Hyperbaric Oxygen Therapy for Enhancing Athletic Performance: A Systematic Review

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Abstract

Background

Hyperbaric oxygen therapy (HBOT) is a medical treatment method that uses pure oxygen. This method has various applications in the treatment of carbon monoxide poisoning, diabetic feet, wound healing, and medical emergencies. HBOT has garnered interest among sports disciplines in enhancing athletic performance. The main aim of this systematic review was to assess the effect of HBOT on athletic performance.

Methods

The study was conducted by searching databases such as PubMed, Cochrane Central, Google Scholar, and Embase between January 1, 2015, and September 15, 2024. The key search terms used in this study were Hyperbaric Oxygen Therapy (HBOT), athletic performance, exercise performance, sports, and athletic recovery. Studies involving athletes or active individuals (both professional and recreational) and using HBOT as the intervention were included. Data was extracted using the PICO framework. Quality assessment was performed using ROB2 and ROBINS-1 tools.

Results

A total of 1510 studies were identified, of which 16 met the eligibility criteria. The HBOT intervention in the included studies ranges between 1.3 ATA and 2.5 ATA. Comparators used in these studies include sham treatment, passive recovery, natural recovery, and without HBOT. Most studies have reported the benefits of HBOT in improving oxygen saturation, muscle soreness reduction, and recovery post-training. The risk of bias in the individual studies was low, making them reliable.

Conclusion

HBOT appears to be an efficient method for improving athletic performance, mainly after injury or intense exercise. However, given the heterogeneity of methods and treatment effects across the studies, further robust research is required to quantify the impact of HBOT and develop a protocol for athletes.

Keywords: athletic performance, Hyperbaric Oxygen Therapy. Muscle repair, Recovery

Introduction

Hyperbaric Oxygen Therapy (HBOT) is a medical treatment approach mainly based on exposure to pure oxygen concentration under increased atmospheric pressure. The pressure may be 1.4 atm or more, according to the Undersea and Hyperbaric Medical Society (UHMS) [1]. HBOT has been used in various applications such as carbon monoxide poisoning, diabetic foot [2], wound healing [3], and medical emergencies such as air or gas embolism, decompression sickness, acute arterial insufficiencies, cyanide poisoning [4], inflammation [5], and cancer [6]. Recently, HBOT has been used by athletes to accelerate recovery from injury or muscle damage caused by exercise [7][8][9]. An ATA of 1.3 can be used to improve recovery in athletes.

HBOT uses oxygen under a pressure greater than the pressure of the Earth's surface at sea level [10]. This pressure equals or exceeds 1.4 ATA when 100% oxygen is inhaled. The more accessible pressure for oxygen intake is 1.2 to 1.3 ATA, which can be used in other applications as well [11][12]. HBOT increases oxygen dissolution into the blood plasma and capillary diffusion owing to partial differences in pressure. This can help improve the availability of oxygen in the tissues, which helps in the maintenance of normal cell function [10][11]. HBOT can be used as an adjuvant treatment for improving muscle repair and recovery in athletes or for muscle damage caused by exercise [8]. Oxygen plays an important role in fatigue recovery [13]. Additionally, HBOT influences the removal of blood lactate, improving recovery after intense exercise [8][12]. Some studies have suggested that inflammatory cytokines, such as fibrinogen, interleukin, and tumor necrosis factors, may be biomarkers for inflammatory responses caused by sports or exercise [14]. Additionally, muscle damage can be indicated by serum creatine kinase (CK) and lactate dehydrogenase (LDH) [15]. HBOT can be employed in the treatment of musculoskeletal injuries caused by sports, as it helps improve oxygen delivery and reduces edema and pathological inflammation. Additionally, HBOT helps to reduce reperfusion of ischemic injuries [16]. The increase in oxygen supply may help to improve the recovery from muscle damage caused by exercise and reduce inflammation, which can improve the physical performance of athletes by improving efficient cellular metabolism.

Athletes involved in high-intensity sports aim to improve their performance by reducing their recovery time. HBOT can help improve recovery, reduce muscle soreness, and enhance endurance and strength in athletes. This method can be effective in athletes who experience repeated muscle injuries, fatigue, and oxidative stress. Despite the interest in using HBOT for sports-related treatment in athletes and fitness professionals, evidence supporting this remains inconclusive. Some studies have reported a significant improvement in recovery and performance, whereas others have shown minimal or no benefits.

