EFFECT OF INTERMITTENT HYPOXIC EXPOSURE DELIVERED VIA CYCLIC VARIATION IN ALTITUDE CONDITIONING CHAMBER ON ANAEORBIC PHYSICAL PERFORMANCE IN WELL-TRAINED ATHLETES

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We certify that we have read this thesis and that, in our opinion, it is satisfactory in scope and quality as a thesis for the degree of Master of Science in Kinesiology.

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"ARIGATO!!"

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PART 1

Introduction

Competitive endurance athletes often participate in altitude training in an effort to improve sea-level performance (Clark, Aughey, Gore, and Hahn, 2004). Traditional altitude training involves living and training continuously at high altitude, which was hypothesized to improve sea-level aerobic performance by stimulating the training intensity and the oxygen carrying capacity of the cell (Eckardt, Boutellier, Kurtz, Schopen, Koller, and Bauer, 1989; Mizuno, Bro-Rasmussen, Mygind, Schibye, Rasmussen, and Saltin, 1990). However, chronic continuous exposure to high altitude has been shown to compromise training intensity (Rusko 1996), thus the negative effects may offset the beneficial effects of altitude training (Levine and Stray-Gundersen, 1997). Moreover, access to high altitude exposure on a regular basis is limited and expensive (Levine, 2002).

Intermittent hypoxic exposure (IHE) is defined as the discontinuous exposure to hypoxia, in an attempt to reproduce the adaptative effects of altitude without sustaining the reverse impact of chronic hypoxia (Levine, 2002). According to a review of the

literature by Levine (2002), IHE can be further divided into two subcategories: 1) hypoxic exposure during exercise, where the main goal is to enhance the training stimulus (e.g., "live-low, train-high" methodology), or 2) hypoxic exposure at rest where the primary goal is to elicit the acclimatization effect (e.g., "live-high, train-low" methodology). Intermittent hypoxic exposure protocols have been administered at sea level with the use of nitrogen houses, hypoxic tents, or hypobaric chambers (Wilber, 2000). Study results indicate that IHE during exercise (Casas, Casas, Pages, Rama, Richard, Ventura, Ibanez, Rodríguez, and Viscor, 2000) or at rest (Rodríguez, Ventura, Casas, Casas, Pages, Rama, Richart, Palacios, and Viscor, 2000; Katayama, Sato, Matsuo, Ishida, Iwasaki, and Miyamura, 2004) can enhance aerobic performance without eliciting the negative effects seen in traditional altitude training.

Intermittent hypoxic exposure has also been proven to stimulate, 'anaerobic' adaptation to altitude training as noted by increases in 100 m sprint swim times and muscle-buffering capacity (Martino, Myers, and Bishop, 1995). Intermittent hypoxic exposure while training physically has been shown to improve Wingate anaerobic test

(WAnT) results of elite triathletes (Meeuwsen, Ingrid, Hendriksen, and Holewijn, 2000). However, conflicting results have been reported with this regimen after moderate- to high-intensity training under hypoxic conditions (Truijen, Toussaint, Dow, and Levine, 2003; Morton and Cable, 2005) as the improvement in performance may be attributed to the effects of the training regimen.

Results of recent studies have revealed significant improvements in anaerobic performance following passive (rest) IHE (Nummela and Rusko, 2000; Gore, Hahn, Aughey, Martin, Ashnden, Clark, Granham, Roberts, Slater, and McKenna, 2001; Roberts, Clark, Townsend, Anderson, Gore and Hahn, 2001; Beidleman, Muza, Fulco, Cymerman, Ditzler, Stulz, Staab, Robinson, Skirinar, Lewis, and Sawka, 2003). However, performance improvement criteria were determined by 400 m sprint time (Nummela and Rusko et al., 2000), and four-minute all-out cycling performance, variables which were part of the sea level weekly training regimen (Nummela and Rusko et al., 2000). In the aforementioned studies, the "live-high, train-low" protocol involved "living" at high altitude for long periods of time (range = 8 to 16.5 hours daily).

Rodriguez, et al. (2000), reported that erythropoiesis was effectively stimulated after relatively short exposures at rest, in a hypobaric chamber (90 minutes per day three weeks at 5,500 m). To our knowledge, the effect of short-term intermittent cyclic hypoxic exposure on anaerobic performance has not been investigated.

The purpose of this study was to investigate the effects of intermittent cyclic hypoxic exposure at rest on 30-second maximal anaerobic performance variables. We hypothesized that: there would be no significant difference in anaerobic performances before and after cyclic IHE delivered via the Cyclic Variation in Altitude Conditioning (CVAC) chamber.

Methodology

Research Design

Two 1 x 2 Analysis of Variance (ANOVA) with repeated measures were used to analyze Biodex System 3 isokinetic dynamometer and the Wingate Anaerobic Test (WAnT) data. Independent variables were hypoxic exposure treatment protocol and pre-post trials. Dependent variables were knee isokinetic: peak torque, mean peak torque, and percent fatigue, and WAnT: peak power, average peak power, fatigue index, Rating of Perceived Exhaustion (RPE), and blood lactate level.

Subjects

Subjects were 13 well-conditioned male (9) and female (4) aerobic athletes. Descriptive data of the subjects are presented in Table 1. Prior to participation, subjects were screened for medical pathologies via a medical history pre-participation physical examination (see Appendix A), and blood test to rule out anemia or other blood pathologies. Written informed consent approved by the University of Hawai'i, Committee on Human Studies was obtained from all subjects (see Appendix B). Subject inclusion criteria consisted of a history of competitive training of at least one year

and maximal oxygen uptake ($\dot{V}O_{2\,max}$) of 40 and 50 $ml \cdot kg^{-1} \cdot min^{-1}$ for females and males, respectively.

Table 1 Subject gender, age, height, weight, and $\dot{V}O_{2\,max}$ means ± SD

Gender	Subjects (n)	Age (yr)	Heights (cm)	Weights (kg)	$VO_{2\,max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)
Male	9	30.1± 9.2	176.9 ± 4.7	73.9 ± 12.9	58.28 ± 7.5
Female	4	30.3 ± 8.9	163.3 ± 7.4	57.2 ± 2.9	47.82 ± 4.7

Intermittent Hypoxic Exposure

The Cyclical Variable Altitude Conditioning (CVAC) chamber (CVAC Systems, Inc., Poway, California) is a portable hypobaric chamber with a fail-safe open valve system that prevents carbon dioxide build-up. Pressure changes simulating altitudes from sea level to 6858 m (22,500 ft) are controlled via a computer program. The computer program cyclically varies the pressure in the chamber simulating different altitudes for several seconds, different "tiers" represent specific maximum altitudes which cycle up and down to baseline altitudes continuously.

Procedures

Subjects were introduced to the University of Hawai'i, Kinesiology Human Performance Laboratory and familiarized with laboratory testing procedures. Subjects were then asked to maintain as consistent a training regimen as possible during the IHE period, and to keep a daily training log including activity, intensity, distance, duration, and maximum heart rate (see Appendix C). Anaerobic performance using bilateral isokinetic knee tests, and WAnT were assessed before (W0) and after (W7) IHE in the CVAC chamber. Intermittent hypoxic exposure protocols consisted of three twenty-minute acclimatization sessions over a three-day period that allowed subjects' tympanic membranes to adjust to the rapid changes in the pressure gradient in the chamber followed by a seven-week CVAC period. The first (W1) and second week (W2) of the study consisted of Tier 1 and Tier 2, respectively, with exposures equivalent to altitudes up to 3,200 m. The third week (W3) consisted of Tier 3, with exposures equivalent to altitudes up to 4,420 m. The fourth week (W4) consisted of Tier 4, with exposures equivalent to altitudes up to 5,639 m. During the fifth (W5) through seventh weeks (W7) the subjects were exposed to Tier 5, which cycled between 610 m and 6,858

m. The pressure in the CVAC chamber is constantly changing by design, either increasing or decreasing. Therefore, the technology used in the CVAC chamber is unique and unlike traditional hypobaric chambers. Figure 1 illustrates the data collection and CVAC IHE schedule.

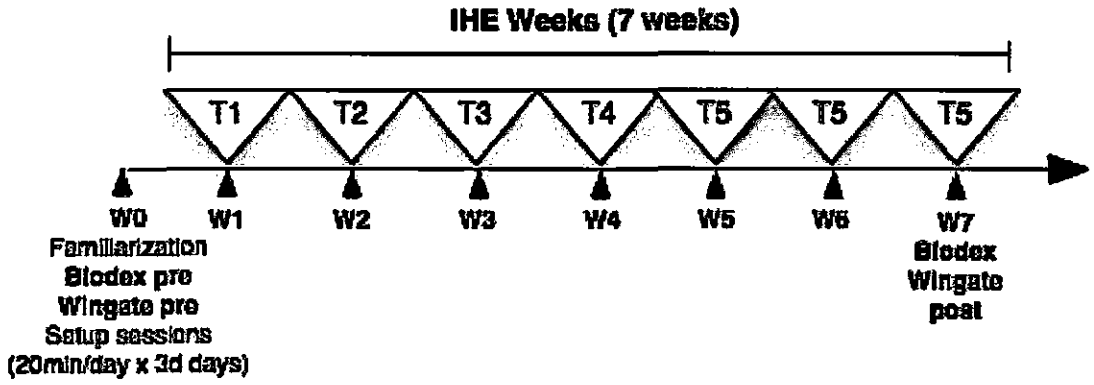

Figure 1 Biodex isokinetic test, WAnT test, and CVAC IHE Tier (T) weekly (W) schedule.

Subjects were randomly assigned to one of the following three groups: 1) Group 1 (n = 3), IHE 60 minutes, three days a week (180 min/ week); 2) Group 2 (n = 2), IHE 80 minutes, three days a week (240 min/week); and 3) Group 3 (n=8), IHE 60 minutes,

five days a week (300 min/week). During IHE sessions, subjects sat passively in the CVAC chamber.

Wingate Anaerobic Test. A Monark 823 cycle ergometer (Monark, Stockholm, Sweden) was used for WAnT data collection. A 20-minute rest period was given before the 30-second trial. Ergometer seat height was adjusted appropriately for each subject and feet were firmly secured to the pedals. Resistance was set at 1.0 and 0.98 percent of the subjects' body mass for males and females, respectively. Subjects were instructed to begin pedaling as hard and as fast as possible (approximately 100 rpm) upon hearing the command "On your mark, set, go." Upon reaching a maximal pedaling rate, the resistance was applied to the flywheel, and the 30-second test commenced. Verbal encouragement to maintain maximal pedaling rate was given throughout the test. Absolute and relative peak power, (W and Wkg) mean power (W and Wkg), and percent decrease in power data were collected from second by second intervals. Rating of perceived exertion (RPE) was determined before and after the 30-second bout to determine the subject's overall effort (Borg, 1982).

Blood Lactate Sampling. Blood lactate samples (25 µl aliquots) were analyzed with a YSI 1500 Sport Lactate Analyzer (Yellow Springs Instrument Co., Inc., Yellow Springs, OH) and performed in duplicate, mean values were used for statistical analysis. Prior to the WAnT a 22 GA 1 inch intravenous catheter with a saline lock was inserted by a Registered Nurse and secured to the forearm or hand until the test and blood collection were completed. Approximately 2 ml of saline solution was used to flush the catheter prior to blood collection. A blood sample was taken before and 7 minutes after completion of WAnT.

