>
</table>

Table 4.24 Results related to the testing of hypotheses.
CHAPTER 5

CONCLUSIONS

This study sought to assess the impact on cycling performance due to simulated high altitude exposures for short periods of time utilizing the AltO₂Lab®. Possible mechanisms responsible for changes in performance were also investigated. The TRT group was progressively acclimatized from a moderate to a high altitude, while the CON group maintained a low placebo altitude for the duration of 15 days.

CONCLUSIONS REGARDING PERFORMANCE CHANGES

Conclusion 1: Performance in well-trained cyclists improved an average of 3-4.5% in aerobic natured events. This is a tremendous improvement in athletic accomplishment for a highly trained individual.

A 1-3% increase in various athletic performances as a result of acclimatization has been well-established when spending 8-20 hours per day for weeks at a time at moderate altitude (Levine & Stray-Gunderson, 1997; Baker & Hopkins, 1998; Chapman et al., 1998, Julian et al., 2003). The data from this study reveals that exposure to simulated high altitude for a much shorter period of time (less than an hour per day) elicits at least similar and quite possibly larger gains in performance adaptations.
The improvement found in the 15m TT performance in the TRT group is similar to that reported in previous literature. In well-trained runners, Levine & Stray-Gunderson (1997) confirmed improved 5k running time that ranged from 1-3%. Other authors have also reported similar performance adaptations (Baker & Hopkins, 1998; Chapman et al., 1998, Julian et al., 2003). The current finding of an average 3% improvement in 15m TT power output is in good agreement to the previously reported athletic adaptations that occur as a result of acclimatization.

Conclusion 2: The finding of an average 4.5% improvement in the 60m TT was substantially better than what has been reported for athletic improvements as a result of moderate altitude stays for several weeks.

Longer events, such as the 60m TT, tend to mimic endurance race conditions and are not often reported in the literature. It was deemed necessary to include such a measure because laboratory testing is often criticized for lacking relationships to real world performance. The Critical Power Protocol allows for such inferences. This protocol predicts 60 minute average power output by using the average power from two different intensities and times to completion as predictor values.

Coyle (1991) has previously observed a high correlation between 60 minute power output and 40k TT performance (r = -0.88; P < 0.001). Our results indicate the TRT group significantly improved their average 60 minute power output at POST by an average of 20 watts. This is a nearly 5% increase in power output from initial performance scores.
Even on the conservative side of performance adaptation, the AltO2Lab® elicits a sizeable improvement in aerobic performance from athletes who are well-trained in their sport.

Conclusion 3: There was no improvement in performance which relied heavily on anaerobic power.

The 3m TT effort was utilized in this investigation, as it requires a large energy contribution from anaerobic means. We found no difference within subjects (FAM, PRE, POST) in the TRT or CON group following the re-breathing form of simulated altitude. A recent publication (Woods et al., 2006) has suggested that events that are highly anaerobic powered may be improved by simulated altitude exposure. This was not found in this investigation.

It is with confidence these findings in performance may be generalized to other well-trained male competitive cyclists between the ages of 18-35. This statement is based upon our findings of an adequate sample size, small individual differences within the groups and the large observed effect size.

A sample size of 8 per group was considered to be the minimum to detect performance adaptations in cycling power output and physiological measures. This goal was achieved, but needless to say, having more subjects would equal greater confidence in one’s findings. In this location, of Columbus, OH, the use of competitive cyclists for the sample population made recruitment a challenge. This may not be the case if a different type of athlete were chosen for the sample population.

Articles in the literature deal with adaptation in a variety of athletes. So, it may be considered likely, that other well-trained athletes of a similar age, who participate in
highly aerobic athletic events, may also improve their performances via a simulated re-breathing device for 15 days. The study of well-trained runners or triathletes may be an easier pool to draw from in Central Ohio. A replication study utilizing a different athlete would add more strength to the findings in this investigation.

CONCLUSIONS REGARDING THE MECHANISM OF CHANGE

It was the aim of secondary and tertiary hypotheses to identify possible mechanisms underlying performance gains. This study provides some indication, but not a conclusive one with respect to clarifying the mechanisms responsible for change. Indicators of erythropoiesis (HTC, RTC) and measures of physiological efficiency (VO$_2$ Index, Lactate Index, HR Index) were examined as the probable candidates for this mechanism of change.

Conclusions Regarding Haematological Characteristics

Conclusion 4: It appears that the re-breathing form of simulated altitude does not spur an enhanced erythropoiesis after 15 days of exposure.

Measurements of erythropoiesis (HTC, RTC), the making of new red blood cells, resulted in no significant changes for either group from PRE to POST. Using a hypobaric chamber, other investigators have also found significant improvements in cycling power outputs following exposure to 1-2 hours of intermittent hypoxia for 10-15 days, accompanied by no significant changes in red blood cell parameters (Terrados et al., 1988; Meeuwsen et al., 2001; Hendriksen & Meeuwsen, 2003).
There are issues which may be account for the inability to achieve such changes. It is possible that an exposure period longer than 15 days may be necessary to elicit haematological changes, as many of the terrestrial altitude studies which report haematological changes are exposed for 3-4 week periods.

Another possibility for failure to improve the erythropoietic response may be linked to the timing of measurement. Hamlin and Hellmans (2004) reveal a minimal increase in HTC at 2 days post-acclimatization compared to more substantial increase at 12 days post (1.5 ± 3.1 day 2 and 3.6 ± 4.1 day 12) acclimatization. This investigation looked at HTC values at 5 days post-acclimatization. This period of time may have been insufficient to produce forth significant changes in HTC or RTC values.

Or, quite possibly, the re-breathing form of simulated altitude does not stimulate an increase in red cell volume. Regardless of the reason for which hematological changes did not occur, the fact remains that performance was improved, but it can not associated with an enhanced erythropoiesis.