This systematic review mainly evaluated the available scientific literature regarding the effects of HBOT on athletic performance. This review focuses on studies that have assessed the efficiency of HBOT in improving the recovery time, muscle strength, endurance, and healing of injuries in athletes or physically active individuals. It also analyzes the physiological effects of HBOT, such as changes in oxygen saturation, muscle soreness, and recovery biomarkers.

Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) [17].

Search strategy

An extensive literature search was made using PubMed, Cochrane Central, Google Scholar, and Embase databases. All databases were searched for eligible articles published from January 1, 2015, to September 15, 2024. The search terms used were hyperbaric oxygen therapy, athletic performance, HBOT, sports injuries, exercise performance, sports, and muscle recovery. Here, the Boolean expression AND/OR was used in appropriate places.

Further searches were conducted using the reference lists of related reviews on this topic to ensure that most studies were included. The search and inclusion criteria did not restrict the gender of the participants. Article screening was done independently, and issues were resolved by discussion.

Inclusion and exclusion criteria

Included were studies involving athletes or active individuals (both professional and recreational) and using hyperbaric oxygen therapy as the intervention. The outcomes of the studies that measured performance or recovery were included. Studies involving non-athletes and those with insufficient methodological quality were excluded. Articles such as reviews, commentaries, and editorials were not considered. Studies in which the primary focus was unrelated to performance were excluded. Additionally, studies with no full text available, those that were non-English, and abstracts were excluded.

Data extraction

This study employed the PICO framework. Here, Population (P) is athletes or active individuals (professional or recreational), intervention (I) has Hyperbaric Oxygen Therapy (HBOT), comparator (C) is no HBOT, placebo, or alternative treatments like physical therapy, rest, and outcome (O) includes measures of athletic performance, muscle recovery, injury healing, and physiological effects such as oxygen saturation and muscle soreness.

The data was independently extracted using standard Excel. All issues were resolved through discussion. The extracted data included author or year, study design, sample size, population, intervention, comparator, and outcome measures, such as changes in athletic performance, speed, strength, and endurance. Improvement in recovery times post-exercise or injury, measures of oxygen saturation, blood lactate concentration, muscle soreness, recovery biomarkers, and changes in pain and inflammation.

Quality assessment

The same reviewers evaluated the quality of individual studies using Cochrane risk of bias assessment tools like ROB 2 and the non-randomized studies (ROBINS-1) tool [18][19]. ROB 2 was used to evaluate the risk of bias in randomized trials and crossover studies. ROBINS-1 was used to evaluate non-randomized studies, such as case series, retrospective, and before-after studies. The assessment was visualized using the Robvis tool [20].

Results

Articles from the aforementioned databases were systematically searched, and 1510 studies were identified. Among these, 49 articles were removed as duplicates, and 1155 articles were removed as they were irrelevant. Subsequently, 306 studies were screened for title and abstract, and 261 articles were excluded. 45 articles were assessed for their eligibility. Among the 45 articles, 19 were excluded because they did not have the required outcomes, and ten were unrelated to the study objectives. Finally, sixteen studies [12][13][21][22][23][24][25][26][27][28][29][30][31][32][33][34] have met the eligibility criteria and are included in this systematic review. The characteristics of the included studies are given in Table 1.

The study design included one double-blind, randomized, placebo-controlled trial [21], two randomized crossover trials [22][13], three randomized controlled trials [12][23] [29], one prospective cohort study [24], one randomized controlled pilot study [25], an experimental animal study [26], one randomized control group design [27], one animal study (rat model) [28], two randomized single-blind studies [30][31], one before-after study [32], one case series [33], and one retrospective case series with post-intervention data analysis [34]. The HBOT intervention in the included studies ranges between 1.3 ATA to 2.5 ATA. Various comparators have been used in individual studies, such as sham treatment [21], passive recovery [22][13], natural recovery [23], without HBOT [24][12], normobaric, normoxic conditions [29][25][31], hypobaric, hypoxic, and HBOT, no treatment [26][28], hyperbaric air therapy [33], and traditional rehabilitation protocol [34].

Quality assessment

The risk of bias for randomized studies was assessed using ROB 2.0 for five domains. All studies showed a low risk of bias, making the studies reliable. All these studies have been well executed, transparently reported, and have had complete data [21][22][23][25][12][29][30]. Non-randomized studies were assessed using the ROBINS-1. All nine studies have a moderate risk of confounding bias; however, other domains were found to be of low risk [13][24][26][27][28][31][32][33][34]. This gives the studies a low overall risk, making them reliable. The studies evaluated by ROB 2.0 and ROBINS I have been shown in Figure 2 and Figure 3, respectively.