Isokinetic Knee Test. The Biodex Multi-Joint System 3 dynamometer (Biodex Medical Systems, Inc., Shirley, New York) was used to assess knee power bilaterally. Limb test order was randomly determined for the pre-test, and alternated for post-test. Subjects were tested seated with 85 degrees of hip flexion, seatback depth was adjusted with a 3 cm space between the popliteal fossa and the edge of the chair. The axis of rotation of the dynamometer was aligned with the lateral femoral epicondyle of the tested knee. The distal lower leg was fixed to the lever arm of the dynamometer

3.12 cm proximal to the distal end of the medial malleolus. Subjects were secured to the chair via belts at the waist, thigh and diagonally across the torso with the arms crossed and the palms on opposite shoulders to minimize excessive upper body movement and muscular substitution. Subjects' test positions were recorded for consistency and reproducibility in subsequent tests. A goniometer was used to set knee range of motion at 0 degree of extension and 100 degrees of flexion. Subjects' test protocol familiarization and warm-up consisted of five repetitions at 30 - 40 percent effort and five repetitions at 100 percent effort followed by a two minute rest period prior to the 30 second maximum effort. The researcher gave verbal encouragement. Contralateral limb testing immediately followed.

Statistical analysis

Statistical computer software SPSS Version 11. 0. 4 (SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. Differences in isokinetic knee test variables between limbs were determined via Student's *t*-test. Since preliminary analyses of variance (ANOVA) with repeated measures did not reveal significant differences in exposure group or gender, data of the 13 subjects were pooled and treated as a single group for

further analyses. Subsequently, two 1 x 2 ANOVAs with repeated measures were used to analyze the dependent variables. The alpha level was adjusted via Bonferroni correction (Feise, 2002). Therefore, the alpha level of the Biodex and WAnT variables were set at 0.00625 and 0.0125, respectively. A 1 x 7 ANOVA with repeated measures was used to analyze the training intensity changes over the seven week CVAC exposure period.

Results

Descriptive data of 13 well-trained male and female athletes are presented in Table 1. Student's *t*-test results revealed no significant differences between isokinetic knee power (see Appendix D), therefore bilateral knee data were averaged (see Appendix I). Averaged data for peak torque, mean peak torque, peak torque per body weight, and work fatigue in both extension and flexion are presented in Table 3. No significant differences in daily training intensities were revealed for the subjects during the seven week CVAC exposure period (P=.285) (see Appendix C)

Wingate Anaerobic Test performance data and a summary of ANOVA results are presented in Table 2. The 1 x 2 ANOVA s with repeated measures revealed a significant decrease in absolute and relative mean power (F=15.737, P=0.002; F=23.398, P=0.000, respectively) after seven weeks of IHE delivered via CVAC (see Figure 3-4). No significant differences (P>0.0125) were revealed in: absolute peak power, relative peak power, relative mean power, fatigue index, post exercise lactate concentrations and RPE scores (see Appendix F and H).

Table 2 Summary Table of WAnT ANOVAs and Measurement Data (Mean ± SD).

Wingate Anaerobic Test	Pre	Post	% change	F	Sig
Peak Power *Absolute* (W)	809 ± 214	799 ± 252	1.3	0.151	0.704
Peak Power *Relative* ($W \cdot kg^{-1}$)	11.7 ± 1.9	11.4 ± 2.0	2.6	0.692	0.422
Mean Power *Absolute* (W)	662 ± 166	611 ± 171	-8.3	15.737	.002**
Mean Power *Relative* ($W \cdot kg^{-1}$)	9.6 ± 1.4	8.8 ± 1.4	-9.1	23.398	.000**
Fatigue Index (%)	36.2 ± 7.1	46.6 ± 16.4	28.7	6.925	0.022
Lactate Delta Value ($mmol \cdot l^{-1}$)	4.0 ± 2.0	2.9 ± 1.4	-37.9	2.627	0.14
Rating of Perceived Exertion (Post-test score)	17.0 ± 2.5	17.9 ± 2.0	1.1	1.17	0.374

**Significant difference between pre- and post-IHE values, $P<0.0125$

Table 3 Summary Table of Isokinetic Knee Extension and Flexion ANOVAs and Measurement Data (Mean ± SD)

Isokinetics-Extension	Pre	Post	% change	F	Sig
Peak Torque (N-M)	119.86 ± 31.2	120.26 ± 32.2	0.33	0.021	0.887
Peak Torque per Body Weight (%)	175.05 ± 33.7	174.84 ± 37.4	-0.12	0.003	0.955
Average Peak Torque (N-M)	104.31 ± 25.7	102.26 ± 25.5	-2.00	0.814	0.385
Work Fatigue (%)	20.51 ± 9.2	26.04 ± 8.4	26.96	23.710	.000**
Isokinetics-Flexion					
Peak Torque (N-M)	62.60 ± 17.0	62.59 ± 13.7	-0.01	0.000	0.992
Peak Torque per Body Weight (%)	91.29 ± 15.9	91.15 ± 13.3	0.15	0.003	0.955
Average Peak Torque (N-M)	58.52 ± 25.2	55.77 ± 26.7	-4.93	1.600	0.229
Work Fatigue (%)	31.18 ± 8.3	36.76 ± 9.0	17.90	6.052	0.034

**Significant difference between pre and post-IHE values, $p<0.00625$

Isokinetic knee flexion and extension power data and a summary of ANOVA results are presented in Table 3. The 1 x 2 ANOVA s with repeated measures revealed a significant increase in post-exposure work fatigue in extension (F=23.708, *P*=.000) (see Figure 4). No significant differences (*P*>0.00625) were observed in extension and flexion peak torque, mean peak torque, peak torque per body weight and flexion work fatigue (see Appendix G and I).

Discussion

To our knowledge, this is the first study that involved investigation of cyclic intermittent exposure delivered via the Cyclic Variation in Altitude Conditioning (CVAC) chamber. The major finding of the present study was that intermittent hypoxic exposure (IHE) did not improve functional anaerobic performance variables at sea level. In contrast, previous IHE protocols that similarly involved passive (rest) hypoxic exposure have revealed improvements in sea level anaerobic performances (Nummela and Rusko, 2000; Roberts et al., 2003; and Beidleman et al., 2003). The lack of improvement in anaerobic performance in the present study may be attributed to the difference in total time of hypoxic exposure to hypoxia (see table 4).

Table 4 Summary Table of Anaerobic Responses to Intermittent Hypoxic Exposure.

	Nummeal et al., (2000)	Roberts et al., (2003)	Beidleman et al., (2003)	CVAC
Altitude	2,200 m	2,650 m	4,300 m	3,810 m*
Subjects	Well-trained 400m sprinters (n=18)	Well-trained cyclists (n=19)	Healthy lowlanders (n=6)	Well-trained cyclists/runners (n=13)
Sea-level training	Controlled	Not controlled (training log)	Controlled	Not controlled (training log)
Performance measured	400 m sprint	4 min all-out cycling	APL muscular edurance test	WAnT, Isokinetic (30-sec max)
Exposure duration	16.5±1.5 h/d 10 con. days (9,900 min)	8-10 h/d 5-15 con. Days (2,400 – 9,000 min)	4h/d 5d/wk 3wks (3,600 min)	60-80 min/d 3-5 d/wk 7 wks (1,260 min)

The total exposure time used in our study was about half that of the lowest exposure times in the previous studies which involved investigation of anaerobic responses with passive IHE. The protocol employed in the present study was based on a study by Rodríguez et al. (2000), which revealed that a minimum of 90-minutes of passive IHE, three times per week over a three-week period (weekly total exposure time: 270 minutes at 5,500 m) was needed to effectively stimulate erythropoiesis. If 90-minute sessions of passive IHE are an effective means of increasing the

oxygen-carrying capacity of the blood, it may be possible that this level of exposure will result in anaerobic adaptations that could affect performance. We based our IHE times on Rodríguez et al's. findings such that the weekly total exposures of 180 to 300 minutes were utilized. However, total exposure time at a given altitude could not be quantified accurately due to CVAC's constant cycling between different altitudes. However, the average altitudes for tiers one through five were: 1,981 m; 2,377 m; 2,926 m; 3,871 m; and 4,816 m; respectively (CVAC Systems, Inc.). Although the average altitude at Tier 5 was similar to the altitude reported by Rodríguez et al. to result in erythropoiesis, improvement in anaerobic power was not seen in the present study. However, it is possible that longer periods of exposure may result in different responses.

While the aforementioned studies (Nummela and Rusko, 2000; Roberts et al., 2003; and Beidleman et al., 2003) and our study involved sea level pre and post testing of performance variables in well-trained athletes; Nummela and Rusko, (2000) and Beidleman, et al., (2003) administered tightly controlled rigid training schedules. A limitation of the present study was that we did not control the subjects training regimens;

rather, we instructed the subjects to try to keep their training levels consistent prior to and during the CVAC training sessions. We depended on self-reported subject daily training logs to verify compliance and did not utilize a control group. Although subject daily training logs indicated that they maintained their overall exercise intensities over the seven week IHE period, a number of the subjects stated that they were training for and participated in competitions during the experimental period, or reported that they could not train for short periods of time due to illness, both of which could have influenced their posttest performance results. However, their daily training logs indicated that all subjects engaged in aerobic training during the CVAC exposure period. Similarly Nummela and Rusko (2000) utilized highly trained 400 m sprinters to evaluate anaerobic muscular endurance via the 400 m sprint, their training over the 10-day IHE period involved 100 m and 400 m speed training, as part of their training regimen during the IHE period. Consequently, their training during the IHE period more specifically targeted the post-test. As such, their results revealed a significant improvement in 400 m sprint performance. Our results also conflict with those of Beidleman et al. (2003)

who observed a significant improvement in adductor pollicis muscular endurance in four out of five subjects following three-weeks of rest and exercise training of the adductor pollicis at a simulated altitude of 4,300 m (4 h/day, 5 days/wk, 4,300 m). Adductor pollicis muscular endurance was determined via repetitive intermittent five second isometric contractions at 50 percent of the individual's pre-exercise maximum, and altitude-specific maximal voluntary contractions (MVC) followed by five seconds of rest until exhaustion. The differences in training and testing protocols make it is difficult to make a direct comparison between the studies. This contrast in our anaerobic variable results with the results of other IHE "Live-high, train-low" studies may be attributed to: lack of control of training regimens, relative short exposure times, and/or failure of cyclic IHE to stimulate changes in muscle that result in improvements in anaerobic power or muscular endurance.

Peak power as determined by the WAnT and by the Biodex isokinetic tests were unchanged following CVAC training. This would indicate that the phosphagan energy system (ATP - PCr system) was not negatively by CVAC training. However,

mean power during the WAnT significantly decreased ($p<0.00625$), and fatigue significantly increased during the isokinetic knee test ($p<0.0125$). This suggests that the anaerobic glycolytic system may have been affected by CVAC conditioning. However, subject compliance to the training protocol may also have influenced the results. For example, if the subjects experienced illness near the end of the protocol or participated in a race near the end of the conditioning period performance may have been negatively impacted. However, the subjects rated their effort to be the same (RPE = 17.0 ± 2.5 pre vs 17.9 ± 2.0 Post, P = 0.3741) after the WAnT, and mean power and was significantly lower ($p < 0.00625$). Thus, it is possible that CVAC training had some negative effect on muscular endurance for a bout of exercise lasting 30 seconds.