**Conclusions Regarding Physiological Efficiency Characteristics**

Physiological efficiency measures offered a promising look into mechanistic properties of change associated with the re-breathing form of simulated altitude. Of the 3 variables examined, 2 exhibited noticeable adaptation in the treatment group compared to the control group.
Conclusion 5: Reductions in submaximal VO$_2$ may indicate an improved cycling efficiency following acclimatization via re-breathing.

In high intensity steady state exercise, the relative VO$_2$ per watt decreased in the TRT group compared to the CON group, $p=.075$. Significant reductions in submaximal VO$_2$ have also been reported in elite runners following acclimatization to moderate altitude (Saunders, Telford, Pyne, et al., 2004), indicative of an improved running efficiency following acclimatization.

This physiological reduction is likely attributed to an adaptation of the VO$_2$ components. According to the Fick equation, maximal VO$_2$ is the product of cardiac output and the difference between arterial and venous oxygen content (a-vO$_2$ difference). Therefore, if VO$_2$ declines, it must be in direct relation to a decrease in either cardiac output and/or extraction of oxygen from the working muscles.

Each of the VO$_2$ components, cardiac output and a-vO$_2$ difference, is a potential candidate for improving efficiency. Cardiac output is the amount of blood pumped per minute and is expected to increase linearly with increasing levels of work. A-vO$_2$ difference is the measure of oxygen extracted by the musculature; this value also typically increases with workload. Neither measure was directly recorded in this study. However, related research findings and indications from the current research may provide some clue as to the likelihood that either of these variables may be part of a mechanistic property of change. The discussion in a succeeding section may help to explain the physiological efficiencies discovered in this investigation.
**HR Index**

Conclusion 6: An improved HR economy, suggests a more efficient delivery of oxygen, as the mechanistic reasoning for an enhancement in performance.

HR and stroke volume are the constituents that make up cardiac output. If it is assumed that SV remains unchanged while HR decreases, then it must be deduced that the TRT group had a lower cardiac output following the simulated altitude treatment. A decrease in VO$_2$ could be related to the finding associated with the variable HR Index. When examining the physiological variable HR, a significant effect of the altitude treatment was evident in the TRT group. The average HR per watt decreased after simulated altitude acclimatization via re-breathing, or, the efficiency of HR was improved in the TRT group. At POST a lesser HR was required to perform the same workload. Other researchers have also found that submaximal HR decreases after acclimatization to altitude (Brugniaux, Schmitt, Robach, et al., 2006; Calbet, Boushel, Rådegran, et al., 2003; Green, Roy, Grant, et al., 2000).

We have observed the TRT group to improve performance and become more efficient in HR response, assuming a lower cardiac output, this points to a more efficient delivery of oxygen as the mechanistic reasoning for an enhancement in performance.

**Possible Factors Leading to more Efficient Physiological Characteristics**

In the following discussion, some literature is described which lends support to the physiological efficiencies observed in the current investigation. It offers help in thinking about the research findings and in possibly guiding future studies.
Indeed, improvements in physiological efficiencies have mostly been attributed to an improved whole body or systemic oxygen (O$_2$) delivery. Whole body O$_2$ delivery refers to the amount of O$_2$ consumed, delivered and utilized to perform work. Systemic O$_2$ consumption is the O$_2$ consumed by a specific body system, for example, the musculature of the leg.

*Improved Whole Body O$_2$ Delivery:* Brugniaux and colleagues, correlate a decrease in submaximal HR to an improvement in VO$_2$max (2006). Following acclimatization, athletes were able to perform the same work at lower submaximal heart rates allowing them to ultimately improve the level of work, which was correlated to an increase in the O$_2$ consumed. This finding supports other reports of a decreased submaximal HR associated with an improved ventilatory threshold (Levine & Stray-Gunderson, 1997) and running/cycling economy (Saunders, Telford, Pyne, et al., 2004; Gore, Hahn, Aughey, Martin, D., et al., 2001).

An enhanced VO$_2$max and/or ventilatory threshold, in any endurance athlete, are often key factors for an improvement in performance. Well-trained athletes practice vigorous physical training on a frequent basis in effort to improve or maintain these parameters. The better trained an athlete becomes, the more difficult it becomes to bring forth changes in VO$_2$max and/or ventilatory threshold.

To become more efficient at whole body exercise, such as cycling or running, means the athlete can perform the same work load as previously done, but conserving valuable physiological processes, which may prove to be extremely beneficial in a competitive situation. Imagine your car which say gets 20 mpg, now gets 30 mpg in gasoline use. You have 25 miles and 1 gallon of gas to get home. The improvement in
fuel utilization allows your car to get you home. In fact, if you were running late, you
could even put the pedal to the floor for the last 5 miles, and get there in record time.
Had your car not become more fuel efficient, you would have been stranded alongside
the road before you got home. Similarly, an improvement in cycling/running efficiency
allows the body to perform more efficiently.

*Improved Systemic O$_2$ Delivery:* Calbet has measured maximal systemic (leg) O$_2$
delivery while performing work on a recumbent ergometer after 5 weeks at 5100m, and
found a 54% improvement after acclimatization than observed in normoxia. Considering
this large increase in systemic delivery, VO$_2$ max (whole body) was only increased
modestly (approximately 10%). Calbet attributes this phenomenon to a decreased Q and
delivery of O$_2$ to non-working muscles (2003). Although a decreased Q may seem
counterintuitive for improving performance, it should be considered that a decrease in Q
allows for a longer diffusing time and a possible increase in oxygen extraction.

