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LITERATURE REVIEW AND STUDY PROPOSAL PREPARED FOR TRIATHLON AUSTRALIA LTD. ON HYPOXIC TRAINING AND HYPERBARIC INTERVENTION AS A MEANS OF SPEEDING RECOVERY POST EXERCISE

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**Introduction:**
The areas of "hypobaric" or altitude training and "hyperbaric" therapy are two distinct areas that warrant further investigation as methods of improving athletic performance as we head towards the year 2000 and beyond. Both practices are thwart with much conjecture and supposition. It is the purpose of this document to briefly review some of the more recent scientific research in these areas to ascertain the worth of these practices from a physical performance perspective with a view to providing Australian Olympians at the 2000 Olympics and beyond with a measurable, legal performance edge over their competition.

Additionally, this document will outline a practical scientific study to be conducted solely at the Australian Institute of Sport (Canberra), or in conjunction with the Alfred Hospital Hyperbaric Medicine Department, under the joint supervision of the head of the aforementioned department; Dr. Ian Millar and representatives of the Triathlon Australia Ltd. Sports Science Committee to ascertain the practical, tangible, measurable performance and physiological responses of 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 has 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 for the treatment of various ailments (e.g. burns, slow healing wounds, etc.), crush and compartment syndrome type injury (personal communication with Dr. Millar - manuscript in press: 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.)

Additionally, a number of elite triathletes have been using techniques whereby they are exposing themselves to hyperbaric air (as distinct to oxygen) and claiming significant improvements in their recovery rates from exercise bouts as a consequence. 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 improved significantly, the athlete may then be able to absorb greater volumes and...
intensities of exercise which potentially translate to improved physical performances.

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 in the first 8 hours after injury, 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 as a normal result of training), hyperbaric oxygen may well have a role to play in speeding recuperation and decreasing the instance of injury in hard training athletes.

However, there are a number of situations in which hyperbaric oxygen therapy may potentially 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 to look directly at the proposition that hyperbaric oxygen will speed 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 hyperbaric oxygen 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 these athletes must either be born and trained in these environments, or spend a significant period of time (3-4 weeks) "acclimatising" 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).

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 sited as a cause of this conjecture is the lack of including control groups in these studies. In recent times some investigators (e.g. MacDougall, Gamow - personal communications) have proposed the "sleep high, train low" theory of athletic training. The only published investigation in which such a study has been completed is by Levine et al (1990) in which they found a group living at 2500 metres and training at 1250 metres (hardly sea level) improved V02 max, 5000 metre run time (by 30 seconds) and increased blood volume by 500ml, whereas a second group living and training at 1250 metres showed no changes in these aforementioned parameters. Unfortunately this study was thwart with a host of shortcomings and as such the results must be viewed with some scepticism.

Reviewing the current literature there simply isn't a wealth of material pertaining to this aforementioned area of investigation. When one considers that many of the negative concerns often sited 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 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 recently such a practice as detailed above would have proven extremely impractical - 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" (produced by Professor Igor Gamow of the University of Colorado at Boulder, USA), as well as purging sleeping quarters with 12% oxygen/nitrogen atmospheres, both allow athletes to sleep at the simulated elevations necessary to stimulate increased EPO releases, whilst still training at sea level.
STUDY PROPOSAL:
Since these (i.e. Hyperbaric therapy and "sleep high, train low") are still relatively new areas of investigation in relation to optimising athletic performance, the following joint investigation between Triathlon Australia Inc., the Alfred Hospital (under the guidance of Dr. Ian Millar) and/or the Sports Science Medicine Department of the Australian Institute of Sport and other interested national sporting organisations is proposed:

STUDY DESIGN:
24 well trained, elite 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 are then divided into four evenly matched groups of 6 and trained equally, as a squad for 6 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).

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 paper, 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 six 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 four groups in an attempt to ascertain whether or not the interventions and protocols (and/or combinations thereof) discussed above have any significant effects on athletic performance.

Should such a study produce significant performance enhancements in some or all of the aforementioned study groups, a series of hyperbaric/hypobaric training and treatment guidelines could be drawn up that would benefit various elite endurance orientated athletes competing in triathlon, swimming, cycling and athletics (running) at the 2000 Sydney Olympic Games.