Studies involving "physical training " at altitude have revealed significant anaerobic performance improvements during sea-level post-tests (Balke, Nagle, and Daniel, 1965; Young, Evans, Cymerman, Pandolf, Knapik, and Maher 1980; Mizuno et al., 1990; Martino et al., 1995) due to the effects of altitude training; or intermittent hypoxic training (Meeuwsen et al., 2001). The possible mechanism for performance

enhancement may be attributed to improvements in muscle buffering capacity due to altitude training (Mizuno et al., 1990). We did not directly measure muscle buffering capacity in our study; however, we did examine blood lactate accumulation following the WAnT. Our results revealed non-significant reductions in post-WAnT blood lactate concentration following seven weeks of IHE delivered via the CVAC protocol. The finding of our study aligned previous studies that utilized passive IHE protocols and also found decreased post-exercise lactate concentrations (Nummela and Rusko, et al., 2000; Gore et al., 2001).

Within the limitations of this study we have concluded that IHE delivered via CVAC had no effect in anaerobic variables, but may have detrimentally affected WAnT mean power and isokinetic knee muscular endurance of highly trained bikers and/or runners. Further research designed to identify factors affecting anaerobic performance subsequent to IHE seem warranted.

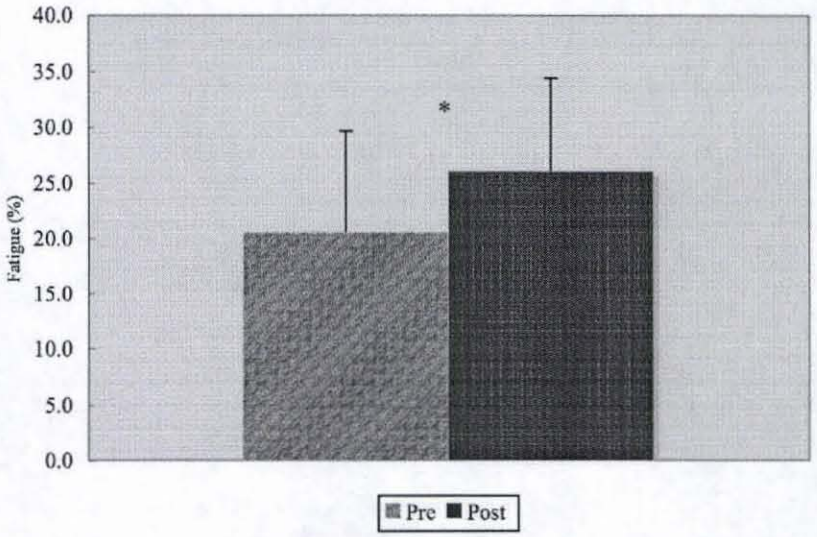

Figure 2 Isokinetic knee extension work fatigue before and after the seven week CVAC exposure period

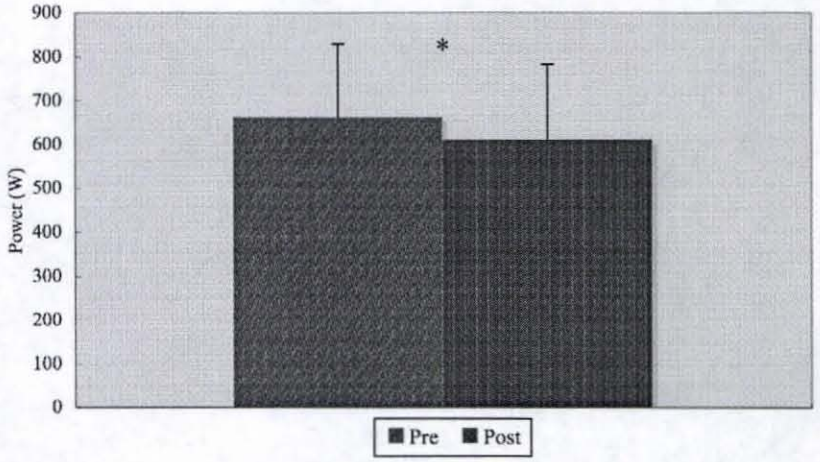

Figure 3 Wingate mean power in absolute value pre- and post-CVAC exposure.

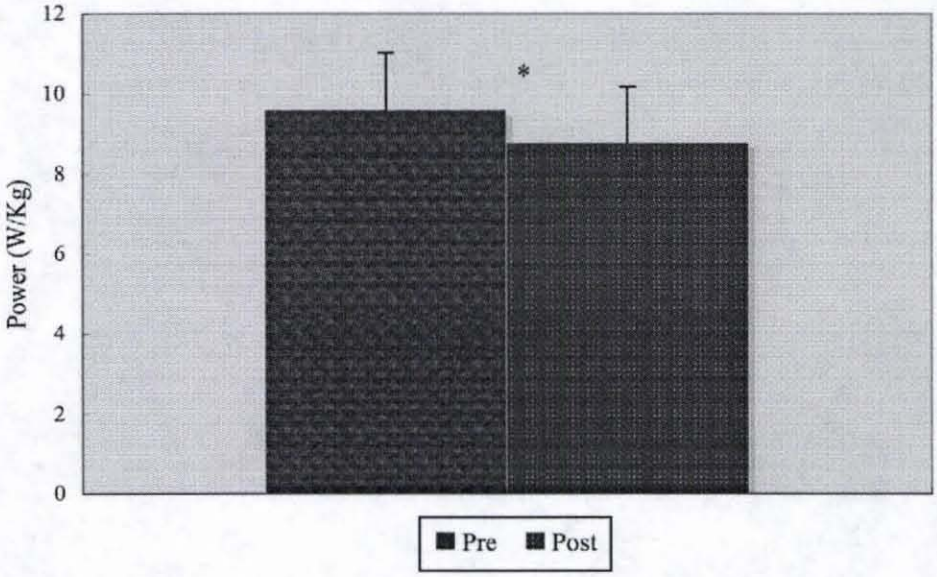

Figure 4 Wingate mean power in relative value pre- and post-CVAC exposure.

Part II

Review of Literature

Altitude Training Overview

Altitude training has been reported to enhance performance aerobically and anaerobically. Aerobic performance improvements have been attributed to increased oxygen carrying capacity and other physiological changes elicited by high altitude acclimatization. These changes include: accelerated renal release of erythropoietin (Eckardt, Boutellier, Kurtz, Schopen, Koller, and Bauer, 1989), increased red blood cell levels, increased hemoglobin concentrations (Jefferson, Simoni, Escudero, Hurtado, Swenson, Wesson, Schreiner, Johnson, and Hurtado, 2004), and improved muscle capillary proliferation (Mizuno, Bro-Rasmussen, Mygind, Schibye, Rasmussen, and Saltin, 1990). The increase in oxygen carrying capacity of working muscles, consequently contributes to improvements in the sea-level aerobic performance (Bailey and Davies, 1997). The clear mechanism of anaerobic performance enhancement has not been delineated, however, it may be related to increases in muscle buffering capacity

(Mizuno et al., 1990; Gore and Hahn, 2001, or glycolytic enzyme activity (Vogt, Puntschart, Geiser, Xuleger, Billeter, and Hoppeler, 2001).

Continuous Altitude Exposure to Anaerobic Performance

Balke, Nagle, and Daniels (1965) investigated the effect 10-days of training at moderate altitude (2,800 m) had on anaerobic work capacity at sea level (400 m) of five subjects. Experimental data were collected at the following four intervals: 1) at sea level; 2) three to four days after the ascent to 2,800 m; 3) after 10 days at altitude; and 4) three to five days after the descent to sea level. Subjects continued their individual training programs as training was not controlled during the study. Anaerobic capacity was determined with an 'all-out' cycle ergometer test (approximately 1 to 2 minutes in duration) and a 400 m sprint. The results of the cycle tests indicated a trend toward improvement in post-altitude anaerobic capacity (From 1'39 to 1'48''). Performance in the 400 m sprint also improved (From 60.1 to 57.4 seconds). The data were not statistically analyzed, consequently the researchers were unable to interpret the results but

rather stated that "something happened" during the period of altitude acclimatization and training which resulted in the performance enhancement.

Mizuno et al. (1990) investigated the effect two weeks of training at altitude had on muscle buffering capacity of gastrocnemius and triceps brachii muscles, as well as $\dot{V}O_{2\,max}$, short-term running performance and maximal accumulated O_2 deficit on ten well-trained male cross-country skiers. The training program (roller skiing or cross-country skiing) consisted of living at 2,100 m and training at 2,700 m for two weeks after a five month period of controlled training at sea level. Treadmill running was performed to determine $\dot{V}O_{2\,max}$ and short-term running performance (range 240- 380 sec) during sea-level training p, and pre- and post-altitude training. Maximal accumulated oxygen deficit (MAOD) was used as the indicator of anaerobic capacity and was calculated from the difference between the predicted $\dot{V}O_2$ and the measured $\dot{V}O_2$ during incremental treadmill exercise test as determined by Medbø (1988). Biochemical analysis included the determination of enzymatic activity and muscle buffering capacity. Results indicated a significant increase in short-term running performance (17%) on

return to sea level ($P<0.05$) and no change in $\dot{V}O_{2\,max}$. Their findings also revealed significant increases in: MAOD (29%) and muscle buffering capacity (6%) in both gastrocnemius and triceps brachii ($P<0.05$) muscles. A significantly positive correlation was observed between change in buffering capacity and in the short-term running time ($P<0.05$). The investigators concluded that the study showed an improvement in short-term (anaerobic) running performance that might be due to the increase in muscle buffering capacity on return to sea level from altitude.

Martino, Myers, and Bishop (1995) investigated the effects 21 days of anaerobic training at 2,800m had on sea-level performance. Thirty-three swimmers were assigned to either an experimental group (live and train at 2,800m); or a control group (live and train at sea-level). The following were collected for analyses: 100 m sprint swim time; lactate recovery slope; and peak power, mean power and fatigue index of upper body Wingate anaerobic test (WAnT). Results indicated significant improvements in 100 m swim time and upper body WAnT peak power ($P<0.05$).

Lactate recovery slope was not significance. Analyses of other variables indicated trends towards improvement although none were significant.

In summary, the above research indicated that living and training at high altitude (2,100 m to 2800 m) for 10 to 21 days facilitated the following increases: one to two minute all-out tests, 400 m sprint performance (Balke et al., 1965), 240- to 380-second short-term running performance, muscle buffering capacity, MAOD (Mizuno et al., 1990), 100 m swimming sprint time and upper body WAnT performance (Martino et al., 1995). These researchers did not clearly identify the clear mechanism for anaerobic performance enhancement. Mizuno et al. (1990) speculated that it might be due to improved muscle buffering capacity upon return to sea level.