This finding would suggest that VO$_2$ max, or whole body oxygen consumption, is
not responsible for improvements in performance, but rather due specifically to an
improved delivery of oxygen to the working muscle. From this stance, our observation of
a decreased HR occurs, not as a result of an increased SV, but rather a decrease found in
Q. A decrease Q, at the same workload, suggests oxygen is being utilized more
efficiently or greater amounts are being delivered to working muscle.

*Improved O$_2$ Carrying Capacity:* Hsia and colleagues demonstrate an increased
O$_2$ carrying capacity associated with a decreased Q (2007). At any given sea level
exercise intensity, a higher alveolar-arterial O$_2$ tension gradient (A-aDO$_2$) and an
increased lung diffusing capacity was observed in a group acclimatized to high altitude
compared to the control group. The A-aDO$_2$ relates to the diffusion limitation of oxygen to skeletal muscle to perform work. A lower A-aDO$_2$ tension gradient, results in a greater amount of O$_2$ being transferred to the artery which then may be delivered to the working muscle. As a result, more oxygen could be delivered with a decreased Q.

Analogously, Beidelman and colleagues correlate an increased oxygen arterial concentration (SaO$_2$) to improved cycling performances ($r=.89$) after intermittent exposure to hypoxia compared to sea level values. It is known, that as workload increases, O$_2$ extraction in skeletal muscle increases for the purpose of aerobic metabolism. A greater amount of O$_2$ delivered in the capillary, would allow for a greater amount of O$_2$ to be extracted delivered to the mitochondria, resulting in an increased ability to metabolize substrates and perform aerobic metabolism. An improved aerobic metabolism permits a quicker aerobic production of adenosine triphosphate (ATP), the body’s major form of energy currency, and an improved ability to perform aerobic work. This phenomenon could account for the improvements in performance seen in aerobic events (15m TT and 60m TT) in the TRT group.

*Substrate Utilization:* A decreased reliance on fats and increased utilization of carbohydrates as a result of acclimatization to altitude have been reported (Roberts, Butterfield, Cymerman, et al., 1996; Roberts, Reeves, Butterfield, et al., 1996; Brooks, Wolfel, Groves, et al., 1992). Roberts et al. (1996), indicates glucose utilization to be increased at rest and under exercise conditions. Per oxygen molecule, carbohydrate metabolism is a more efficient compared to fat metabolism. This theory is further supported by the works of Kennedy and colleagues (2001) who demonstrate a decrease in
enzymes that are responsible for the utilization and oxidation of fats in cardiac, liver and skeletal muscle tissue following chronic (5 weeks) live high conditions.

The implications of an increased carbohydrate utilization and decreased fat utilization following simulated altitude, is a decreased requirement of oxygen at the cellular level. This possibility could account for the observed decrease in the TRT VO$_2$.

*Skeletal Muscle Microstructure:* In support of the above findings, increased skeletal muscle capillarity (Desplanches, et al., 1993; Mizuno et al., 1990) increased concentrations of myoglobin (Terrados et al., 1990), mitochondrial oxidative enzyme activity (Terrados et al., 1990), and mitochondria (Desplanches, et al., 1993) have been previously reported. All of these findings would lead to enhanced oxygen utilization and improved aerobic energy production. On the other hand, it must be pointed out that only one of these acclimatization studies was performed in well-trained athletes (Mizuno et al., 1990). Whether or not these adaptations are present in competitive athletes has not been well established.

If muscle capillarity were increased in this study, oxygen could have been better delivered to the working muscle, allowing for the decrease observed in HR Index in the TRT group. Additionally, greater concentrations of myoglobin, mitochondria, and oxidative enzymes would have led to oxygen being utilized to a faster degree, improving aerobic metabolism. This may account for decreases in VO$_2$ (whole body) associated with the TRT group.
Summary

In this study, the parameters of maximal VO$_2$ or systemic O$_2$ delivery and/or utilization were not determined. Intuitively, our finding of a more efficient HR leads us to believe there may have been an improved whole body or systemic delivery and/or utilization of oxygen by the working muscle at POST. The trend observed in lower relative VO$_2$ scores in the TRT group gives support to this assumption.

Reports of improved whole body VO$_2$ have been previously reported in the literature for terrestrial altitude acclimatization (see earlier parts of this chapter). On the other hand, maximal VO$_2$ has not been reported in studies that have examined intermittent hypoxia (Terrados, et al., 1988; Meeuwsen et al., 2001; Hendriksen & Meeuwsen, 2003). For this reason, it is suggested that further examination of oxygen utilization be directed at skeletal muscle microstructure.

IMPLICATIONS OR SUGGESTIONS FOR FUTURE RESEARCH

**Suggestion 1:** Sample size should be increased.

Appropriate steps were taken prior to collecting data to insure an appropriate sample size was used to detect changes in performances, with successful results. But frankly an even larger sample size would have been beneficial especially when examining physiological parameters. With a larger sample size, the confidence in the results would have been enhanced. Recall, that there was a strong trend in the data which indicates a more efficient VO$_2$ in the TRT group. More subjects could help further elucidate this finding.
**Suggestion 2:** Subjective reports should be replaced with direct measures.

In this study we relied upon subjects to honestly, correctly and on a timely basis report their training and diet regimens. It is known that a deficit/surplus in training or diet can affect performance variables, as such, it would have been ideal to directly observe these parameters.

Compared to other athletes, cyclists are somewhat unconventional in their training on their own, and in groups, and they often follow their own training regimens. The ability to supply activity monitors, such as accelerometers, power meters, or heart rate monitors to quantify training practices would have been desirable in this instance. Unfortunately, the revenue to support a more direct measure of training was not available for this investigation.

The use of athletes, who train according to the same protocol in an observed environment, would have been better for monitoring the training variable. For example, crew athletes commonly perform similar workouts as a team on rowing ergometers and/or the skull. The ability to monitor a group of athletes who train in such a similar fashion would be ideal for the purposes of control.