Discussion

The studies in this review observed HBOT and its benefits in athletic performance. HBOT can improve various physiological parameters that can help improve performance outcomes in athletes. Hadanny et al. [21] observed that HBOT showed some improvement in maximal oxygen uptake (VO_2Max) and mitochondrial respiration in middle-aged athletes. This suggests that HBOT may improve aerobic capacity. Similarly, Mihailovic et al. [22] reported improved cycling power output and heart rate variability recovery after post-exercise HBOT. This indicates that HBOT can help endurance athletes.

However, not all studies have demonstrated similar improvements after HBOT. In a study by Solakovic (2020), HBOT did not lead to significant strength gains compared with the control groups using anabolic steroids. However, some cardiovascular benefits, such as a reduction in LDL cholesterol, were noted. This shows that HBOT may help in recovery and some physiological improvements in athletic performance but may not be an optimal solution.

One of the advantages observed in using HBOT treatment in athletes is that it helps in improving recovery after an injury or exercise in the context of Creatine Kinase (CK) levels [35][36]. CK is mainly used to analyze the adaptation of muscles to the intensity of exercise and injury after exercise. Damage to the muscle membrane or any changes in permeability will increase blood CK levels due to cell membrane damage perpetuating oxidative stress [37]. In a study by Zhu et al. [23], a significant reduction in oxidative stress markers and muscle damage enzymes, such as CK, was observed after a four-week HBOT treatment in elite athletes. Yamamoto et al. [26] have also observed that HBOT can improve muscle healing, reduce inflammation, and promote angiogenesis. Regardless, some researchers believe that HBOT may not be effective in reducing CK levels after exercise. There are also some studies in which the HBOT intervention has failed in improving muscle pain and reducing CK levels [38][39].

Park et al. [12] have identified that HBOT can improve the clearance of lactase and recovery of heart rate. This shows that HBOT has helped in reducing fatigue after exercise and improves metabolic recovery. Similarly, Ishii et al. [8] have also reported that HBOT has shown lactate recovery in athletes. The accumulation of lactate can be considered a major determinant of fatigue [40]. Hence, the removal of lactate is a significant factor in exercise performance [41]. Also, the studies by Branco et al. [13] and Widiyanto & Hartono [27] have also observed improvements in recovery and lactate metabolism. This suggests that HBOT can help in post-exercise recovery.

The performance endurance of athletes can be assessed by VO_2Max, AT, and efficiency of exercise [42]. The capacity of mitochondrial oxidative phosphorylation in skeletal muscles is key for all three components. The VO_2Max value of a person will be limited by blood flow in muscles, cardiac output and also the capacity of blood to carry oxygen [43]. There is a linear relationship between VO_2Max and mitochondrial volume density [44]. Of note, the oxidative capacity of skeletal muscles is also related to mitochondrial capacity [45]. HBOT improves the availability of the oxygen necessary for metabolic functions like mitochondrial function and reduction of oxidative stress. Hadanny et al. [21] have analyzed that HBOT can improve mitochondrial respiration and oxygen phosphorylation capacity. This may act as a mechanism for improving endurance performance. Similarly, the study by Zhu et al. [23] has also found that HBOT reduced oxidative stress and improved the enzyme activity of antioxidants. This may enable athletes to manage their physiological strain effectively during high-intensity exercise. In the study carried out on animal models by Oyaizu et al. [28], it was observed that HBOT helped increase tissue oxygenation, reduce inflammation, and improve muscle regeneration.

Some studies, nevertheless, did not demonstrate consistent results with respect to the overall relationship between HBOT and muscle recovery markers. In the study by Branco et al. [13] and Zinner et al. [30], it was observed that HBOT did not affect important recovery markers like blood lactate concentration or muscle activity. This affects the overall efficiency of the HBOT in some areas. Also, in the study by Solakovic [24], the benefits of HBOT have not been stated clearly, and it may limit HBOT from being a standalone treatment method for improving athlete performance.

Despite the positive influence of HBOT on athlete's performance, some limitations are present in this systematic review. The inconsistency across the studies can be attributed to the variability in their individual HBOT protocol (i.e., pressure and duration) and varying measures of athletic performance. Additionally, several studies included only recreational athletes or athletes from specific sports, which may not reflect the broader question of athletic performance. HBOT likely exhibits treatment effect heterogeneity, and the variability in the methodology across the included studies makes it challenging for this systematic review to quantify the treatment effect of HBOT on athletic performance. Future researchers must aim to standardize these variations across diverse athletic populations to obtain more reliable and generalizable results. It is also essential for athletes and sports medicine practitioners to assess the benefits of HBOT in recovery and healing with performance metrics like endurance and strength.