Intermittent Hypoxic Exposure during Exercise on Anaerobic Performance

Meeuwsen, Ingrid, Hendriksen, and Holewijn (2001) investigated the effect of intermittent hypoxic exposure (IHE) during exercise on anaerobic performance at sea level. Sixteen nationally and internationally competitive triathletes were divided into two fitness-matched groups: eight were assigned to the hypoxia group, and the 8 were

assigned to the sea-level group. The hypoxia group trained for 10 days in a hypobaric chamber at an altitude of 2,500 m. their training program consisted of cycling for 75 to 105 minutes per day at 60-70% heart rate reserve. The hypoxia group were tested with the WAnT at sea level one week before and two and nine days after training in the hypobaric chamber. After one year the authors conducted a cross-over study). Student's *t*-test and one-sample *t*-test on the WAnT data of the hypobaric and control groups indicated that anaerobic mean power and peak power values nine days after training termination significantly increased by 4.1 % ($P<0.01$) and 3.8 % ($P<0.01$), respectively. The control group results were not statistically significant. The author concluded that altitude exposure during low-intensity exercise significant effects on the anaerobic system.

Truijens, Toussaints, Dow, and Levine (2003) conducted a study to investigate the effectiveness of IHE during exercise on 100 and 400 m freestyle swimming performance. Sixteen competitive swimmers were assigned to either the control group (living and training in normoxia) or the experimental group (living in normoxia, training

in hypoxia; simulated altitude of 2,500m). The experimental group underwent five weeks of high-intensity training in a water flume under hypoxic, and supplemental low- and moderate-intensity conditions. Training in normoxic conditions included three sets of high-intensity, short-term exercises (30 seconds-1 minutes) weekly. Anaerobic capacity was indirectly estimated via MAOD. Experimental tests were conducted at pre- and post training intervals. A two-way ANOVA with repeated measure revealed significant improvements in both groups in the 100 m (hypoxic group: -11%, control group: -1.2%, P=0.02), and 400 m freestyle (hypoxic group: -1.7%, control group: -1.2%, P<0.001). No significant difference in performance outcomes was observed between the hypoxic and control groups. Results of the MAOD test were not significant. The authors concluded that five weeks of high-intensity training using a water flume significantly improved 100 m and 400 m swimming performances at sea level, however, no additive effect of hypoxic exposure during the training sessions were revealed in well-trained swimmers.

Morton and Cable (2005) investigated the effects of short-term Intermittent Hypoxic Training during exercise on anaerobic performance measured via a WAnT. A total of sixteen moderately trained males were divided into a hypoxic training group (HT) and a normoxic training group (SLT). The HT group performed 30 minutes of moderate- to high-intensity cycling exercise three times per week for four weeks under hypoxic conditions in a hypobaric chamber (altitude = 2,750 m), while the SLT group completed the same training protocol at sea level. Pre and post test WAnT data analyzed with a two-way repeated measures ANOVA revealed significant improvements ($P<0.01$) in peak power (2.9 vs. 9.3%) and mean power (8.0 vs. 6.5%) in both the hypoxic and normoxic training groups. No group differences were indicated between the two training interventions. The investigators concluded that short-term (30 minutes) moderate- to high-intensity training under hypoxic condition did not elicit advantages on anaerobic performance, possible due to the short exposure times (6 hours).

In summary, above research results indicated significant improvements in WAnT peak and mean power variables of the Hypoxic group after 10 days of moderate

intensity exercise at a simulated altitude of 2,500 m (Meeuwsen et al. 2001). Conversely, no group differences in anaerobic performance variables were revealed, although performance improved in both groups, indicating that changes were most likely due to the effect of the moderate- to high-intensity training (Truijens et al., 2003 and Morton et al. 2005).

Intermittent Hypoxic Exposure at Rest on Anaerobic Performance

Levine and Stray-Gundersen (1997) investigated the effects acclimatization to moderate altitude (2,500 m) in conjunction with training at low altitude (1,250 m) had on aerobic and anaerobic capacity of 13 well-trained runners. Experimental design consisted of four weeks of altitude training camp after six weeks of a standardized sea-level training period. During the four-week training camp, the subjects were randomly assigned to three groups: "high-low" (living at 2,500m and training at 1,200-1,400m); "high-high" (living and training at 2,500m); and "low-low" control (living and training at sea level). Anaerobic capacity was indirectly determined with the MAOD. High-intensity short duration running times (3 minutes) calculations were

based on the total treadmill time. Results revealed no significant changes in MAOD in any of the training methods. Significantly improved short term running performance was observed in high-high group ($P<0.05$) only. Although aerobic variables showed significant improvements, no significant effect on anaerobic capacity was observed in passive acclimatization with sea-level training. The "traditional altitude training (high-high)" group results revealed improvements in short duration run times, which speculated to be due to improvement in muscle buffering capacity..

Nummela and Rusko (2000) investigated the effects of IHE at rest (live high-train-low) on 400 m sprint performance at sea level. Eighteen well-trained 400 m sprinters were divided into two groups: altitude and control groups. Eight runners in the altitude group spent 16.5 ± 1.5 hours daily in an altitude room, which was kept normobaric hypoxia equivalent to 2,200 m altitude for 10 consecutive days. Maximal anaerobic run test and 400 m run or hurdle run were conducted at sea level two to 10 days before and three to four days after altitude exposure to observe the maximal speed, the speeds at several lactate concentration points of 3, 5, 7, 10 and 13 $mmol \cdot l^{-1}$, and 400 m

race time. Concurrently, ten sprinters in the control group lived and trained at sea level and performed the identical performance tests. The results indicated that 400 m or 400 m hurdle times significantly improved pre- to post- altitude exposure in the altitude group ($P<0.01$). The altitude group also showed a significant increase in running speed and blood lactate concentrations of 5 and 7 $mmol \cdot l^{-1}$. Analysis of blood gases revealed significant increases in blood pH at rest among six athletes in the altitude group from 0.003 to 0.067 pH unit ($P<0.05$). The authors concluded that improvement in 400 m run performance after 10 days of passive discontinuous hypoxic exposure in conjunction with training at sea level may be attributed to the change in the acid-base balance and lactate metabolism.

Gore, Hahn, Aughey, Maritin, Ashenden, Clark, Garnham, Roberts, Slater, and McKenna (2001) investigated effects of 23 consecutive nights of "live-high train low" exposure to muscle buffering capacity (β m) and mechanical efficiency during submaximal exercise in male athletes. Thirteen male athletes were divided into fitness-matched groups control (CON), and LHTL treatment groups, according to the

power output achieved during the last two minutes of an incremental cycle ergometer test. The LHTL group spent 9.5 hours per night for 23 consecutive days in a normobaric hypoxic room equivalent to 3000 m altitude, while the CON group remained at sea level (600 m). The series of tests were conducted pre (PRE), middle (MID) and post (POST) exposures. The submaximal test was consisted of four incremental sets in which each set lasted four minutes to assess $\dot{V}O_2$. After a four minute rest period, a four minute maximal effort test was conducted. Workload was set at 5.6 ± 0.4 $W \cdot kg^{-1}$ for the first two minutes of the test, followed by a two minute 'all-out' bout to measure total work, $\dot{V}O_2$ and $\dot{V}O_{2\,peak}$. Two vastus lateralis muscle biopsies were taken before and after the LHTL protocol at rest, and after a standardized two minute cycle test, and analyzed for metabolites and buffering capacity. A significantly lower submaximal $\dot{V}O_2$ at MID and POST were observed, thus efficiency of the LHTL group was calculated to have significantly improved 0.8% from the pre-test ($P<0.01$). Results also indicated that resting muscle buffering capacity significantly increased in the LHTL group (17.7 ± 4.9%) after the exposure, but no change was observed in the CON group. Investigators

concluded that LHTL hypoxic exposure for 23 nights significantly increased muscle buffering capacity with absence of muscle H+ level during intense exercise, as well as improved cycling efficiency.

Roberts, Clark, Townsend, Anderson, Gore and Hahn (2003) conducted a study to determine the effect five, ten, and fifteen days of intermittent hypoxic exposure at rest had on exercise performance and anaerobic energy system capacity of 19 well-trained cyclists. Subjects were divided into three exposure groups (5, 10, and 15 days). Each group was tested on two occasions; in a control condition (lived and trained in normobaric normoxia), and in an intermittent hypoxic condition. Under hypoxic conditions, athletes spent eight to ten hours per night in normobaric hypoxia, which was equivalent to 2,650 m altitude. An incremental cycle ergometer test was performed 72 hours before and 36 hours after completion of the hypoxic exposure treatment. The incremental test comprised a consecutive thee set six minute submaximal effort bout; four minutes of active and passive rest; and a four minute all-out bout. Maximal mean power output for four minutes ($MMPO_{4min}$), $\dot{V}O_{2\,max}$ and MAOD were determined. Since

ANOVA did not reveal significant differences for all dependent variables between groups, data were pooled for further analyses. The results indicated significant improvements in the hypoxic group in $MMPO_{4min}$ (+3.7%), MAOD (+9.6%) between pre- and post altitude exposure treatments ($P>0.05$). No significant differences in $MMPO_{4min}$ and MAOD were revealed for the control subjects. Group differences were not detected in $\dot{V}O_{2\,max}$ values. Authors concluded that well-trained athletes could prepare for the short-term competitions (approximately four minutes) with short periods of passive hypoxic exposure training at sea level, as the hypoxic conditioning may have stimulated additional improvements in anaerobic capacity.

Beidleman, Muza, Fulco, Cymerman, Ditzler, Stulz, Staab, Robinson, Skirinar, Lewis, and Sawka (2003) investigated the effect three weeks of intermittent hypoxic exposure (IHE) combination rest and exercise had on adductor pollicis longus endurance of six subjects. Hypoxic treatment consisted of four hours per day, five days per week for three weeks at a simulated altitude of 4,300 m. Subjects were randomly assigned to the training program composed of 45 to 60 minutes of continuous and interval training on

a cycle ergometer during hypobaric hypoxic altitude exposure conditioning or to a control group that rested during IHE treatment. All volunteers were required to maintain their physical fitness with aerobic training one to two hours per week at sea level. Adductor pollicis endurance tests consisted of intermittent five second static muscle contractions at 50 percent of individual pre-exercise, altitude-specific maximal voluntary contraction (MVC) followed by five seconds of rest until exhaustion. Maximal voluntary contraction was performed every sixth contraction for five seconds. Failure to reach the target force would indicate the cessation of the test. Tests were performed at the following four intervals; 1) at sea level (SL), 2) after a 30-hour acute exposure to the altitude, 3) pre, and 4) post a three week period of IHE. A two way ANOVA revealed no significant group differences in cycle training during IHE, thus the data were pooled. Result revealed a significant improvement in adductor pollicis endurance (63 ± 26%) in four of five individuals. A significant increase (10 ± 4%) in resting arterial oxygen saturation from pre- to post-IHE was also observed. A strong correlation between muscular performance ncreases and arterial oxygen saturation was

revealed following three weeks of IHE. The authors concluded that IHE improved muscular performance at 4,300 m altitude therefore IHE may be used as an alternative to chronic altitude residence.