**Suggestion 3:** Measurements of cardiac output, maximal oxygen consumption, substrate utilization, and skeletal muscle microstructure may provide more insight as to the underlying mechanism(s) of change.

The paramount question for future investigation is in regard to determining a definitive mechanism of change associated with re-breathing. Future studies may examine any of the previously named variables in an effort to better assess oxygen utilization following acclimatization via re-breathing. These evaluations may expound
the adaptation process and may aid in the identification of mechanistic properties of change.

**Suggestion 4:** Future research should examine various re-breathing protocols.

The performance adaptations in this study were quite impressive and support the directions for the use of the methodology as described by the manufacturer. Yet, to our knowledge, the 15 day altitude stimulus, with progressive increments to high altitude, is the only re-breathing protocol to be studied. Of practical concerns from an athlete or coach’s perspective, is identification of the ideal re-breathing exposure protocol for performance enhancement. Because this methodology is still under-investigated, the protocol used in this study may not be the ideal for eliciting optimal performance gains.

**Suggestion 5:** Research should also investigate performance adaptations in other groups of athletes.

Athletes from various sports such as running, swimming, rowing, skiing and various team sports should be examined. As well, the effect of the re-breathing device with women, minority populations and athletes of varying abilities should be explored.

**SUMMARY**

In conclusion, chronic exposure to simulated altitude via re-breathing resulted in no change in a sea level cycling event which relied heavily upon anaerobic power (3m TT). Chronic exposure to simulated altitude via re-breathing did improve sea level performance when tests relied highly on aerobic power (15m TT and estimated 60m TT). An improved HR economy as a result of improved oxygen utilization may be a contributing factor which is accountable for this occurrence. These findings are in
agreement with other conclusions drawn subsequent to chronic terrestrial or simulated altitude exposures.

The findings of this study warrant the use of a re-breathing device (AltO₂Lab® as employed in this investigation) as an alternative to terrestrial altitude or other forms of simulated altitude. This was done to mediate performance gains in events which rely heavily upon aerobic power. In fact, the re-breathing form of simulated altitude could possibly become the preferred method of acclimatization. The large performance gains associated with minimal time of exposure and considerably less cost as compared to other forms of simulated altitude makes this device quite a noteworthy methodology.


APPENDIX A

INSTITUTIONAL BIOMEDICAL SCIENCES REVIEW BOARD APPROVAL
BIOMEDICAL SCIENCES INSTITUTIONAL REVIEW BOARD
RESEARCH INVOLVING HUMAN SUBJECTS
THE OHIO STATE UNIVERSITY

ACTION OF THE REVIEW BOARD

Research Protocol:

2005H0247 THE EFFECT OF INTERMITTENT SIMULATED ALTITUDE EXPOSURE ON CYCLISTS' PERFORMANCE AND BLOOD PARAMETERS, Timothy E. Kirby, James W. Altschuld, Diane L. Habash, Nicole Y. Leenders, Carmen Jill Babcock, Sport and Exercise Science

Presented for review by the Biomedical Sciences Institutional Review Board to ensure the proper protection of rights and welfare of the individuals involved with consideration of the methods used to obtain informed consent and the justification of risks in terms of potential benefits to be gained.

The protocol was APPROVED by The Biomedical Institutional Review Board.

NOTE: Inclusion of vulnerable subjects (OSU students and employees) is permissible as described in 45 CFR 46.111(b). Additional safeguards have been included in the study to protect the rights and welfare of these subjects.

Approval for proposed research includes all materials submitted by the investigator unless otherwise noted.

It is the responsibility of the principal investigator to retain a copy of each signed consent form for at least three (3) years beyond the termination of the subject's participation in the proposed activity. Should the principal investigator leave the University, signed consent forms are to be transferred to the Biomedical Sciences Institutional Review Board for the required retention period. This application has been approved for a period of not more than one year. You are reminded that you must promptly report any problems to the Review Board, and that no procedural changes may be made without prior review and approval. You are also reminded that the identity of the research participants must be kept confidential.

Date: January 23, 2006  Signed: William F. Mier mo
Chairperson
APPENDIX B

SCREENING FORMS
STUDY INFORMATION SHEET  
and Preliminary Participant Screening Questionnaire

As a participant in this study, you will be exposed to simulated altitude over a period of 15 consecutive days. You will be required to maintain detailed records of training, diet, and well-being on a daily basis. You will perform exercise tests on four occasions: a familiarization trial, a baseline trial one week later (the day prior to simulated altitude exposure) and on Days 3 and 12 post-treatment. You will have blood draws 1 day before, and on Days 3 and 12 post-treatment. You will be required to take iron supplementation to facilitate any increase in red-blood cell production.

To participate in this study, you will be required to maintain your existing fitness training beginning 2 weeks prior to baseline testing and ending with the last performance trial. Your fitness training is to consist of moderate to high intensity cycling.

All subjects will be screened for pre-existing medical conditions and history of banned supplement or ergogenic aid use. To participate in this study you must be apparently healthy and free from medical stipulations or enhancement pre-conditions (banned supplement, ergogenic aids, acclimatization to altitude).

If you would like to be considered for inclusion in this study, please complete the form and return to the address given below. If you have questions, please contact me directly at (614) 292-5959 or Email at babcock.11@osu.edu.

Thank You, Return to:

Carmen J. Babcock
The Ohio State University
Primary Investigator: Carmen J. Babcock, M.A.
Co-Investigator: Timothy E. Kirby, Ph.D.
Co-Investigator: James W. Altschuld, Ph.D.

