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The benefits of Mild Hyperbaric Oxygen Therapy (mHBOT) in the Fitness Industry

-A review by

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INTRODUCTION

The physical and psychological demands on elite athletes today are ever increasing and require careful management to ensure performance excellence is sustained and player wellbeing is protected.

The ecology of modalities employed by elite athletes and their high performance coaches are multi-disciplinary with programs personally tailored to the athletes needs and the teams higher goals.

This paper outlines the compelling research findings that document the multiple benefits of mild hyperbaric oxygen therapy (mHBOT) for the elite athlete.

The innovative AirPod Hydroxy therapy delivers mild hyperbaric pressure and uniquely combines oxygen and molecular hydrogen to provide broad based benefits.

For the professional teams and coaching personnel, this is an opportunity to extract higher performance levels, reduce injury recovery timeframes, prevent major injuries and proactively manage the impact of concussion and sub-concussive episodes to protect the long term wellbeing of the elite athlete and to retain key players over a season.

Importantly, the AirPod Hydroxy also supports athlete wellbeing by strengthening the foundational elements of sleep optimisation, stress reduction, self-care and mindfulness.

This report will outline the physiological benefits of the AirPod Hydroxy therapy and our evidence-based belief that it can function as an adjunct therapy in the following domains.

- Cognitive performance
- Performance optimisation
- Injury prevention and recovery
    - Ligament healing
    - Muscle recovery
    - Delayed onset muscle soreness (DOMS)
    - Fractures
    - Concussion recovery

Throughout this paper, studies cited may utilise a higher level of HBOT than a mild HBOT (mHBOT) such as our AirPod Hydroxy. However, the fundamental physiology of the system remains relevant and studies show that mHBOT provides comparable effects. In fact, several studies that perform statistical analyses between various pressures of HBOT found no statistical differences between pressures of 1.3ATA and 2.0ATA (Ishii, Ushida, Tateishi, Shimojo, & Miyanga, 2002).

PERFORMANCE OPTIMISATION

Oxygen is carried throughout the blood by hemoglobin and partially dissolved within the blood plasma itself. Under normal conditions, hemoglobin is already 98% saturated with oxygen, so there is limited additional oxygen that can be carried. The benefits of HBOT come from its ability to dissolve additional oxygen into the blood plasma fluid. In this way, it can travel more easily through thinner or otherwise obstructed vessels to accelerate every healing process in the body. It also significantly elevates oxygen concentration to enable an increase in energy production.

The body produces energy via an oxygen-dependent process called aerobic respiration. This process occurs in mitochondria and requires the inputs of glucose and oxygen, turning them into energy in the form of adenosine triphosphate (ATP). Conceptualising this process as a simple supply-demand situation we can see that when more energy is required (i.e. exercising) oxygen will need to be supplied in greater amounts.

Regular production of energy eventually takes a toll on cells. This is an inevitability of life, however in athletes, due to the higher production of energy, this damage accumulates much more quickly. This strain is known as oxidative stress, and over time it acts as a precursor to multiple metabolic disorders and neurodegenerative diseases.

There is currently a clinical trial in place which is looking at measuring the long-term effects of HBOT on aerobic exercise performance. The study is based around the fundamental physiological principal of HBOT; increasing the blood oxygen content by increasing the plasma-dissolved O_2 concentration, we can effectively increase mitochondrial function, and therefore provide greater amounts of energy when needed.

Our AirPod Hydroxy treatment works on different levels to provide a broad range of benefits over both the short, and long-term.

Mitochondrial function

Acutely, the increased mitochondrial function achieved by elevating blood O_2 levels allows athletes to metabolise glucose more quickly. This in turn allows the production of more energy, increasing both muscular endurance as well as power (Earnest , Snell, Rodriguez, Almada, & Mitchell, 1995).

Over a longer term however, in order to see the potential benefits of HBOT we can look to the structures that support energy production in our athletes. In normal people, the mitochondria are already placed under large amounts of

stress, thereby accumulating a certain amount of damage. In our athletes, these stressors are significantly elevated, and so too is the damage done to our mitochondria.