In summary, results of previous studies indicated that passive (rest) IHE methodology improved anaerobic performances, such as 400 m sprint run (Nummela and Rusko, 2000), 4-minute all-out cycle ergometer test (Roberts et al., 2003) or adductor pollicus longus muscular performance (Beidleman et al., 2003). Performance enhancement was attributed to improved muscle buffering capacity after the "live-high, train-low" protocol (Gore et al., 2001) or improved MAOD (Roberts et al., 2003). Exposure times of approximately eight to 16.5 hours daily were needed to elicit significant performance improvements (Nummela and Rusko, 2000; Gore et al., 2001; Roberts et al., 2003; Beidleman et al., 2003). In the study of Levine and Stray-Gundersen (1997), anaerobic performance was not examined, however, the MAOD was calculated as an indicator of anaerobic capacity, however no differences were revealed.

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Appendices

Appendix A

Pre-Participation Physical Exam Form

Pre-participation Physical Evaluation
University of Hawai`i at Mānoa - Department of Kinesiology
Hypobaric Hypoxic Conditioning via the CVAC Systems Portable Chamber

History Date_____

Name_____ Sex_____ Age_____ DOB_____

Activity: (Please circle one): Run Cycle Triathlon

	Explain "Yes" answers below:	Yes	No
1.	Have you ever been hospitalized?	☐	☐
	Have you ever had surgery?	☐	☐
2.	Are you presently taking any medications or pills?	☐	☐
3.	Do you have any allergies (medicine, bees or stinging insects)?	☐	☐
4.	Have you ever passed out during or after exercise?	☐	☐
	Have you ever been dizzy during or after exercise?	☐	☐
	Have you ever had chest pain during or after exercise?	☐	☐
	Do you tire more quickly than your friends during exercise?	☐	☐
	Have you ever had high blood pressure?	☐	☐
	Have you ever been told that you have a heart murmur?	☐	☐
	Have you ever had racing of your heart or skipped heartbeats?	☐	☐
	Has anyone in your family died of heart problems or a sudden death before age 50?	☐	☐
5.	Do you have any skin problems (itching, rashes, acne)?	☐	☐
6.	Have you ever had a head injury or concussion? If yes, how many times?_____	☐	☐
	Have you ever been knocked out, become unconscious or lost your memory? If yes, how many times?_____	☐	☐
	Have you ever had a seizure?	☐	☐
	Have you ever had a stinger, burner, or pinched nerve?	☐	☐
7.	Have you ever had heat or muscle cramps?	☐	☐
	Have you ever been dizzy or passed out in the heat?	☐	☐
8.	Do you have trouble breathing or do you cough during or after activity?	☐	☐
9.	Do you use any special equipment (pads, braces, neck rolls, mouth guards, eye guards, etc.)?	☐	☐
10.	Have you ever, or are you presently diagnosed with anemia.	☐	☐
	Do you wear glasses or contacts or protective	☐	☐
11.	Have you ever sprained, dislocated, broken or had repeated swelling or other injuries of any bones or joints?	☐	☐
	☐Head ☐ Neck ☐Shoulder ☐Elbow ☐Forearm ☐ Wrist ☐ Hand ☐ Chest		
	☐ Back ☐ Hip ☐Thigh ☐Knee ☐ Shin/calf ☐ Ankle ☐ Foot		
12.	Do you suffer from chronic muscle strains (pulls).	☐	☐
13.	Have you had any other medical problems (mononucleosis, diabetes, kidneys, etc.)?	☐	☐
14.	Have you had a medical problem since your last evaluation?	☐	☐
15.	When was your last tetanus shot?_____ When was your last measles immunization?_____		
16.	Females: When was your first menstrual period?_____ When was your last menstrual period?_____ What was the longest time between your periods in the past year?_____		
17.	Have you ever been exposed to hypobaric conditions before?	☐	☐
	Have you ever experienced altitude sickness?	☐	☐
18.	Do you SCUBA dive on a regular basis?	☐	☐
19.	When was the last time you SCUBA dove? _____days ago_____weeks ago		
20.	Have you ever been treated for the bends (decompression sickness)?	☐	☐
21.	Have you ever been treated for pressure injury to the ears of sinuses related to SCUBA diving? (barotraumas, reverse blocks, sinus squeezes)	☐	☐
22.	Have you ever experienced problems clearing your ears during SCUBA diving or airplane travel?	☐	☐
23.	Do you have a history of ear problems, swimmers ear, punctured ear drums, sinus infection, etc.?	☐	☐

Explain "Yes" answers:_____

I hereby state that, to the best of my knowledge, my answers to the above questions are correct.

Signature of participant_____ Date_____

6/18/2008

Appendix B
Informed Consent

INFORMED CONSENT

To participate in a research study

I. INVESTIGATORS:

Principal Investigators:

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II. Title

Hypobaric Hypoxic Conditioning via the CVAC Systems Portable Chamber

III. Introduction

Because you are in good physical condition, 18 years of age or older, and participate regularly in aerobic activities you are being asked to participate in this research study. The purpose of this study is to investigate the effects of artificial altitude exposure on athletic performance delivered via a chamber that simulates the low oxygen and air pressure found at altitude. Your participation will help determine the amount of exposure needed to change the oxygen carrying ability of your blood. The reason for giving you the following information is to help you decide if you would like to take part in this study.

This consent form may contain words that are unfamiliar to you. Please discuss any questions you have about the wording or this study with the research staff members.

Your participation in this research is voluntary, and you will not be paid. Be assured that all information collected on you will be kept confidential. You and the researchers will be the only ones to know your individual test results.

IV. Description of Procedures

Prior to participation you will be asked to complete a health history questionnaire to determine if it is safe for you to be a subject in this study. The questionnaire will be reviewed by a medical doctor for your clearance to participate. You should not volunteer if your doctor recommends non-participation, or if you have one or more of the following conditions: recent (within two weeks) scuba diving activity, claustrophobia (fear of close spaces), barotraumas (injury to the middle ear or sinuses caused by a pressure imbalance) , cardiorespiratory or cardiovascular disease, hypertension (high blood pressure), anemia (iron deficiency), hemochromatosis (a genetic disease characterized by an increased absorption of iron in the liver, pancreas, and skin, this is also known as bronze diabetes), chronic medication for asthma, pregnancy, previous diagnosis of malignancy (cancer), recent surgical procedures, known kidney or liver disease.

Prior to fitness testing you will be asked to give a small blood sample (about one teaspoon or 5 mls) as outlined on pages 4 and 5 to determine your iron status. Iron pills will be provided and you will be asked to begin taking them two weeks before starting the altitude chamber exposure sessions and throughout the study. This should help to protect you from developing low iron levels in your blood (anemia). The US DRI (Daily Recommended Intake as instituted by the National Academy of Sciences) is 8-27 mg/day for women who menstruate (unless you are on depo-provera), 12-24 mg/day in women who do not menstruate and 8-11 mg/day in men. The recommendation is increased to 150-200 mg/day (elemental iron) when you are iron deficient (anemia). If your blood test results indicate that you are anemic you will be treated for anemia

prior to your participation in the study. The pills you will be taking will provide 65mg or iron per day; this will be a sufficient amount to protect you from altitude related anemia.

Participation in this study requires a large time commitment from you. We appreciate your willingness to participate and will do our best to schedule altitude chamber sessions and performance test sessions during times that are convenient for you. Scheduling problems may arise, we would appreciate your flexibility and cooperation in this regard. You will be assigned to one of five groups scheduled to spend a prescribed amount of time in the altitude chamber every week (3 to 5 days per week from 40 to 100 minutes per session), over a period of eight consecutive weeks (see chart below). Based on your blood test results, you may be asked to participate in an additional three-week maintenance program otherwise you will be excused from the study after completing your fitness tests. Some people will not show changes because of their genetic make-up, others may not show changes due to the experimental procedure. Everyone will be given altitude treatment during the altitude chamber sessions; you will not be assigned to a placebo/sham group.

Altitude chamber exposure

schedule (minutes/day)

GROUPS	M	TUES	WED	THUR	FRIDAY	TOTAL MIN/WEEK
5A	100		100		100	300 = 5 hour
2	40		40		40	120 = 2 hours
3	60		60		60	180 = 3 hours
4	80		80		80	240 = 4 hours
5	60	60	60	60	60	300 = 5 hours

If you are unable to attend a scheduled altitude chamber session, please call 956-3801 and inform the research team contact person. We will do our best to reschedule a make-up session. Missing two scheduled sessions may result in you being dropped from the study.

We ask that you try to maintain your conditioning routine throughout the length of the study. You will be required to maintain a workout diary during the entire study, a form will be provided for you every week (please see the attached form). You will be asked to write down the type of exercise (run, cycle, swim, etc), length of time of the workout (minutes), mileage or distance (if applicable), and the intensity of the workout, and if available, your maximum HR response to that session. You will also be asked to confirm that you have taken your iron supplement on this form. You must return the completed form on the first scheduled day of altitude chamber sessions each week so that we can determine if changes in exercise performance occurred due to altitude chamber treatment rather than a change in your conditioning routine. Failure to comply may result in you being dropped from the study.

Depending on the group you are in, you will be scheduled to report to the Kinesiology Human Performance Laboratory for altitude chamber treatments three or five times per week. Parking may be a problem between 7:30 and 11:45 A.M. or on evenings when there is an event at the Stan Sheriff Center, so please plan accordingly. You may be required to pay for your own parking. You will be randomly assigned to a treatment group. The total time per session will depend on your treatment group (40, 60, 80 or 100 minutes of exposure). Prior to starting the altitude chamber sessions, you will have four electrodes and wires attached to your chest to monitor your heart rate responses to the altitude chamber session. The altitude chamber works by increasing and decreasing air pressure in a cyclic manner using a pump and valve system and a number of different protocols simulating altitude exposure. The first week will be spent allowing your ear drums to get used to small but rapid changes in pressure. After your ear drums have become accustomed to the changes in pressure you will be exposed to pressure changes, ranging from air pressures found at sea level to 21,000 ft. The altitude chamber has a safety switch, which allows you to stop the session anytime you desire. These chambers have been used without medical complications in over 10,000 hours of human exposure. You may bring school work, books, CD or MP3 players to pass the time while during your treatment sessions. Please do not use radios, cell phones, or lap tops computers as they may interfere with data collection.

Blood samples: Blood sample collection has been designed to provide you with minimal

discomfort and risk for infection. The routine blood sampling procedure of venipuncture is safe and every precaution will be taken to protect you from infection. The blood sample schedule was developed to learn more about how your blood chemistry responds to altitude chamber sessions over a period of time. Over the course of the study you will have blood samples taken from your arm and the back of your hand via insertion of a small needle (venipuncture) for multiple blood samples (saline lock), and finger sticks to collect lactate samples after the anaerobic power tests. All venipunctures will be performed by qualified personnel.

The following procedures will be used for collecting blood samples:

Venipuncture:

A tourniquet will be applied just above the elbow, the area will be cleansed with alcohol, a needle will be inserted into a vein in the forearm, and a collection tube will be inserted on the other end of the needle to collect a blood sample. Upon completion of the sampling direct pressure will be used to stop the bleeding and a dressing will be placed over the area to cover the wound.

Saline Lock:

The area will be cleansed with alcohol and betadine and an IV catheter will be inserted using a needle into the hand or forearm. Once the catheter is in place the needle will be removed and the catheter will be secured and a saline lock will be attached and flushed with approximately 2ml of saline solution. This will remain in place for approximately 3hours or until the conclusion of Performance Testing. Once all samples have been drawn the catheter will be removed, direct pressure will be applied to control any bleeding and a dressing will be placed over the wound.