144 Cunz Hall
1841 Millikin Rd.
Columbus, OH 43210

Name: ____________________________ Date: ________________
Email: ____________________________ Phone: ________________
Number of years participating in competitive cycling: ____________________________
Number of races competed in the last 6 months: ____________________________
Average number of hours spent training per week (on the bike) in last month: ____________________________
HEALTH/FITNESS SCREENING QUESTIONNAIRE
MARK all true statements

History
You have had:
___ a heart attack
___ heart surgery
___ cardiac catheterization
___ coronary angioplasty (PTCA)
___ pacemaker/implantable cardiac
defibrillator/rhythm disturbance
___ heart valve disease
___ heart failure
___ heart transplantation
___ congenital heart disease

Symptoms
___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, or blackouts.
___ You take heart medications.

Other health issues
___ You have diabetes.
___ You have asthma or other lung disease.
___ You have sickle cell disease or other blood-related disorder
___ You have burning or cramping sensation in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity.
___ You have concerns about the safety of exercise.
___ You take prescription medication(s).
___ You take ergogenic aids or supplement(s).

Cardiovascular risk factors
___ You smoke, or quit smoking within the previous 6 months.
___ Your blood pressure is > 140/90 mm Hg.
___ You do not know your blood pressure.
___ You take blood pressure medication.
___ Your blood cholesterol level is >200 mg/dL.
___ You do not know your cholesterol level.
___ You have a close blood relative who had a heart attack or heart surgery before age 55
   (father or brother) or age 65 (mother or sister).
___ You are physically inactive
___ You are >20 pounds overweight.

___ None of the above


Subject Signature __________________________________________ Date __________
American College of Sports Medicine Risk Stratification

Once responses have been given to the AHA/ACSM Health/Fitness Facility Preparation Screening Questionnaire, symptom and risk factor screening can occur by using Table A-C. Knowing the risk factor for each individual, a decision can be made regarding the medical coverage for the exercise stress test using Table D.

Table A.

| Coronary Artery Disease Risk Factor Thresholds for Use with ACSM Risk Stratification |
|---------------------------------|---------------------------------|
| **Risk Factors**                | **Defining criteria**            |
| **Positive:**                   |                                 |
| Family history                  | Myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father or other male first-degree relative (i.e., brother or son), or before 65 years of age in mother or other female first-degree relative |
| Cigarette smoking               | Current cigarette smoker or those who quit within the previous 6 months |
| Hypertension                    | Systolic blood pressure of ≥ 140 mmHg or diastolic ≥ 90 mmHg, confirmed by measurements on at least 2 separate occasions, or on anti-hypertension medication. |
| Dislipidemia                    | Low-density lipoprotein cholesterol (LDL) is available use > 130 mg/dL (3.4 mmol/L) or high-density lipoprotein cholesterol (HDL) of < 40 mg/dL (1.03 mmol/L) or on lipid-lowering medication. If total serum cholesterol is all that is available use > 200 mg/dL (5.2 mmol/L) rather than low-density lipoprotein (LDL) > 130 mg/dL. |<br>Impaired fasting glucose | Fasting blood glucose of ≥ 100 mg/dL (5.6 mmol/L) confirmed by measurements on at least two separate occasions. |
| Obesity+                         | Body mass index of ≥ 30 kg/m² or waist girth of > 102 cm for men and >88 cm for women or waist/hip ratio: ≥ 0.95 for men and ≥ 0.86 for women. |
| Sedentary lifestyle             | Persons not participating in a regular exercise program or meeting the minimal physical activity recommendations* from the US Surgeon General’s report. |
| **Negative:**                   |                                 |
| High serum HDL cholesterol^     | > 60 mg/dL (1.6 mmol/L)          |

+ Professional opinions vary regarding the most appropriate markers and thresholds for obesity; therefore exercise professionals should use clinical judgment when evaluating risk factor.
*Accumulating 30 minutes or more of moderate physical activity on most days of the week.
^ It is common to sum risk factors in making clinical judgments. If high-density lipoprotein (HDL) cholesterol is high, subtract one risk factor from the sum of the positive risk factors because high HDL decreases CAD risk.
American College of Sports Medicine Risk Stratification

Table B.

<table>
<thead>
<tr>
<th><strong>ACSM Risk Stratification Categories</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low risk:</strong></td>
</tr>
<tr>
<td>Men &lt; 45 years of age; women &lt; 55 years of age who are asymptomatic and meet no more than one risk factor threshold from Table A.</td>
</tr>
<tr>
<td><strong>Moderate Risk:</strong></td>
</tr>
<tr>
<td>Older individuals (men ≥ 45 years of age; women ≥ 55 years of age) or those who meet the threshold for two or more risk factors from Table A.</td>
</tr>
<tr>
<td><strong>High risk:</strong></td>
</tr>
<tr>
<td>Individuals with one or more signs/symptoms listed in Table C. For known cardiovascular (cardiac, peripheral vascular, or cerebrovascular disease), pulmonary (chronic obstructive pulmonary disease, interstitial lung disease, or cystic fibrosis), or metabolic disease (diabetes mellitus (types 1 and 2), thyroid disorders, renal or liver disease).</td>
</tr>
</tbody>
</table>

American College of Sports Medicine Risk Stratification

Table C.

<table>
<thead>
<tr>
<th>Major signs or symptoms suggestive of Cardiovascular and Pulmonary Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain, discomfort (or other anginal equivalent) in the chest, neck, jaw, arms, or other areas that may be result from ischemia</td>
</tr>
<tr>
<td>Shortness of breath at rest or with mild exertion</td>
</tr>
<tr>
<td>Dizziness or syncope</td>
</tr>
<tr>
<td>Orthopnea or paroxysmal nocturnal dyspnea</td>
</tr>
<tr>
<td>Ankle edema</td>
</tr>
<tr>
<td>Palpitations or tachycardia</td>
</tr>
<tr>
<td>Intermittent claudication</td>
</tr>
<tr>
<td>Known heart murmur</td>
</tr>
<tr>
<td>Unusual fatigue or shortness of breath with usual activities</td>
</tr>
</tbody>
</table>

ACSM Recommendations for (A) Current Medical Examination* and Exercise Testing Prior to Participation and (B) Physician Supervision of Exercise Tests

Table D.