PROPOSED TIME FRAME:
The 1997 ITU World Triathlon Championships are to be conducted in Perth, Australia on November 16th. The timing and location of these championships will see as similar a set of circumstances as we can hope to achieve between now and the 2000 Sydney Olympics (i.e. Athletes will be coming off major international competition and travel in the northern hemisphere - May to September - and preparing for the pinnacle of the year's competition here in Australia. As a consequence there will be no confounding variables such as; extended international travel and associated time zone changes/jet-lag; cultural differences (e.g. Food and language barriers) and extreme changes in environmental conditions (e.g. Temperature and altitude), to effect the generally agreed upon theoretical competition enhancing benefits this investigation will produce.

Conducting the investigation at this time, also allows ample time to "fine tune" the pre-competition protocols in the lead up to Sydney, 2000 in the "real world" under circumstances similar to those that will be experienced by our athletes in the lead up to the 2000 Olympics.

The proposed time-line for the investigation is therefore, commencing September, 1997:

24 elite junior Australian triathletes are bought into a centralised training camp at the Australian Institute of Sport (AIS) to prepare for the ITU World Triathlon Championships in Perth. The training/investigation period at the AIS is to be broken up in the following manner:
September 28th until October 5th: Athletes familiarised with the AIS, tested and divided into the four study groups as previously indicated within this document, and allowed a week acclimatisation to the test interventions.

October 5th until November 2nd: Training, blood testing and interventions as per study outline.

November 2nd until November 9th: Common taper and retesting of initial performance indicators.

November 9th -> Travel to ITU World Championship location in Perth, Australia.

Obviously there is some room to move within the above time-line, however this gives a fair indication of how to best serve the long term purposes of Australian athletes for the 2000 Olympics. The junior elite squad has been suggested as subjects for a number of reasons:

* They will be less resistant to change and innovation, as well as being interested in the novelty aspect of being involved in a cutting edge scientific investigation that will potentially give them a "performance edge".

* Starting at a grassroots level such as this we'll be able to educate these athletes as to the important role all the various sport sciences can play in the conditioning process and preparing them for major international competition.

* Some of these young athletes will likely be those representing Australia at the 2004 Olympics so it gives ample time to familiarise and fine tune this type of preparation for these young athletes.

* If the actual physical performances (both lab. based and at the 1997 ITU Triathlon Championships) of the athletes gaining the combined hypoxic/hyperbaric intervention is significantly better than of the other athletes, which theory would suggest will be the case, it will be far easier to involve the senior elite athletes in 1998 and beyond.
COSTS:

Meals and accommodation for 24 athletes at the AIS for 42 nights: $41,328.00

Meals and accommodation for coordinator and coach at AIS for 42 nights: $3,444.00

Use of AIS training facilities:
- Pool (3 lanes X 2 hours X 42 days plus entry): $6,500.00
- Gym (3 times per week for each athlete): $900.00
- Track (2 times per week for each athlete): $900.00

Sports physiologist to prepare, coordinate, oversee study, as well as prepare the report, findings and practical guidelines of the investigation (total time of involvement in the project 4-6 months): $12,000.00

Statistician to analyse and report on collected data: $1,730.00

Use of hyperbaric chamber (i.e. Consumables, technical support, etc.): $15,000.00

Use of nitrogen house (i.e. Consumables): $5,000.00

Two observers to stay awake all night to monitor the athletes in the nitrogen house (2 X $150 X 42 nights): $12,600.00

AIS sports science/medicine staff for sample/data collection, medical support: $1,440.00

Consumables for data collection (i.e. Blood sampling): $9,888.00

Performance testing (2 X VO2 max (bike/run) X 2 (pre/post intervention) X 24 athletes @ $70/test): $6,720.00

Accredited multi-sport coach to liaise and coordinate with the aforementioned sports physiologist to ensure appropriate training practices, athlete liaison and coordination takes place (cost to be incurred by Triathlon Australia Ltd.).

TOTAL COST OF PROJECT: $117,450.00
REFERENCES:


