Using hypobaric oxygen techniques and hyperbaric intervention to level the playing field in olympic distance triathlon: Literature review and study proposal

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1998 saw the cycling world rocked to its very foundations by the well publicised exposure of the widespread use of performance enhancing drugs during the Tour de France of that same year.

Since then athlete after athlete in a myriad of different sports around the world have "gone positive" as Sports Drug Agencies, and indeed law enforcement agencies, worldwide crack down on the use and traffic of performance enhancing drugs in sport.

The UCI, in what could only be described as a "knee jerk" reaction to the scandal surrounding its show-piece event, Tour de France, introduced "blood testing" as a means of determining the "potential" illicit use of erythropoitin (EPO) as an ergogenic agent. By setting an arbitrary figure of 50% as a haematocrit "competition cut off" (i.e. When an cyclist records a Hct greater than 50% they are not allowed to compete for "health reasons"), the UCI opened a Pandora's box of potential "false positive" disqualifications from competition being called against "clean" athletes.

In a recent paper by Browne et al (1999), the authors concluded that blood testing as a means of detecting the illicit use of performance enhancing substances such as EPO is "not yet justifiable in sport" (Browne et al, 501, 1999).

While not exposed to the sort of scandal and resultant media pressure of the UCI, the ITU has been able to adopt a more conservative, mainstream approach to drug control within the sport of triathlon. It would however be naive to believe for one moment that a sport such as triathlon, which has its training basis in aerobic strength/endurance, requires voluminous repetitive training and offers the elite of the sport a lucrative lifestyle, is immune to drug abuse.

While various researchers and academics have offered a myriad of "natural alternatives" to drug use for various athletes (e.g. Report of the Ross Symposium on Muscle Development: Nutritional Alternatives to Anabolic Steroids. 1988), the last few years have seen major advancements in sports science and bio-technical instrumentation that provide startling new possibilities in leveling the playing field between those athletes who chose to avail themselves to illicit, and currently largely undetectable, performance enhancing drugs, and those that wish to compete “clean”.

Without doubt, the areas of "hypobaric" or altitude training and "hyperbaric" therapy are the two areas that warrant further investigation as methods of improving athletic. While both practices are thwart with much conjecture and supposition, particularly in Western Society, Eastern Bloc countries such as the then Soviet Union, have been using such techniques with resounding success for more than a decade (Latushkevich et al 1993, Vorob’ev et al 1994).

It is the purpose of this discussion to briefly review some of the more recent scientific research, pilot and case studies in these areas to ascertain their potential worth as legal performance enhancing practices as we head towards the new millenium. This presentation will also outline an applied research study to be conducted at the Runaway Bay Sports Super Centre (Gold Coast, Queensland) within the next 6-12 months, to ascertain the practical, tangible, measurable performance and physiological benefits and responses to these practices.

Hyperbaric Therapy:

Hyperbaric medicine is not a new area of interest for the medical fraternity, indeed human physiological responses to increased pressure gradients have been something that has interested the medical profession for hundreds of years - ever since man started descending to the depths of the ocean floors for commerce and recreational reasons (Mader, 1989). The use of hyperbaric intervention however in the treatment of various ailments (e.g. Burns, slow healing wounds, etc.), crush and compartment syndrome type injury (personal communication with Dr. Ian Millar, Biophysical Journal (71): 1997) has a relatively short history (Hunt and Pai, 1972).

A considerable body of scientific evidence now exists that illustrates significant improvements in the speed of recovery from a variety of ailments including; burns (personal communications with Drs: Millar and Larkins), wound healing (Hunt and Pai, 1972; Anderson et al, 1992; Storch and Talley, 1988) as well as a number of commonly experienced sporting injuries involving; ligament, tendon, muscle and bone (Vujuovic, 1983; Wilcox and Koloding, 1976; Abbot et al, 1994; Ashley L. 1994; Favalli et al. 1990.)

When one considers that many of the injuries athletes experience at a cellular level, particularly in those activities which have a large eccentric muscular contraction component - such as running - are as a direct consequence of "hypoxia" (i.e. A lack of oxygen supply), it stands to reason that practices which augment oxygen supply to muscles that have been worked in an anaerobic environment, may indeed speed the rate of recovery from one exercise bout to another. It then follows, if an athletes' rate of recovery between exercise bouts can be significantly improved, the athlete will then be able to absorb greater volumes and intensities of training which would potentially translate to improved physical performances (Nb. This is one of the rationales for the use of anabolic steroids such as nandrolone by endurance athletes – an improved recovery rate.).

Studies of both animal (Staples et al 1995) and human models (Staples,

1996) suggest treatment with hyperbaric oxygen may decrease the inflammatory process and actually modulate tissue injury as a consequence of augmented eccentric exercise (i.e. downhill running).

Additionally, "interesting evidence suggests that adjunctive treatment with hyperbaric oxygen therapy enhances recovery from soft tissue injuries, specially the type of injury seen most often in sports medicine. The most impressive results appear to be generated by prompt treatment. When hyperbaric oxygen is initiated within the first 8 hours post trauma, the effects seem to be the most dramatic." (Staples and Clement, 1996). When one considers that much of the post training response encountered by athletes after a hard training session mimic soft tissue injuries (e.g. Microscopic tears of muscle fibres and the resultant edema, leading to increased diffusion distances between the cell and blood supply, as a normal result of training). Hyperbaric oxygen, the effects of which are often referred to as “internal icing”, may well have a role to play in speeding recuperation and decreasing the instance of injury in hard training athletes.

There are however some situations in which hyperbaric oxygen therapy may have complications and adverse side effects, particularly at higher atmospheric pressures (i.e. 3 atmospheres): Grand mal seizures (Clark and Fisher, 1977; Clark et al, 1991; Lambertsen et al, 1953) and even at lower atmospheres (i.e. 2 atmospheres) (Adameic, 1977; Clark and Fisher, 1977; Stevens et al, 1991). Apart from these potential neurological based problems there is also the risk of nausea, tooth and sinus pain and blurred vision (Jain, 1990). Those people suffering upper respiratory tract infections, fever, etc. should be excluded from hyperbaric therapy until they overcome such ailments. One group of people that should be excluded entirely from hyperbaric oxygen treatments are those suffering from pneumothorax (chest trauma) (Foster, 1992).

As yet there have been no controlled, scientifically based investigations looking directly at the proposition that hyperbaric oxygen therapy speeds the rate of recovery from one exercise bout to the next for hard training athletes, although the indications are (from related areas of investigation) that such treatment may well have a role to play in speeding athlete recuperation from training.

Hypobaric Training:

It has long been recognised that for athletes to perform to their optimal capabilities at elevations of 1400 metres or greater such athletes must either be born and trained in these environments, or spend a significant period of time (3-4 weeks) "acclimatizing" to these rarefied atmospheric environments if they are to perform to their potential. The physiological reasoning behind this phenomena is quite simple, and related to red blood cell concentrations and the decreased partial pressure of oxygen and has been well documented in a number of classic scientific investigations (Buskirk et al 1969; Raynaud et al 1986; Terrados et al 1990; Terrados et al 1988).

VARIABLE	Pre IHT exposure	Post IHT exposure
* Resting heart rate (bpm)	35	28
* Body weight (kilograms)	68.7	67.9
* Skinfolds (sum of eight sites – mm)	32.3	29.3
* Hematocrit	44%	51%
* Performance time for for 4km track time trial at fixed aerobic heart rate of 152bpm (mins/seconds)	15.25	14.56

There is less decisive scientific evidence available as to the benefits of training at altitude for a period of time, to gain the various physiological adaptations associated with such environments, and then competing, at sea level, at a later date. Those investigations that have been conducted have returned a host of conflicting results (Levine and Stray-Gunderson 1992; Mizuno et al 1990; Wolski et al 1996). One of the principal reasons often cited as a cause of this conjecture is the lack of including control groups in these studies. In recent times some investigators (e.g. Mac Dougall, Gamow - personal communications, Levine and Stray-Gundersen, 1990 and 1997.) have proposed the "sleep high, train low" theory of athletic training. The only published investigations in which such a practice has been investigated are by Levine and Stray-Gunderson (1990 and 1997). In these studies they found a group living at 2500 metres and training at 1250 metres (hardly sea level) improved VO2 max, 5000 metre run time (by 30 and 13.4 seconds in their 1990 and 1997 investigations respectively) and increased blood volume by 500ml (1990 investigation) and red cell mass (Hct) by 9% (1997 investigation). The control groups, living and training at 1250 metres, showed no changes in these aforementioned parameters. Unfortunately this study (1990) was thwart with a host of shortcomings and as such the results must be viewed with a degree of skepticism.