<table>
<thead>
<tr>
<th></th>
<th>Low Risk</th>
<th>Moderate Risk</th>
<th>High Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate exercise</td>
<td>NN</td>
<td>NN</td>
<td>R</td>
</tr>
<tr>
<td>Vigorous exercise</td>
<td>NN</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td><strong>B.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Submaximal test</td>
<td>NN</td>
<td>NN</td>
<td>R</td>
</tr>
<tr>
<td>Maximal test</td>
<td>NN</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

NN - Not Necessary  R - Recommended

THE UNION CYCLISTE INTERNATIONALE PROHIBITED LIST

The present list is incorporated in the UCI’s Anti-Doping Rules (art. 21 ADR).

January 2005

The use of any drug should be limited to medically justified indications

SUBSTANCES AND METHODS PROHIBITED AT ALL TIMES

(IN- AND OUT-OF-COMPETITION)

PROHIBITED SUBSTANCES

S1. ANABOLIC AGENTS

Anabolic agents are prohibited.

1. Anabolic Androgenic Steroids (AAS)

a. Exogenous* AAS including: 18α-homo-17β-hydroxyestr-4-en-3-one; bolasterone; boldenone; boldione; calusterone; clostebol; danazol; dehydrochloromethyl-testosterone; delta1- androstene-3,17-dione; delta1-androstenediol; delta1-dihydro-testosterone; drostanolone; ethylestrenol; fluoxymesterone; formebolone; furazabol; gestrinone; 4-hydroxytestosterone; 4-hydroxy-19-nortestosterone; metanolone; mesterolone; metenolone; methandienone, methandriol, methylidenolone; methyltrienolone; methyltestosterone; mibolerone; nandrolone; 19- norandrostenediol; 19 norandrostenedione; norbolethone; norclostebol; norethandrolone; oxabolone; oxandrolone; oxymesterone; oxymetholone; quinbolone; stanozolol; stenbolone; tetrahydrogestrinone; trenbolone and other substances with similar chemical structure or similar biological effect(s).
b. Endogenous** AAS: androstenediol (androst-5-ene-3β,17β-diol), androstenedione (androst-4-ene-3,17-dione); dehydroepiandrosterone (DHEA); dihydrotestosterone, testosterone.

The Prohibited list 2005 and the following metabolites and isomers:
5α-androstane-3α,17α-diol; 5α-androstane-3α,17β-diol; 5α-androstane-3β, 17α-diol; 5α-androstane-3β,17 β-diol; androst-4-ene-3α, 17α-diol; androst-4-ene-3α, 17β-diol; androst-4-ene-3β, 17α-diol; androst-5-ene-3α, 17α-diol; androst-5-ene-3α, 17β-diol; androst-5-ene-3β, 17α-diol; 4-androstenediol (androst-4-ene-3β,17β-diol);
5-androstenedione (androst-5-ene-3,17-dione); epi-dihydrotestosterone; 3α-hydroxy-5α-androstan-17-one; 3β-hydroxy-5α-androstan-17-one; 19-norandrostérone; 19 norétiocholanolone.

Where a *Prohibited Substance* (as listed above) is capable of being produced by the body naturally, a *Sample* will be deemed to contain such *Prohibited Substance* where the concentration of the *Prohibited Substance* or its metabolites or markers and/or any other relevant ratio(s) in the *Athlete’s Sample* so deviates from the range of values normally found in humans that is unlikely to be consistent with normal endogenous production. A *Sample* shall not be deemed to contain a *Prohibited Substance* in any such case where the *Athlete* proves by evidence that the concentration of the *Prohibited Substance* or its metabolites or markers and/or the relevant ratio(s) in the *Athlete’s Sample* is attributable to a physiological or pathological condition. In all cases, and at any concentration, the laboratory will report an *Adverse Analytical Finding* if, based on any reliable analytical method, it can show that the *Prohibited Substance* is of exogenous origin. If the laboratory result is not conclusive and no concentration as referred to in the above
paragraph is found, the relevant *Anti-Doping Organization* shall conduct a further investigation if there are serious indications, such as a comparison to reference steroid profiles, for a possible *Use of a Prohibited Substance*. If the laboratory has reported the presence of a T/E ratio greater than four (4) to one (1) in the urine, further investigation is obligatory in order to determine whether the ratio is due to a physiological or pathological condition, except if the laboratory reports an *Adverse Analytical Finding* based on any reliable analytical method, showing that the *Prohibited Substance* is of exogenous origin. In case of an investigation, it will include a review of any previous and/or subsequent tests. If previous tests are not available, the *Athlete* shall be tested unannounced at least three times within a three month period. Should an *Athlete* fail to cooperate in the investigations, the *Athlete’s Sample* to contain shall be deemed to contain a *Prohibited Substance*.

2. *Other Anabolic Agents, including but not limited to:*

Clenbuterol, zeranol, zilpaterol.

*For purposes of this section:* *“exogenous” refers to a substance which is not capable of being produced by the body naturally. **“endogenous” refers to a substance which is capable of being produced by the body naturally.*

**S2. HORMONES AND RELATED SUBSTANCES**

The following substances, including other substances with similar chemical structure or similar biological effect(s), and their releasing factors, are prohibited:

1. Erythropoietin (EPO);

2. Growth hormone (hGH) and Insulin-like Growth Factor (IGF-1), Mechano Growth Factors (MGFs);
3. Gonadotrophins (LH, hCG);
4. Insulin;
5. Corticotrophins.