Finger stick:

The area will be cleansed with alcohol, a finger lancet will be inserted into the tip of the fleshy part of the finger to allow a blood sample to be drawn into a 75mm capillary tube (less than a teaspoon) sampling is completed a dressing will be placed over the wound.

Depending on how you respond to altitude exposure you may experience only 10 blood draws over an 8-week period, or 13 blood draws over a 14 week period.

Blood samples using the venipuncture will be collected as follows:

1. Prior to your first scheduled altitude chamber session
2. During weeks 2, 4, and 6 of altitude chamber sessions
3. Two days after the final scheduled altitude chamber session;
4. Depending on your response, three weeks after the final altitude chamber session.
5. Depending on your response, the final blood sample will be collected prior to your last performance/fitness test 6weeks after your final altitude chamber sessions.

Thus, over the course of the study you may give approximately 100 ml of blood. This is a relative small amount, and equals less than 1/4 of the blood given when donating blood (1 pint = 473 mls). The blood sampling procedure is routine and safe. However, with all the blood collecting procedures there is a risk of bleeding, hematoma, bruising, pain or discomfort, light-headedness, fainting, or infection. The risk of infection is small, and every precaution will be taken to protect you from infection (e.g. only new, clean, sterile needles will be used and the area will be cleaned with alcohol and betadine prior to inserting the needle).

Blood draw Schedule

(needle sticks per week)				ALTITUDE EXPOSURE				POST TEST				
Week	pre	1	2	3	4	5	6	7	8	1	2	3
Venipuncture (arm)	1		2		2		2			1		1
Finger stick (hand)	2									2		2
Saline lock (hand)	1									1		1

Your weight and hydration level will be determined on bi-weekly basis, via a scale and bioelectrical impedance just prior to blood sample collection. Bioelectrical impedance is a non-invasive, safe, and painless procedure used for determination of the percentage of intercellular water your body contains. Four electrodes will be applied to your limbs, two on your right hand and two on your right foot. A small insensible current will be passed through your body. Calculation of total body water is based on the resistance to electrical current flow. This entire procedure takes no longer than 3 minutes.

You will be required to participate in three fitness-testing sessions over a 2-3day period. Runners will perform running tests, cyclist will perform cycling tests, and triathletes will perform either running tests or cycling tests.

Running Tests	Cycling Tests
Treadmill Running	Stationary Cycling
200M sprint/dash	30second Stationary Cycling
Knee Strength Test	Knee Strength Test

Heart Rate Variability(HRV): Heart Rate Variability data will be collected at rest, prior to and after IHE training sessions using the same chest electrodes as mentioned earlier. Data will be collected for twenty minutes of supine rest, using a predetermined breathing rate of 12-breaths per minute, and then for five minutes more after a head up tilt position. Data will be collected prior to starting the altitude chamber sessions and bi-weekly thereafter on a BIOPAC MP30.

Spirometry and Nerve Activity (EMG): Determination of your lung volumes during inhalation and exhalation will be measured using a spirometer, a special machine that records the volume of air you are able to inhale and exhale. The activity of the nerve (phrenic nerve) which controls your diaphragm, the main muscle involved with inhalation, will also be monitored at this time. Two electrodes will be placed on your upper right chest, just below your collar-bone and close to

the sternum (middle of your chest), a third will be placed on your right shoulder. The electrodes will be connected to wires and will measure the electrical activity produced by the phrenic nerve. You will not feel anything as this is similar to the procedure used to monitor your heart rate mentioned before. These measurements will be collected every two weeks during IHE training sessions and resting conditions.

V. Risks

There are slight risks associated with taking iron supplements, although rare they include: upset stomach, constipation, decreased effectiveness of antibiotics (this is reduced by taking the antibiotics two hours prior to taking the iron supplement). If you are, or become pregnant or diagnosed with hematochromotosis you should not take iron supplements or be involved in this study. Your iron status will be determined prior to the beginning of the study with a blood test to assure your safety. During CVAC Exposure you may experience ear and sinus discomfort and possible claustrophobia, please let us know if at any time you experience any of these symptoms during exposure and we will make the necessary adjustments.

There may be temporary pain or discomfort felt at the site of the blood draw needle entry. Excessive bleeding or infection of the venipuncture site, although rare, may also occur, and bruising at the site is a common side effect.

During the application of the chest electrodes you may feel uncomfortable, if you desire electrode placement will be provided by a technician of your gender. Additionally, you may feel some minor discomfort with placement of the electrodes on your skin.

During the fitness testing you may feel: fatigue, nausea, stomach upset, muscle pain or soreness, shortness of breath. Because you are in good physical condition and exercise regularly the risk of a myocardial infarction (heart attack) or other cardiac event is unlikely.

In the event of any physical injury from the research procedure, only immediate and essential

medical treatment is available. FirstAid/CPR and a referral to a medical emergency room will be provided. The investigators are First Aid/CPR certified and trained to use the portable automated external defibrillator (AED) on site. Supplemental oxygen will also be available. You should understand that if you are injured in the course of this research procedure that you alone may be responsible for the costs of treating your injuries.

VI. Benefits

You may not directly benefit from this study although you will gain the experience of being part of a scientific experiment and obtain information concerning your aerobic and anaerobic fitness levels. Knowledge gained from this study may benefit individuals who must travel to altitude for athletic competition, to perform their jobs, or military applications.

VI. Confidentiality

Your research records will be kept confidential to the extent permitted by law. You will not be personally identified in any publication about this study. However, the University of Hawaii at Manoa Committee on Human Studies may review your records.

A code, which will be known only to study personnel and you, will be used instead of your name on laboratory records of this study. The code will be stored in a safe place. Personal information about your test results will not be given to anyone without your written permission.

VII. Certification

I certify that I have read and that I understand the foregoing, that I have been given satisfactory answers to my inquiries concerning the project procedures and other matters and that I have been advised that I am free to withdraw my consent and to discontinue participation in the project or activity at any time without prejudice.

I here within give my consent to participate in this project with the understanding that such consent does not waive any of my legal rights, nor does it release the Principal Investigator or

institution or any employee or agent thereof from liability for negligence.

If you have any questions related to this research, you can call Ron Hetzler at 956-3802 or Iris F. Kimura at 956-3797 at any time.

_____ _____

Signature of individual participant Date

(If you cannot obtain satisfactory answers to your questions or have complaints about your treatment in this study, contact:
Committee on Human Subjects, University of Hawaii, 2540 Maile Way, Honolulu,
Hawaii 96822. Phone (808) 956-5007.

Appendix C

Daily Training Log

Instructions for Completing Training Log Sheet

1. Please enter your subject number and group number
2. Please enter the dates for the days of the week you are recording
3. Check the line under the heading, Supplement Taken, when you have taken your iron supplement.
4. Please enter the following information for the activity you perform on the corresponding day:

Intensity:

		Examples	
Classification*	%Heart Rate*	Running	Cycling
1 = very light	<35	>12min/mi	<10mph
2 = Light	35-59	10.5-12min/mi	10.5-14.5mph
3 = Moderate	60-79	8-10min/mi	15-16mph
4 = Heavy	80-89	6-8.5min/mi	16.5-19.5mph
5 = Very heavy	>90	<6min/mi	>20mph

Duration: This is the amount of time you spent performing your workout or activity

Heart Rate: This is the maximum heart rate you achieved during your workout or activity level. This is best determined using a heart rate monitor, but can also be calculated manually at the carotid or radial pulse.

5. There are blank spaces where you can record other exercise activities you may perform as part of your normal workout routine, please feel free to use them and make note on the back of the page should you feel explanation is needed. You may also use the back to provide more detail on the other exercises listed.
6. This sheet needs to be handed in the first session of each week. Please make sure to be truthful and diligent in recording your workouts.

Subject Number:_____ Group:_____

Week 1	SUN __/__	MON __/__	TUES __/__	WED __/__	THUR __/__	FRI __/__	SAT __/__
Activity	Supplement Taken ____	Supplement Taken ____	Supplement Taken ____	Supplement Taken ____	Supplement Taken ____	Supplement Taken ____	Supplement Taken ____
Run							
Intensity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Distance	____	____	____	____	____	____	____
Duration	____	____	____	____	____	____	____
Heart Rate	____	____	____	____	____	____	____
Swim							
Intensity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Distance	____	____	____	____	____	____	____
Duration	____	____	____	____	____	____	____
Heart Rate	____	____	____	____	____	____	____
C .e							
Intensity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Distance	____	____	____	____	____	____	____
Duration	____	____	____	____	____	____	____
Heart Rate	____	____	____	____	____	____	____
Weights							
Intensity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Duration	____	____	____	____	____	____	____
Area of Body	____	____	____	____	____	____	____
Aerobics							
Intensity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Duration	____	____	____	____	____	____	____
Heart Rate	____	____	____	____	____	____	____
Intensity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Duration	____	____	____	____	____	____	____
Heart Rate	____	____	____	____	____	____	____
Intensity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Duration	____	____	____	____	____	____	____
Heart Rate	____	____	____	____	____	____	____

Appendix D

Student's t-test Summary Tables for Differences in Isokinetic Knee Test Variables Between Limbs

Appendix D-1 t-test for Bilateral Isokinetic Knee Peak Torque Extension

PTE Pre	R	L
Mean	121.2615385	119.8615385
Variance	1193.624231	973.2775641
Observations	13	13
df	24	
t Stat	0.10843765	
P(T<=t) one-tail	0.457275023	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.914550047	
t Critical two-tail	2.063898547	

PTE Post	R	L
Mean	120.9607692	119.5615385
Variance	1066.599341	1029.404231
Observations	13	13
df	24	
t Stat	0.110195793	
P(T<=t) one-tail	0.456585198	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.913170396	
t Critical two-tail	2.063898547	

Appendix D-2 t-test for Bilateral Isokinetic Knee Average Peak Torque Extension

AvPTE Pre	R	L
Mean	105.0153846	103.6
Variance	681.5897436	662.2466667
Observations	13	13
df	24	
t Stat	0.139210805	
P(T<=t) one-tail	0.445222584	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.890445168	
t Critical two-tail	2.063898547	

AvPTE Post	R	L
Mean	102.9692308	101.5538462
Variance	698.0939744	613.179359
Observations	13	13
df	24	
t Stat	0.140928728	
P(T<=t) one-tail	0.444551225	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.889102449	
t Critical two-tail	2.063898547	

Appendix D Continued.

Appendix D-3 t-test for Bilateral Isokinetic Knee Peak Torque per Body Weight Extension

PTBWE Pre	R	L
Mean	176.0191647	174.0707204
Variance	1420.642651	944.3431138
Observations	13	13
df	23	
t Stat	0.144459266	
P(T<=t) one-tail	0.443198096	
t Critical one-tail	1.713871517	
P(T<=t) two-tail	0.886396193	
t Critical two-tail	2.068657599	

PTBWE Post	R	L
Mean	176.0726947	173.6125662
Variance	1542.028666	1318.885807
Observations	13	13
df	24	
t Stat	0.165835318	
P(T<=t) one-tail	0.43483782	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.869675639	
t Critical two-tail	2.063898547	

Appendix D-4 t-test for Bilateral Isokinetic Work Fatigue Extension

WFE Pre	R	L
Mean	20.4	20.62307692
Variance	62.57333333	138.4569231
Observations	13	13
df	21	
t Stat	-0.056727757	
P(T<=t) one-tail	0.477649178	
t Critical one-tail	1.720742871	
P(T<=t) two-tail	0.955298356	
t Critical two-tail	2.079613837	

WFE Post	R	L
Mean	26.76153846	25.30769231
Variance	89.2675641	67.43910256
Observations	13	13
df	24	
t Stat	0.418741873	
P(T<=t) one-tail	0.339564273	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.679128545	
t Critical two-tail	2.063898547	

Appendix D-5 t-test for Bilateral Isokinetic Knee Peak Torque Flexion

PTF Pre	R	L
Mean	63.92307692	61.28461538
Variance	339.3285897	274.7980769
Observations	13	13
df	24	
t Stat	0.383878214	
P(T<=t) one-tail	0.352224304	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.704448609	
t Critical two-tail	2.063898547	

PTF Post	R	L
Mean	63.40769231	61.76153846
Variance	255.7724359	151.0892308
Observations	13	13
df	23	
t Stat	0.294251517	
P(T<=t) one-tail	0.385602496	
t Critical one-tail	1.713871517	
P(T<=t) two-tail	0.771204991	
t Critical two-tail	2.068657599	

Appendix D-6 t-test for Bilateral Isokinetic Knee Average Peak Torque Flexion

AvPTF Pre	R	L
Mean	59.49230769	57.55384615
Variance	666.6541026	629.4660256
Observations	13	13
df	24	
t Stat	0.194136072	
P(T<=t) one-tail	0.423851599	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.847703197	
t Critical two-tail	2.063898547	

AvPTF Post	R	L
Mean	56.81538462	54.72307692
Variance	866.3397436	606.1035897
Observations	13	13
df	23	
t Stat	0.196597474	
P(T<=t) one-tail	0.42293469	
t Critical one-tail	1.713871517	
P(T<=t) two-tail	0.845869379	
t Critical two-tail	2.068657599	

Appendix D-7 t-test for Bilateral Isokinetic Knee Peak Torque per Body Weight Flexion

PTBWF Pre	R	L
Mean	92.82846154	89.74923077
Variance	249.3421974	342.086841
Observations	13	13
df	23	
t Stat	0.456522926	
P(T<=t) one-tail	0.32614799	
t Critical one-tail	1.713871517	
P(T<=t) two-tail	0.652295981	
t Critical two-tail	2.068657599	

PTBW Post	R	L
Mean	91.86065694	90.43170132
Variance	163.8476397	243.4704809
Observations	13	13
df	23	
t Stat	0.255283974	
P(T<=t) one-tail	0.400386396	
t Critical one-tail	1.713871517	
P(T<=t) two-tail	0.800772793	
t Critical two-tail	2.068657599	

Appendix D-7 t-test for Bilateral Isokinetic Knee Work Fatigue Flexion

WFF Pre	R	L
Mean	26.26923077	27.92307692
Variance	193.7723077	222.8552564
Observations	13	13
df	24	
t Stat	-0.292141183	
P(T<=t) one-tail	0.386344609	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.772689217	
t Critical two-tail	2.063898547	

WFF Post	R	L
Mean	36.93076923	35.28461538
Variance	144.710641	131.1997436
Observations	13	13
df	24	
t Stat	0.357320616	
P(T<=t) one-tail	0.361987391	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.723974781	
t Critical two-tail	2.063898547	

Appendix E

ANOVA Summary Table for Daily Training Intensity Over Seven-Week CVAC Exposure Period

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
WEEK	Sphericity Assumed	1.365	6	.227	1.419	.285
	Greenhouse-Geisser	1.365	1.904	.717	1.419	.344
	Huynh-Feldt	1.365	6.000	.227	1.419	.285
	Lower-bound	1.365	1.000	1.365	1.419	.356
Error (WEEK)	Sphericity Assumed	1.924	12	.160		
	Greenhouse-Geisser	1.924	3.808	.505		
	Huynh-Feldt	1.924	12.000	.160		
	Lower-bound	1.924	2.000	.962		

Appendix F
ANOVA Summary Tables for WAnT Variables

Appendix F-1 ANOVA Table for WAnT Absolute Peak Power

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	591.385	1	591.385	.151	.704
	Greenhouse-Geisser	591.385	1.000	591.385	.151	.704
	Huynh-Feldt	591.385	1.000	591.385	.151	.704
	Lower-bound	591.385	1.000	591.385	.151	.704
Error(TIME)	Sphericity Assumed	46946.615	12	3912.218		
	Greenhouse-Geisser	46946.615	12.000	3912.218		
	Huynh-Feldt	46946.615	12.000	3912.218		
	Lower-bound	46946.615	12.000	3912.218		

Appendix F-2 ANOVA Table for WAnT Relative Peak Power

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.529	1	.529	.692	.422
	Greenhouse-Geisser	.529	1.000	.529	.692	.422
	Huynh-Feldt	.529	1.000	.529	.692	.422
	Lower-bound	.529	1.000	.529	.692	.422
Error(TIME)	Sphericity Assumed	9.171	12	.764		
	Greenhouse-Geisser	9.171	12.000	.764		
	Huynh-Feldt	9.171	12.000	.764		
	Lower-bound	9.171	12.000	.764		

Appendix F-3 ANOVA Table for WAnT Absolute Mean Power

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	17265.385	1	17265.385	15.737	.002
	Greenhouse-Geisser	17265.385	1.000	17265.385	15.737	.002
	Huynh-Feldt	17265.385	1.000	17265.385	15.737	.002
	Lower-bound	17265.385	1.000	17265.385	15.737	.002
Error(TIME)	Sphericity Assumed	13165.615	12	1097.135		
	Greenhouse-Geisser	13165.615	12.000	1097.135		
	Huynh-Feldt	13165.615	12.000	1097.135		
	Lower-bound	13165.615	12.000	1097.135		

Appendix F-4 ANOVA Table for WAnT Relative Peak Power

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	4.356	1	4.356	23.398	.000
	Greenhouse-Geisser	4.356	1.000	4.356	23.398	.000
	Huynh-Feldt	4.356	1.000	4.356	23.398	.000
	Lower-bound	4.356	1.000	4.356	23.398	.000
Error(TIME)	Sphericity Assumed	2.234	12	.186		
	Greenhouse-Geisser	2.234	12.000	.186		
	Huynh-Feldt	2.234	12.000	.186		
	Lower-bound	2.234	12.000	.186		

Appendix F-5 ANOVA Table for WAnT Fatigue Index

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	706.163	1	706.163	6.925	.022
	Greenhouse-Geisser	706.163	1.000	706.163	6.925	.022
	Huynh-Feldt	706.163	1.000	706.163	6.925	.022
	Lower-bound	706.163	1.000	706.163	6.925	.022
Error(TIME)	Sphericity Assumed	1223.672	12	101.973		
	Greenhouse-Geisser	1223.672	12.000	101.973		
	Huynh-Feldt	1223.672	12.000	101.973		
	Lower-bound	1223.672	12.000	101.973		

Appendix F-6 ANOVA Table for WAnT Blood Lactate Value

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	5.618	1	5.618	2.627	.140
	Greenhouse-Geisser	5.618	1.000	5.618	2.627	.140
	Huynh-Feldt	5.618	1.000	5.618	2.627	.140
	Lower-bound	5.618	1.000	5.618	2.627	.140
Error(TIME)	Sphericity Assumed	19.246	9	2.138		
	Greenhouse-Geisser	19.246	9.000	2.138		
	Huynh-Feldt	19.246	9.000	2.138		
	Lower-bound	19.246	9.000	2.138		

Appendix G
ANOVA Tables for Isokinetic Test Variable

Appendix G-1 ANOVA Table for Isokinetic Knee Peak Torque Extension

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	171.362	1	171.362	6.052	.034
	Greenhouse-Geisser	171.362	1.000	171.362	6.052	.034
	Huynh-Feldt	171.362	1.000	171.362	6.052	.034
	Lower-bound	171.362	1.000	171.362	6.052	.034
Error(TIME)	Sphericity Assumed	283.151	10	28.315		
	Greenhouse-Geisser	283.151	10.000	28.315		
	Huynh-Feldt	283.151	10.000	28.315		
	Lower-bound	283.151	10.000	28.315		

Appendix G-2 ANOVA Table for Isokinetic Knee Average Peak Torque Extension

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	27.214	1	27.214	.814	.385
	Greenhouse-Geisser	27.214	1.000	27.214	.814	.385
	Huynh-Feldt	27.214	1.000	27.214	.814	.385
	Lower-bound	27.214	1.000	27.214	.814	.385
Error(TIME)	Sphericity Assumed	401.296	12	33.441		
	Greenhouse-Geisser	401.296	12.000	33.441		
	Huynh-Feldt	401.296	12.000	33.441		
	Lower-bound	401.296	12.000	33.441		

Appendix G-3 ANOVA Table for Isokinetic Knee Peak Torque per Body Weight Extension

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.266	1	.266	.003	.955
	Greenhouse-Geisser	.266	1.000	.266	.003	.955
	Huynh-Feldt	.266	1.000	.266	.003	.955
	Lower-bound	.266	1.000	.266	.003	.955
Error(TIME)	Sphericity Assumed	973.767	12	81.147		
	Greenhouse-Geisser	973.767	12.000	81.147		
	Huynh-Feldt	973.767	12.000	81.147		
	Lower-bound	973.767	12.000	81.147		

Appendix G-4 ANOVA Table for Isokinetic Knee Work Fatigue Extension

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	198.278	1	198.278	23.708	.000
	Greenhouse-Geisser	198.278	1.000	198.278	23.708	.000
	Huynh-Feldt	198.278	1.000	198.278	23.708	.000
	Lower-bound	198.278	1.000	198.278	23.708	.000
Error(TIME)	Sphericity Assumed	100.362	12	8.363		
	Greenhouse-Geisser	100.362	12.000	8.363		
	Huynh-Feldt	100.362	12.000	8.363		
	Lower-bound	100.362	12.000	8.363		

Appendix G-5 ANOVA Table for Isokinetic Knee Peak Torque Flexion

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	2.404E-03	1	2.404E-03	.000	.992
	Greenhouse-Geisser	2.404E-03	1.000	2.404E-03	.000	.992
	Huynh-Feldt	2.404E-03	1.000	2.404E-03	.000	.992
	Lower-bound	2.404E-03	1.000	2.404E-03	.000	.992
Error(TIME)	Sphericity Assumed	277.649	12	23.137		
	Greenhouse-Geisser	277.649	12.000	23.137		
	Huynh-Feldt	277.649	12.000	23.137		
	Lower-bound	277.649	12.000	23.137		

Appendix G-6 ANOVA Table for Isokinetic Knee Average Peak Torque Extension

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	49.294	1	49.294	1.604	.229
	Greenhouse-Geisser	49.294	1.000	49.294	1.604	.229
	Huynh-Feldt	49.294	1.000	49.294	1.604	.229
	Lower-bound	49.294	1.000	49.294	1.604	.229
Error(TIME)	Sphericity Assumed	368.704	12	30.725		
	Greenhouse-Geisser	368.704	12.000	30.725		
	Huynh-Feldt	368.704	12.000	30.725		
	Lower-bound	368.704	12.000	30.725		