Clearance of metabolites

Aerobic respiration results in the secondary production of reactive oxygen species (ROS). Whilst many of these ROS have important functions in the body, some are more malicious, and can cause damage to our mitochondria amongst other structures. This ROS is known as a hydroxyl radical (OH^-).

The inclusion of Hydrogen gas in our AirPod Hydroxy treatment allows us to proactively manage this risk due to Hydrogen's proven benefits as a powerful antioxidant. It is important to note however that some ROS have important functions in the body that we do not want to get rid of. Another benefit of using Hydrogen however is that it is very selective, and will only react with the hydroxyl radical (Ohsawa, et al., 2007).

Mitochondriogenesis

Oxidative stress within skeletal muscles is largely regulated by several factors, one of which being PCG-1a (Gu, et al., 2010). This co-activator molecule is responsible for the creation of new mitochondria (Vina, et al., 2009).

The study by Gu et al., (2010) exposed diabetic rats to hyperbaric treatment at a pressure equivalent to 1.7ATA. The purpose of the study was to investigate the effects of HBOT on glucose clearance and insulin resistance, however, the premise is useful for our application. They found that there was a significantly elevated concentration of PCG-1a, as well as more effective glucose clearance.

The increase in PCG-1a ultimately means that there were increased rates of mitochondria, allowing the oxidative capacity of skeletal muscle to increase. Furthermore, the overall increase in glucose clearance alludes to a generally more efficient respiration pathway.

Put simply, the increased number of mitochondria, as well as the increased efficacy of aerobic respiration will result in a sustainably higher production of energy within the body.

Neurogenesis

Exercise causes an increase in the formation of neurons in the dentate gyrus of the hypothalamus (van Praag, 2008). This happens so that the 'learning' associated with the exercise can become muscle memory.

In HBOT too, neurogenesis of a similar nature is induced. In tandem with exercise, the research suggests that HBOT should accelerate the formation of such neural connections (Zhang, et al., 2010).

Not only is neurogenesis important for muscular co-ordination, but also for regular cognition. High-order operations such as decision-making and problem solving rely on vast networks of neurons within the neocortex (Tan & Shi, 2012). By inducing neurogenesis through HBOT, the density of neurons within these areas will also increase, facilitating greater development in those areas of cognition.

Put simply, the increased rates of neurogenesis will assist in formation of muscle memory, as well as help to develop greater facilities for decision-making and problem solving.

Delayed onset muscle soreness (DOMS)

Delayed onset muscle soreness (DOMS) is a universal consequence that all athletes face. Typically, DOMS presents as mild muscle tenderness and there are several proposed mechanisms behind DOMS such as a build-up of lactic acid, inflammation and general muscular damage (Cheung, Hume, & Maxwell, 2012).

In all these three mechanisms, our treatment has the ability to ameliorate the downstream effects of this process. It should be noted that there are other proposed theories such as enzyme malfunction, that our treatment does not work to manage.

The build-up of lactic acid is a result of ceasing exercise causing an accumulation of a toxic metabolites of aerobic respiration. Through its circulatory benefits, HBOT can help to increase the removal of such metabolites from areas of high concentration.

The study by Staples et al., (1996) focuses on the inhibitory effects of HBOT on the inflammatory process thereby preventing further injury to the muscular tissue. The study showed that patients in the hyperbaric treatment group regained eccentric strength faster than the control group.

The benefits of HBOT in terms of general muscular damage will be expanded upon further within this paper. In short form however, the study by Cervaens et al., (2013), proposes that HBOT has the ability to accelerate recovery time of muscular damage.

INJURY AND RECOVERY

For years, sports medicine has expanded upon its arsenal of treatment protocols in order to combat the inevitability of sports, especially at an elite level; *injury*. Such treatments involve massage, anti-inflammatory drugs, ice baths or acupuncture. These treatments can be quite unpleasant as they require quite invasive, or pharmaceutically regulated management.

HBOT on the other hand, provides a litany of benefits that can help accelerate the recovery of athletes from a variety of common injuries. The following research provides evidence of the ways in which the AirPod Hydroxy therapy is able to assist with problems such as inflammation, poor blood flow, ligament and muscle healing and delayed onset muscle soreness (DOMS).