Unless the Athlete can demonstrate that the concentration was due to a physiological or pathological condition, a Sample will be deemed to contain a Prohibited Substance (as listed above) where the concentration of the Prohibited Substance or its metabolites and/or relevant ratios or markers in the Athlete’s Sample so exceeds the range of values normally found in humans so that it is unlikely to be consistent with normal endogenous production. The presence of other substances with similar chemical structure or similar biological effect(s), diagnostic marker(s) or releasing factors of a hormone listed above or of any other finding which indicate(s) that the substance detected is of exogenous origin, will be reported as an Adverse Analytical Finding.

S3. BETA-2 AGONISTS

All beta-2 agonists including their D- and L- isomers are prohibited. Their use requires a Therapeutic Use Exemption. As an exception, formoterol, salbutamol, salmeterol and terbutaline, when administrated by inhalation to prevent and/or treat asthma and exercise-induced asthma/broncho constriction require an abbreviated Therapeutic Use Exemption. Despite the granting of a Therapeutic Use Exemption, when the Laboratory has reported a concentration of salbutamol (free plus glucuronide) greater than 1000 ng/mL, this will be considered as an Adverse Analytical Finding unless the athletes proves that the abnormal result was the consequence of the therapeutic use of inhaled salbutamol.
S4. AGENTS WITH ANTI-OESTROGENIC ACTIVITY

The following classes of anti-estrogenic substances are prohibited:

1. Aromatase inhibitors including, but not limited to, anastrozole, letrozole, aminogluthetimide, exemestane, formestane, testolactone.

2. Selective Estrogen Receptor Modulators (SERMs) including, but not limited to, raloxifene, tamoxifen, toremifene.

3. Other anti-estrogenic substances including, but not limited to, clomiphene, cyclofenil, fulvestrant.

S5. DIURETICS AND OTHER MASKING AGENTS

Diuretics and other masking agents are prohibited. Masking agents include but are not limited to: Diuretics*, epitestosterone, probenecid, alpha-reductase inhibitors (e.g. finasteride, dutasteride), plasma expanders (e.g. albumin, dextran, hydroxyethyl starch.) Diuretics include: acetazolamide, amiloride, bumetanide, canrenone, chlortalidone, etacrynic acid, furosemide, indapamide, metolazone, spironolactone, thiazides (e.g. bendroflumethiazide, chlorothiazide, hydrochlorothiazide), triamterene, and other substances with similar chemical structure or similar biological effect(s).

* A Therapeutic Use Exemption is not valid if an Athlete’s urine contains a diuretic in association with threshold or sub-threshold levels of a Prohibited Substance(s).

PROHIBITED METHODS

M1. ENHANCEMENT OF OXYGEN TRANSFER

The following are prohibited:

a. Blood doping, including the use of autologous, homologous or heterologous
blood or red blood cell products of any origin, other than for medical treatment.
b. Artificially enhancing the uptake, transport or delivery of oxygen, including but not limited to, perfluorochemicals, and efaproxiral (RSR13) and modified hemoglobin products (e.g. hemoglobin-based blood substitutes, microencapsulated hemoglobin products).

M2. CHEMICAL AND PHYSICAL MANIPULATION

The following is prohibited: Tampering, or attempting to tamper, in order to alter the integrity and validity of Samples collected in Doping controls. These include but are not limited to intravenous infusions*, catheterisation, and urine substitution.

* Except as a legitimate acute medical treatment, intravenous infusions are prohibited.

M3. GENE DOPING

The non-therapeutic use of cells, genes, genetic elements or of the modulation of gene expression, having the capacity to enhance athletic performance, is prohibited.

SUBSTANCES AND METHODS PROHIBITED IN-COMPETITION

In addition to the categories S1 to S5 and M1 to M3 defined above, the following categories are prohibited in competition:

PROHIBITED SUBSTANCES

S6. STIMULANTS

The following stimulants are prohibited, including both their optical (D- and L-) isomers where relevant: Adrafinil, amfepramone, amiphenazole, amphetamine, amphetaminil, benzphetamine, bromantan, carphedon, cathine*, clobenzorex, cocaine, dimethylamphetamine, ephedrine**, etilamphetamine, etilefrine, famprofazone, fencamfamin, fencamine, fenetylline, fenfluramine, fenproporex, furfenorex, mefenorex,
mephentermine, mesocarb, methamphetamine, methylamphetamine,
methylenedioxyamphetamine, methylenedioxymethamphetamine, methylephedrine**, methylphenidate, modafinil, nikethamide, norfenfluramine, para hydroxyamphetamine, pemoline, phendimetrazine, phenmetrazine, phentermine, prolintane, selegiline, strychnine, and other substances with similar chemical structure or similar biological effect(s)***. * Cathine is prohibited when its concentration in urine is greater than 5 micrograms per milliliter. ** Each of ephedrine and methylephedrine is prohibited when its concentration in urine is greater than 10 micrograms per milliliter. *** The substances included in the 2005 Monitoring Program (bupropion, caffeine, phenylephrine, phenylpropanolamine, pipradrol, pseudoephedrine, synephrine) are not considered as Prohibited Substances. NOTE: Adrenaline associated with local anaesthetic agents or by local administration (e.g. nasal, ophtamologic) is not prohibited.

S7. NARCOTICS

The following narcotics are prohibited:
buprenorphine, dextromoramide, diamorphine (heroin), fentanyl and its derivatives, hydromorphone, methadone, morphine, oxycodone, oxymorphone, pentazocine, pethidine.

S8. CANNABINIODS

Cannabinoids (e.g. hashish, marijuana) are prohibited.