Appendix G-7 ANOVA Table for Isokinetic Knee Peak Torque per Body Weight Flexion

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.132	1	.132	.003	.955
	Greenhouse-Geisser	.132	1.000	.132	.003	.955
	Huynh-Feldt	.132	1.000	.132	.003	.955
	Lower-bound	.132	1.000	.132	.003	.955
Error(TIME)	Sphericity Assumed	485.456	12	40.455		
	Greenhouse-Geisser	485.456	12.000	40.455		
	Huynh-Feldt	485.456	12.000	40.455		
	Lower-bound	485.456	12.000	40.455		

Appendix G-8 ANOVA Table for Isokinetic Knee Work Fatigue Flexion

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	171.362	1	171.362	6.052	.034
	Greenhouse-Geisser	171.362	1.000	171.362	6.052	.034
	Huynh-Feldt	171.362	1.000	171.362	6.052	.034
	Lower-bound	171.362	1.000	171.362	6.052	.034
Error(TIME)	Sphericity Assumed	283.151	10	28.315		
	Greenhouse-Geisser	283.151	10.000	28.315		
	Huynh-Feldt	283.151	10.000	28.315		
	Lower-bound	283.151	10.000	28.315		

Appendix H Wingate Anaerobic Test Raw Data

	Peak Power				Mean Power				Fatigue Index		Blood Lactate						Rating of Perceived Exersion (RPE) Scale			
	Pre		Post		Pre		Post		Pre	Post	Pre			Post			Pre		Post	
Subject	W	W·kg	W	W·kg	W	W·kg	W	W·kg	%	%	Pre-WG (mmol·l)	Post-WG (mmol·l)	Delta (mmol·l)	Pre-WG (mmol·l)	Post-WG (mmol·l)	Delta (mmol·l)	RPE1pre	RPE1post	RPE2pre	RPE2post
1	1178	11.9	1248	12.7	964	9.8	974	9.9	41.2	50.2				1.57	9.97	8.4				
2	915	14.3	843	13.2	781	12.2	692	10.8	48	47.4	3.23	9.39	6.16	2.38	5.41	3.03	8	18	7	19
3	525	9.5	483	8.9	429	7.8	396	7.3	37	42.4	2.74	6.3	3.56	1.74	4.82	3.08	7	16	8	19
4	771	13.2	627	10.8	594	10.2	546	9.4	38.4	25.3	3.17	6.83	3.66				8	13		
5	855	11.5	885	12	728	9.8	669	9	32.9	44.3	2.27	6.04	3.77		6.54		11	18	13	20
6	617	11.3	531	9.6	475	8.7	410	7.4	34.9	36.8	3.52	6.14	2.62	2.97	5.51	2.54	9	13	10	15
7	744	9.5	691	8.9	691	8.8	544	7	22.9	35.5	3.37	4.11	0.74	2.1	3.11	1.01	9	15	7	18
8	519	9	523	9.1	438	7.6	410	7.1	32.6	40	0.97	7.45	6.48	2.5	7.25	4.75	6		6	15
9	586	9.5	573	9.5	483	7.8	461	7.6	32.7	34.1	3.37	6.66	3.29	2.6	3.83	1.23	8	18	7	18
10	815	13.3	830	12.93	706	11.5	684	10.65	32.3	41.3	3.58	9.82	6.24	7.29	9.1	1.81	6	17	6	19
11	1151	13.59	1087	12.45	822	9.7	710	8.13	48.4	74.5	2.04	6.32	4.28	1.35	6.49	5.14	6	20	6	20
12	931	13.97	946	14.21	728	10.93	654	9.81	39.8	85.6	4.33	9.17	4.84	4.72	7.2	2.48	6	20	8	19
13	906	11.4	1122	13.94	778	9.8	797	9.9	29.5	48.7	3.95	5.77	1.82	2.75	7.11	4.36	12	19	9	15

Appendix I-1 Isokinetic Strength Test Raw Data

Extension (180°/s) Bilateral

	Peak Torque (N-M)				Average Peak Torque (N-M)				Peak Torque per Body Weight (%)				Work Fatigue			
	Pre		Post		Pre		Post		Pre		Post		Pre		Post	
subject #	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	197.9	192.9	185.3	186.7	158.5	157.7	149.8	144.0	200.9	195.8	188.1	189.5	29.3	28.6	36.7	33.3
2	149.8	142.4	167.9	154.4	130.4	128.6	145.0	132.7	235.6	224.1	264.1	243.5	13.2	8.9	22.3	15.4
3	77.3	73.8	82.9	73.4	68.6	63.8	71.5	65.5	140.7	134.4	150.9	133.7	18.5	28.8	29.6	23.8
4	86.2	90.8	92.7	87.5	81.0	83.9	83.1	79.7	149.5	157.5	160.8	151.8	11.3	16.6	25.7	16.4
5	121.3	121.9	110.4	108.8	110.2	110.7	98.8	96.2	164.9	165.8	150.1	146.9	8.3	7.0	8.7	13.5
6	112.3	99.1	101.1	103.0	94.7	81.3	83.6	81.9	206.1	181.8	185.6	189.1	28.0	24.8	28.8	31.6
7	118.1	133.4	120.2	129.2	105.1	113.5	108.9	111.7	168.9	190.8	171.9	184.8	14.4	-4.0	9.7	16.1
8	84.5	96.1	89.6	97.5	72.9	78.2	74.1	79.2	145.4	165.4	154.2	167.8	26.8	37.3	29.0	35.4
9	82.8	89.0	93.9	96.1	78.2	79.0	77.7	81.2	134.0	144.1	152.1	155.7	11.2	20.7	35.5	26.7
10	156.3	145.4	162.7	162.1	125.7	124.1	131.6	136.1	255.1	237.3	265.5	264.5	29.6	32.8	40.2	39.3
11	134.1	120.9	114.6	120.7	121.7	113.1	98.6	101.8	158.8	143.1	135.7	142.9	21.4	13.0	23.1	25.3
12	121.9	126.4	116.6	109.3	100.5	106.1	96.9	96.2	184.0	190.8	175.9	164.9	28.2	28.7	33.4	26.8
13	133.9	126.1	134.6	125.6	117.7	106.8	119.0	114.0	168.6	158.7	169.4	158.0	25.0	24.9	25.2	25.4

Appendix I-1 Continued.

Flexion (180°/s) Bilateral

	Peak Torque (N-M)				Average Peak Torque (N-M)				Peak Torque per Body Weight (%)				Work Fatigue			
	Pre		Post		Pre		Post		Pre		Post		Pre		Post	
subject #	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	114.4	101.8	108.2	85.1	91.3	78.4	84.6	57.4	116.1	103.3	109.8	86.4	39.7	39.3	39.8	43.7
2	70.1	54.9	67.7	67.6	130.4	128.6	145.0	132.7	110.2	86.4	106.5	106.3	10.3	-10.3	30.0	21.2
3	50.2	46.6	53.7	45.6	44.0	41.7	43.8	39.5	91.4	84.9	97.8	83.0	34.4	32.3	40.6	30.5
4	48.7	54.0	53.2	53.3	42.7	40.6	42.6	46.3	84.5	93.6	92.2	92.4	21.8	35.9	37.1	20.0
5	69.4	67.5	61.6	58.0	61.7	62.5	49.6	46.6	94.3	91.7	83.8	78.9	14.3	16.7	6.5	37.3
6	59.6	53.8	55.0	62.0	52.2	44.8	47.6	49.1	109.4	98.7	101.0	113.8	38.9	29.2	35.5	36.3
7	70.0	58.2	67.1	59.2	65.1	52.1	55.9	51.9	100.0	83.2	96.0	84.7	26.5	9.9	32.9	31.1
8	50.1	54.5	45.2	49.5	43.6	47.1	35.8	41.9	86.2	93.8	77.8	85.1	20.7	36.6	40.8	37.2
9	38.5	39.3	46.4	45.6	34.2	34.0	35.1	36.4	62.3	63.7	75.2	73.8	-2.5	21.0	39.5	39.3
10	63.2	80.5	72.8	81.7	54.5	70.5	60.9	64.9	103.2	131.3	118.8	133.2	34.0	38.7	27.6	51.6
11	71.1	71.2	70.0	69.2	60.7	60.0	47.7	46.1	84.3	84.3	82.9	82.0	34.4	35.7	57.3	58.7
12	69.5	67.5	61.4	60.5	53.3	51.3	49.8	44.8	104.9	101.9	92.6	91.3	48.3	37.7	49.8	28.7
13	56.2	46.9	62.0	65.6	39.7	36.6	40.2	53.8	70.8	59.0	78.1	82.6	20.7	40.3	42.7	23.1

Appendix I-2 Isokinetic Strength Test Raw Data (Combined)

Extension (180°/s) Averaged

	Peak Torque (N-M)		Average Peak Torque (N-M)		Peak Torque Per Body Weight (%)		Work Fatigue (%)	
Subject #	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	192.9	186.0	158.1	146.9	198.2	188.6	29.0	35.0
2	142.4	161.1	129.5	138.9	229.0	251.8	11.1	18.9
3	73.8	78.2	66.2	68.5	137.4	144.6	23.7	26.7
4	90.8	90.1	82.5	81.4	152.1	155.1	14.0	21.1
5	121.9	109.6	110.5	97.5	164.1	148.0	7.7	11.1
6	99.1	102.1	88.0	82.8	193.6	185.2	26.4	30.2
7	133.4	124.7	109.3	110.3	160.2	161.5	5.2	12.9
8	96.1	93.6	75.6	76.7	156.0	162.4	32.1	32.2
9	89.0	95.0	78.6	79.5	139.0	156.8	16.0	31.1
10	145.4	162.4	124.9	133.9	245.7	253.0	31.2	39.8
11	120.9	117.7	117.4	100.2	150.5	134.8	17.2	24.2
12	126.4	113.0	103.3	96.6	186.4	169.6	28.5	30.1
13	126.1	130.1	112.3	116.5	163.5	161.6	25.0	25.3

Appendix I-2 Continued.

Flexion (180°/s) Averaged

	Peak Torque (N-M)		Average Peak Torque (N-M)		Peak Torque Per Body Weight (%)		Work Fatigue (%)	
Subject #	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	108.1	96.7	84.9	71.0	109.7	98.0	39.5	41.8
2	62.5	67.7	129.5	138.9	98.3	105.7		25.6
3	48.4	49.7	42.9	41.7	88.2	91.9	33.4	35.6
4	51.4	53.3	41.7	44.5	89.1	91.7	28.9	28.6
5	68.5	59.8	62.1	48.1	93.0	80.8	15.5	21.9
6	56.7	58.5	48.5	48.4	104.1	106.2	34.1	35.9
7	64.1	63.2	58.6	53.9	81.7	81.8	18.2	32.0
8	52.3	47.4	45.4	38.9	90.0	82.2	28.7	39.0
9	38.9	46.0	34.1	35.8	63.0	75.9		39.4
10	71.9	77.3	62.5	62.9	117.3	120.3	36.4	39.6
11	71.2	69.6	60.4	46.9	84.3	79.7	35.1	58.0
12	68.5	61.0	52.3	47.3	103.4	91.5	43.0	39.3
13	51.6	63.8	38.2	47.0	64.9	79.3	30.5	32.9