Soft-Tissue Damage

When a sporting injury occurs, it can quite often lead to a case of ischemia. Ischemia occurs when a certain region of the body is starved of oxygen due to poor blood flow. This is known as a 'crush injury' and HBOT has been established as a highly effective treatment. Crush injuries is an umbrella term that include conditions like soft-tissue and blood vessel damage.

The most crucial factor for recovering from such injuries, is to restore effective blood flow, so that the tissue can receive the necessary nutrients for healing.

HBOT does this by administering oxygen at a higher pressure than regular atmospheric oxygen, effectively loading our blood with more oxygen, thereby increasing its perfusion pressure. This increased perfusion pressure allows oxygen to get into harder to reach places much more easily. This aids dramatically in the healing process, some studies even suggesting that it can save up to 70% in injury time.

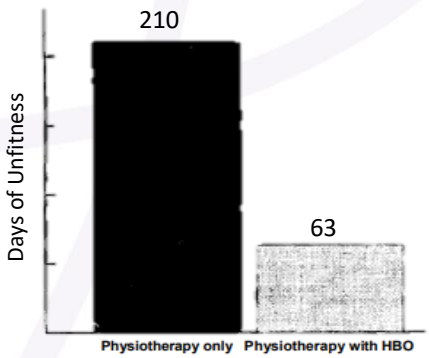


Figure 1. Comparison of recovery from sports injuries between Physiotherapy and Physiotherapy supplemented with regular HBOT. (n=20) [Taken from *(James, Scott, & Allen, 1993)*.]

Muscular Recovery

Muscular injuries account for 30-55% of all sporting injuries, with the hamstring group being the most frequently injured (6-29% of all muscle injuries in the AFL) (Orchard & Seward, 2002). Furthermore, the rates of injury recurrence are quite high for the hamstring muscles (30-70%), which make this particular injury such a daunting prospect for many atheletes (Copland, Tipton, & Fields, 2009). Depending on the severity of the injury, recovery time can range from up to a few days for a grade-1 injury, to 3 weeks for a grade-2 injury.

A case study completed by Botha et al., (2015), analysed the treatment of 42 rugby players with hamstring injuries using HBOT (2.4ATA) and compared them to control treatments of traditional therapies. The study found that there was a 38% reduction in injury time for players recovering from a grade-1 injury, and a 45.7% reduction in injury time for players recovering from grade-2 injuries. Furthermore, 62% of players with grade-1 injuries did not report recurring injuries, and no players with grade-2 injuries reported injury recurrence.

The AirPod Hydroxy therapy works in a variety of different ways to aid the recovery. Much like its role in other forms of injury recovery, the key factors are increased vessel formation, decreased inflammation and increased circulation. Within muscular injuries however, HBOT is seen to also enhance the effects of platelet rich plasma (PRP) (Mishra, et al., 2011; Bakker & Cramer, 2002).

Platelet rich plasma plays a crucial role in helping to deliver nutrients to areas of muscular trauma to help restore effective muscular tissue. By inducing a hyperoxic environment through HBOT, our treatment increases the amount of nutrients carried by PRP (Botha, et al., 2015).

Put simply, the use of HBOT as an adjunct therapy can be fully credited with an accellerated recovery time when compared with traditional methods when rehabilitating players from hamstring injuries.

Ligament Healing

The joints around our body are supported by fibrous connective tissue known as ligaments. Quite often in sports that place repetitive strain on the joints in our body this can lead to tearing of a ligament. At the top of this list are the ligaments that support the knee, specifically the ACL. Injuries like an ACL tear require surgical intervention and anywhere from six to nine months to return to full activity.

For quite a while now HBOT has been established as a suitable adjunct treatment to regular physiotherapy in ligament healing. The study by Horn et al., (1999) was the first to present compelling evidence for the use of HBOT in this way and has become the go-to authority on its application. Using a rat model (*n=48)*, the study examined the effect of HBOT (2.8ATA) on recovery from surgically lacerated medial collateral ligaments (MCL). The results of the study suggest that "hyperbaric oxygen seems to accelerate return to normal force to failure at 4 weeks".

Another study by Ishii et al., (2002), expands upon the work of Horn to see if his results can be replicated at lower pressures of HBOT. By any measure, the 2.8ATA HBOT employed in Horn's study seems slightly excessive.

Ishii was able to replicate Horn's results at pressures of 1.5ATA. Statistical testing was then done to determine if there was any significant difference between the different intensities *i.e. were there more benefits of a HBOT treatment at 2.0ATA than at 1.5ATA?* The testing reported that no, there was no significant difference in the benefits of HBOT attained 2.0ATA compared to 1.5ATA.

Fractures

An epidemiological study found that fractures made up 10.1% of all injuries sustained by US high school athletes (Swenson, Yard, Collins, Fields, & Comstock, 2010). Understandably, this makes it a major concern for sporting institutions, with athletes often being unable to compete for six to eight weeks on average.

Under normal circumstances, bone healing is dependent on the amount of nutrients supplied by the surrounding blood vessels. Quite often, if there is a fracture, this blood supply is compromised, and so the recovery process can be impaired (Lu, Miclau, Hu, & Marcucio, 2006). This ischemia compromises the delivery of nutrients to the fracture site, and can lead to cell death, delayed osteoblast differentiation and ultimately impaired fracture healing (Lu, Miclau, Hu, & Marcucio, 2006). Hence the importance of regaining blood flow to the area as soon as possible to enable the healing process.

This is where HBOT comes in to play. One key benefit of the treatment is its ability to increase circulation and plasma-dissolved oxygen concentration (Sorice, et al., 2016). By rapidly increasing circulation, HBOT may be able to prevent the more drastic effects of ischemia.

Additionally, studies have shown that HBOT has the ability to increase the concentrations of vascular growth factors like VEGF and bFGF (Jung, Wermker, Poetschik, Ziebura, & Kleinheinz, 2010). This will help to increase the rates of blood vessel formation, and ultimately may help to accelerate the recovery process.

After blood flow is restored, the actual restorative process involves the formation of cartilage to 'fill the fracture', followed by a process of bone formation known as *endochondral ossification.* In this space too, HBOT has a strong argument for application.

Many studies have suggested HBOT as an adjunct therapy to regular immobilization treatment, proposing that it helps to aid the formation of cartilage (Yablon & Cruess, 1968). This study sheds some light on the mechanisms responsible for the accelerated healing process. Yablon & Cruess propose that by increasing oxygen tension at the fracture site HBOT increases the formation of cartilage, as well as speeding up endochondral ossification.

Whilst they were not yet able to isolate the exact mechanism for this phenomenon, many studies suggest that the increased oxygen tension elevate the release of lysosomal enzymes from cartilage cell, facilitating a greater conversion of cartilage to bone.

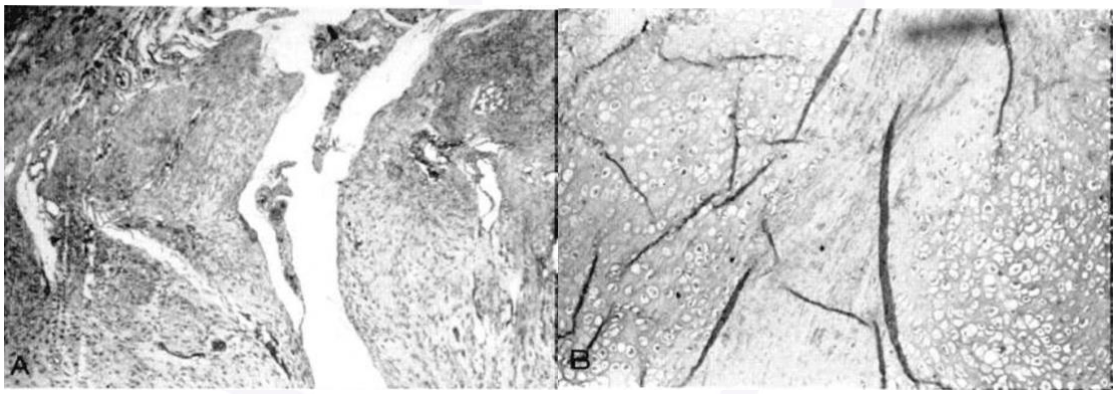


Figure 2. A, control; B, experimental animal. At 22 days, there is almost complete union with cartilaginous callus in the experimental animal, but a cleft is still present in the control animal.[Taken from Yablon & Cruess, 1968]

The study by Lu et al., (2013) speaks to the importance of tissue oxygen as a key modulatory factor for the coordination of stem cells post-fracture.

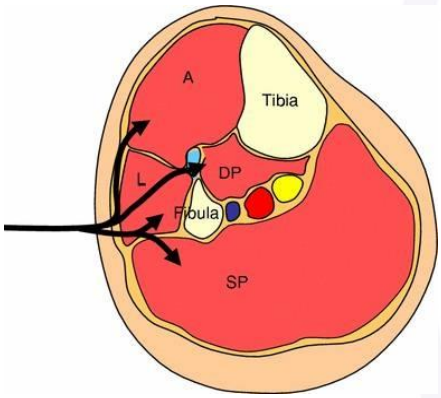
Several studies link oxygen to stem cell maintenance, mobilisation, and recruitment to fracture site (Lin, Lee, & Yun, 2006; Thom, et al., 2006; Gallagher, et al., 2007; Liu & Velazquez, 2008; Kulkarni, et al., 2004). Thom et al., (2006), investigated the use of HBOT to achieve similar recruitment of stem cells. The

study found that there was a 50% incrase in circulating stem cell factors in response to a single exposure of HBOT at 2.0ATA. By doing so, it will result in a faster accumulation of cartilage to the fracture site.

Understandably, this is a more clinical benefit of HBOT that is slightly beyond the scope of our reach as a wellness industry, however the benefits are still relevant, but at a significantly lower level.

Compartment Syndrome

Chronic exertional compartment syndrome (CECS) is a frequent problem that athletes face, particularly in sports that require a high amount of running. The problem occurs in several regions of the body and but most frequently presents in the calf-region.



Many muscles lie within the calf-region, and they are all surrounded by a tight fascial sheath. When running, there is an increase in blood flow to these muscles. This forces the muscles to swell and since they reside within a tight fascial sheath already, it forces the muscles to compress the AVN[1] bundle, which can induces ischemia and myonecrosis (Karam, Amendola, & Mendoza-Lattes, 2010).

Our AirPod Hydroxy therapy, with the inclusion of H_2 gas allows us to mitigate these issues. By increasing the concentration of plasma-dissolved oxygen, our treatment allows oxygen to get into 'tighter spaces' that a regular oxygen-carrying red blood cell cannot. Additionally, the proven anti-inflammatory action of hydrogen means that our treatment uniquely targets the built-up pressure in our periphery (Yang, Zhu, & Xi, 2018).

It is important to note however, that CECS does not only present in the calf region, but in any region where muscles are subject to large intra-fascial pressures. Another example of this are the *erector spinae* muscles enclosed in *thoracolumbar fascia*. The study by Karam et al., (2010), explains a case study whereby an athlete developed paraspinal compartment syndrome after a weightlifting strain. Upon being admitted to hospital, a T2-weighted MRI[2]

[1] Artery, vein and nerve
[2] T2-weighted MRI allows better clarity of fat and water deposition in the body- *a sign of edema*

revealed significant edema[3] throughout his paraspinal muscles. After being treated with six HBOT sessions, the patient was discharged with significantly increased mobility and decreased paraspinal edema.

Another case study published in 1998 talks of the use of HBOT to treat exertional compartment syndrome in a 29-year old male active duty soldier. The patient reported tingling and aching pains in his right leg when he presented with restlessness, excessive sweating, and hyperventilation. After four treatments of HBOT at 2.4ATA, intra-fascial pressures and myonecrosis were significantly decreased (Fitzpatrick & Murphy, 1998).

[3] Edema: *increased water deposition in areas of the body*

CONCUSSION

A concussion is defined as any transient neurological dysfunction resulting from physical trauma and affects 10% of all contact sports athletes (Brain Injury Research Institute, 2020). To deal with brain injuries, the literature generally recommends low pressures of HBOT, as the increase in intercranial pressures can exacerbate existing injuries.

A crucial factor in the management of concussions is that not all of them are detected. It is not a certainty that every head-knock within a sports game will lead to a concussion, and what this leads to is the accumulation of damage caused by sub-concussive injuries. In this way, our therapy can work to help manage the accumulation of oxidative damage at intermmitent points, rather than waiting for a specifically diagnosed concussion.

Concussion is generally associated with acute confusion, dizziness and headaches, with the underlying mechanism related to ischemia[4], and therefore hypoxia[5]. These conditions are known to be associated with a poor clinical outcome (van de Brink et al., 2000; Stiefel et al., 2006). Hyperbaric therapy increases the O_2 delivery gradient, providing the brain with more oxygen, thus mitigating ischemia and hypoxia (Beynon et al., 2012).

Many studies show an improvement in the functional outcome of TBI[6] patients with HBOT (Boussi-Gross et al., 2013). The study by Boussi-Gross et al., (2013) took 56 patients with a history of TBI, and induced them to 40 HBOT sessions at 1.5ATA. The parameters measured were cognitive brain function and quality of life. The study found that the 40 exposures of HBOT yielded significant improvements in both factors. Furthermore, Boussi-Gross et al., was able to demonstrate that the benefits of HBOT did not apply on a short-term basis, but were extended to patients 1-5 years after their respective incidences.

The study by Harch et al., (2020), supports such results. The study takes 63 subjects with a history of mild TBI from a military background, and exposes them to 40 treatments of HBOT at 1.50ATA. The study found that there were significant cognitive improvements in patients whose incidents of brain injury occurred on average 4.6 years prior to treatment. The functional improvement was measured

[4] Low Blood flow
[5] Poor oxygen delivery
[6] Traumatic brain injury

by several cognition tests such as the Wechsler Test of Adult Reading, Wechsler Adult Intelligence Scale and the Benton Visual Retention Test amongst others.

As concussions are directly a result of trauma to the head, there is usually a good chance there is some damage to blood vessels in the brain. If this occurs, one of the more drastic outcomes is internal bleeding which increases the intercranial pressures, further leading to more chronic issues. It is crucial that the blood vessels be repaired as soon as possible to mitigate the pressure-related consequences such as impaired brain function.

Many studies show that in this space, HBOT has benefits. HBOT increases the blood concentration of several blood vessel growth factors such as VEGF and bFGF (Zhou, Liu, & Liu, 2016; Jung et al., 2010). By doing so, HBOT may be able to accelerate the healing process, and reduce the severity of the intercranial bleed.

Another important benefit of HBOT is its unique ability to dissolve oxygen within the plasma, which enables it to reach areas a regular red blood cell (RBC) cannot. This is particularly relevant in concussion cases. As mentioned previously, when a TBI occurs, there is often damage to blood vessels in the brain. This means that some areas of the brain become starved of blood, and therefore oxygen. By dissolving oxygen in the plasma, our treatment is able to provide oxygen to areas that would otherwise go without.

Put simply, the longer a region of the brain is without oxygen, the more neurons will die and subsequently, there will be a greater degree of cognitive impairment. By reducing this ischemia, we can reduce the amount of neuronal death, thereby minimising the risk of developing more severe cognitive impairment.

The chronic aspect of concussive symptoms presents a larger problem. Long-term deficits in cerebral processing are a well-established possibility of severe concussions. On a biochemical level, trauma to the head begins a cascade of short-term physiological changes that force neurons to over-fire. This hyperexcitability places large amounts of strain on neurons and the structures that support them (Giza & Hovda, 2001). This ultimately leads to programmed cell death of said structures (apoptosis).

A study published in 2008 states that HBOT stimulates neural stem cells to proliferate and differentiate, thus ameliorating the damage (Yang, et al., 2008). The study uses rats with hypoxic-ischemic brain damage, which provides a comparable model to human concussions.

Stem cells are a key player in our body's repair process. In their undifferentiated form, they have the potential to fit into a diverse range of roles. By initiating stem cell proliferation, HBOT can help to scaffold a restorative process of greater intensity.

This is a promising opportunity for the industry, but as a wellness company we are conscious of our limits and this is beyond the scope of our application. More clinical evidence is needed in order for us to expand upon the benefits of AirPod Hydroxy therapy with more confidence

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