Reviewing the current literature reveals a scarcity of information pertaining to this aforementioned area of investigation. When one considers that many of the negative concerns often cited as being counterproductive to athletes remaining for extended sojourns, particularly at higher altitudes, are as a direct result of modifications in body composition. Namely a loss of lean muscle mass, and/or changes in neuromuscular innervation patterns, as a consequence of not being able to train at a high enough intensity, due to a lack of oxygen, to fully innervate type two, fast twitch muscle fibres (Wolski et al 1996). It stands to reason that if the positive aspects of prolonged hypoxic exposure can be maintained (i.e. Increases in RBC (Sutton et al, 1988; Mairbauri et al 1990), improved sub-maximal aerobic function (Vallier et al 1996)), whilst those negative aspects can be removed (e.g. Dehydration, loss of muscle mass, lower maximal oxygen uptake etc.), then athletic performance may well be augmented.

It has been theorised that by "sleeping high and training low" athletes may well be able to gain the positive EPO release, which will produce the desired increases in RBC populations that will improve oxygen delivery to working muscles, whilst avoiding the negative changes in body composition and counterproductive neural innervation patterns that comes with extended stays at altitudes above 3000 metres.

Until relatively recent times such a practice as detailed above would have proven extremely impractical (i.e. Having to transport athletes from high altitude accommodation to appropriate low lying training facilities.). This however is no longer the case. The advent of various, relatively inexpensive, portable hypoxic chambers such as the "Gamow bed" (Patented by Professor Igor Gamow of the University of Colorado at Boulder, USA), as well as purging sleeping quarters (bedrooms and tents) with 12-15% oxygen/nitrogen atmospheres, all allow athletes to sleep at the simulated altitudes necessary to stimulate increased EPO releases, invoke the positive skeletal muscular adaptations to enhance endurance performance, whilst still training at sea level and hence maintaining the intensity of exercise necessary to maintain appropriate neuromuscular patterning.

Intermittent hypoxic training (iht): the next frontier in altitude training.

Introduction:

Intermittent Hypoxic Training or “IHT” which has its origins in the Russian military and space programs heralds the new frontier in “altitude” training. Approximately 18 months ago this form of altitude simulation was introduced to New Zealand sports by Dr. Alexei Korolev.

This method of “altitude training” – which is claimed to be equivalent and even superior to conventional altitude training by being able to control the altitude “dose” – is achieved by exposing athletes to hypoxic air containing 9-16% oxygen (equating to an altitude exposure of 2,000 to 6,500 metres above sea level) intermittently at 4-6 minute intervals interspersed with breathing normoxic air for the same periods, for 60-90 minutes per session, once or twice a day.

Exposing the athlete to such hypoxic gases in the aforementioned manner, via a machine called an “hypoxicator”, is thought to stimulate EPO release and hence red blood cell production resulting in increased oxygen carrying capacity within the blood.

Preliminary Research and Case Studies:

In a pilot study of a group of 10 elite endurance athletes (swimmers, triathletes and runners), Dr. John Hellemans (1998) found:

1. Endurance performance over a series of performance tests (swimming, cycling and running) improved on average by 3.1%.
2. Hemoglobin concentration increased on average by 4.4%.
3. Hematocrit increased on average by 4.8%.
4. Reticulocyte count increased on average by 28.7%

Dr. Hellemans summarised the findings of this investigation as follows:

Ten endurance athletes were tested with the method of Intermittent Hypoxic Training (IHT) in relation to hematological factors and performance over a period of three weeks. Results show an overall improvement in hematological factors related to oxygen transport and performance. The results indicate that IHT is an effective method to simulate altitude training. On the basis of the results it is recommended that further research and testing is done in the area of maximising outcome for individual athletes. However in general the method of IHT can be strongly recommended for any serious athlete as part of their training and preparation.