S9. GLUCOCORTICOSTEROIDS

All glucocorticosteroids are prohibited when administered orally, rectally, intravenously or intramuscularly. Their use requires a Therapeutic Use Exemption approval. All other
routes of administration require an abbreviated Therapeutic Use Exemption.

Dermatological preparations are not prohibited.

**SUBSTANCES PROHIBITED IN PARTICULAR SPORTS**

**P1. ALCOHOL**

Alcohol (ethanol) is prohibited *in-Competition* only, in the following sports. Detection will be conducted by analysis of breath and/or blood. The doping violation threshold for each Federation is reported in parenthesis.

- Aeronautic (FAI) (0.20 g/L) · Karate (WKF) (0.10 g/L)
- Archery (FITA) (0.10 g/L) · Modern Pentathlon (UIPM) (0.10 g/L)
- Automobile (FIA) (0.10 g/L) for disciplines involving shooting
- Billiards (WCBS) (0.20 g/L) · Motorcycling (FIM) (0.00 g/L)
- Boules (CMSB) (0.10 g/L) · Skiing (FIS) (0.10 g/L)

**P2. BETA-BLOCKERS**

Unless otherwise specified, beta-blockers are prohibited *in-Competition* only, in the followings sports.

- Aeronautic (FAI) · Modern Pentathlon (UIPM) for
- Archery (FITA) (also prohibited disciplines involving shooting *out-of-competition*) · Nine-pin bowling (FIQ)
- Automobile (FIA) · Sailing (ISAF) for match race
- Billiards (WCBS) helms only
- Bobsleigh (FIBT) · Shooting (ISSF) (also prohibited)
- Boules (CMSB) *out-of-competition*
- Bridge (FMB) · Skiing (FIS) in ski jumping & free
• Chess (FIDE) style snow board
• Curling (WCF) · Swimming (FINA) in diving &
• Gymnastics (FIG) synchronised swimming
• Motorcycling (FIM) · Wrestling (FILA)

Beta-blockers include, but are not limited to, the following:
acebutolol, alprenolol, atenolol, betaxolol, bisoprolol, bunolol, carteolol, carvedilol,
celiprolol, esmolol, labetalol, levobunolol, metipranolol, metoprolol, nadolol, oxprenolol,
pindolol, propranolol, sotalol, timolol.

The Prohibited list 2005

9 SPECIFIED SUBSTANCES*

“Specified Substances” * are listed below: Ephedrine, L-methylamphetamine,
methylephedrine; Cannabinoids; All inhaled Beta-2 Agonists, except clenbuterol;
Probenecid; All Glucocorticosteroids; All Beta Blockers; Alcohol.

* “The Prohibited List may identify specified substances which are particularly
susceptible to unintentional anti-doping rule violations because of their general
availability in medicinal products or which are less likely to be successfully abused as
doping agents.” A doping violation involving such substances may result in a reduced
sanction provided that the “…Athlete can establish that the Use of such a specified
substance was not intended to enhance sport performance…”
USA CYCLING SUPPLEMENT POSITION STATEMENT

(January 26, 2004)

Warning Label

**WARNING:** Using any form of dietary supplement may result in a positive test for prohibited substances leading to a suspension and/or other penalties. Vitamins, minerals, herbs, amino acids and other dietary supplements may contain prohibited or illegal substances that may or may not be listed on the label. *Any athlete who takes a vitamin, mineral, herb, amino acid, or other dietary supplement does so at his or her own risk of committing a doping violation.*

General Information

USA Cycling does not condone or promote the medically unsupervised use of dietary supplements. Because the dietary supplement industry is loosely regulated in the United States, the ingredients in a given supplement cannot be guaranteed for purity. For this reason, it is possible that a dietary supplement could lead to a positive doping control test for a substance prohibited by the Union Cycliste Internationale (UCI), US Anti-Doping Agency (USADA), World Anti-Doping Agency (WADA), and/or the International Olympic Committee (IOC). Anti-doping rules make the presence of a prohibited substance in an athlete’s urine or blood a doping offense regardless of how the substance got there. *Any athlete who takes a vitamin, mineral, herb, amino acid, or other dietary supplement does so at his or her own risk of committing a doping violation.*

Every athlete is responsible for knowing the doping control rules and categories of
prohibited substances. Information on prohibited substances is available from USADA via its website (www.usantidoping.org). Athletes are encouraged to consult with USADA through its toll free drug information line (1.800.233.0393).

**Remember, the athlete is always responsible for what he or she puts into his or her body.**
APPENDIX C

DATA COLLECTION FORM
## EXERCISE TESTING RECORD FORM

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<thead>
<tr>
<th>STUDY ID: EXPHYS 03</th>
<th>SUBJECT ID:</th>
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<tbody>
<tr>
<td>DATE:</td>
<td>VISIT: fam pre post</td>
</tr>
<tr>
<td>NAME:</td>
<td>AGE:</td>
</tr>
<tr>
<td>HEIGHT:</td>
<td>DOB:</td>
</tr>
<tr>
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<td>TECH:</td>
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<table>
<thead>
<tr>
<th>REST</th>
<th>HR</th>
<th>BP</th>
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</thead>
<tbody>
<tr>
<td>warm-up (15min)</td>
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<table>
<thead>
<tr>
<th>TI (15min)</th>
<th>LACTATE 3min</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LACTATE 6min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LACTATE 9min</td>
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<tr>
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<tr>
<td>LACTATE 15min</td>
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<tr>
<td>POWER (avg)</td>
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<tr>
<td>HR (avg)</td>
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</tr>
<tr>
<td>VO2 (avg)</td>
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<table>
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<th>REST INTERVAL (15min)</th>
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<table>
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<th>POWER (avg)</th>
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<tr>
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<table>
<thead>
<tr>
<th>cool-down</th>
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<table>
<thead>
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<th>Est W over 60min</th>
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Comments:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________