A further case study was recently (August-September 1999) undertaken at the Runaway Bay Sports Super Centre on Queensland's Gold Coast. The results of this case study are indicated below and occurred over a ten to fourteen (10-14) day period during which time the training of the athlete remained constant.

The athlete involved in this case study was an elite ultra-distance triathlete (Nb. Training performances prior to IHT exposure suggested that he has the potential to record in the vicinity of 8 hours for an Ironman distance triathlon) training 30+ hours per week. His weekly training comprises 25-30km per week or swimming, 400-600km per week of cycling, 100-120km per week of running and two to three weight training sessions per week. This athlete's training was not altered in any other way during the IHT exposure. All factors listed above show tendencies to improved aerobic function as a consequence of a greater red cell mass – this is conclusively supported by a 7.25 second per kilometre improvement in performance time for the fixed heart rate aerobic track run (Cedaro, Unpublished observations, 1999).

Conclusions:
On the strength of these findings of the above mentioned case study, and those of Dr. Hellemans, the Sports Science Medicine Department of the Runaway Bay Sports Super Centre purchased two hypoxicator machines (one four station and one two station) for use by RBSSC Triathlon Squad members and visiting athletes to the facility.

Study Proposal:

Since these interventions (i.e. Hyperbaric therapy and "sleep high, train low" and IHT) are still relatively new areas of investigation in relation to optimising athletic performance, the following investigation will be undertaken at the RBSSC within the next 6-12 months:

Study Design:
30 well trained, triathletes are pre-screened and tested for:

* Performance tests (e.g. 1km. swim for time, 30km. time trial, 6km track run)
* VO2 max: Standard test protocols (bike/run)
* Key strength/power indicators (e.g. Knee extension)
* Anthropometric data (i.e. Height, weight, skin-folds, etc.)
* Various blood parameters (e.g. Uric acid, Hct, RBCM, blood viscosity, plasma volume)

They will then be divided into five evenly matched groups of 6 and trained equally, as a squad for five weeks by the same accredited multi-sport coach, in the same manner with the following interventions:

(a) Group one acts as the control group, lives in close proximity to the other study groups and trains under the guidance of the study coach. This group receives the same coaching advice, nutrition, medical/physiotherapy support, etc. as the other three study groups.

(b) Group two, is treated in precisely the same manner as group one, the only difference being that once a day, for 60-90 minutes they are placed into a hyperbaric chamber and breath pure oxygen under two atmospheres of pressure.

(c) Group three, is treated in the same manner as group one, but unlike group two, this group sleeps in a hypobaric chamber/nitrogen house for 8 hours per night at a simulated elevation of 2500 metres.

(d) Group four, is once again treated in the same manner as the other three groups in relation to the training provision, nutrition, massage, etc. provided. The interventions provided for this test group are: (i) Sleeping for 8 hours in the hypoxic environment (as per group three) and (ii) 60-90 minutes per day of hyperbaric exposure (as per group two).

(e) Group five will be provided with the same interventions as group four, however the eight hours of sleeping at 2,500 metres will be replaced by IHT exposure for 60 minutes per day as per the exposure protocols manual provided with the hypoxicator device.

Throughout this intervention period the athletes will on a weekly basis:

(a) Keep detailed training logs in relation to:
   (i) Work completed (Volume and intensity - heart rate readings, etc.).
   (ii) Monitors of overtraining (as per Hooper et al, 1995) and illness log.

(b) Be assessed for changes in blood chemistry:
   (i) RBC populations (MCHb, MCV, RBCM, Reticulocytes).
   (ii) Blood viscosity.
   (iii) Indicators of recovery (CPK, urea).
   (iv) EPO concentrations.
   (v) Iron status.

(c) Assessed for changes in body composition via standard anthropometrical practices (e.g. skin-folds, body mass index).

After a common taper, at the end of the five week intervention period the triathletes will be reassessed for the initial performance indicators recorded at the commencement of the investigation for statistical comparison within and across all five groups in an attempt to ascertain whether or not the interventions and protocols (and/or combinations thereof) discussed above have any significant effects on endurance performance.

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