Conclusion

HBOT seems to be an efficient method for improving athletic performance, mainly after injury or intense exercise. Several studies in this review have observed the potential benefits of HBOT. That includes the improvement in muscle recovery, reduction in soreness, and improvement in oxygen saturation. However, the direct evidence for their impact on athletic performances, such as speed, strength, and endurance, is inconclusive due to the heterogeneity of treatment effect and variability across the studies. Regardless, HBOT has shown potential as a supportive recovery tool during injury or high-intensity exercise. There is simply a need for large-scale trials and standard HBOT protocols to determine HBOT efficiency in athletic performance. HBOT may be considered a complementary treatment method for the improvement of athletic performance rather than a primary intervention method.

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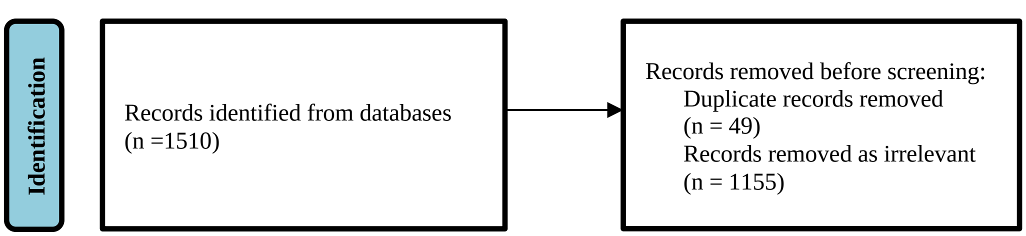

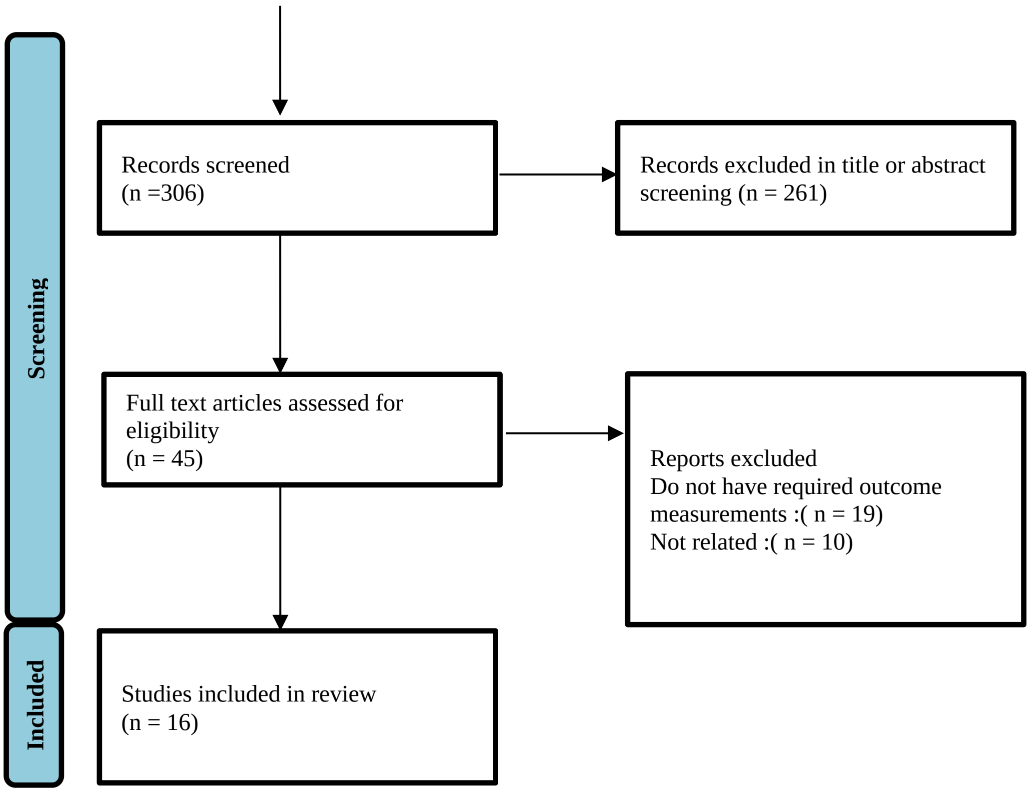

Figure 1. PRISMA flow diagram

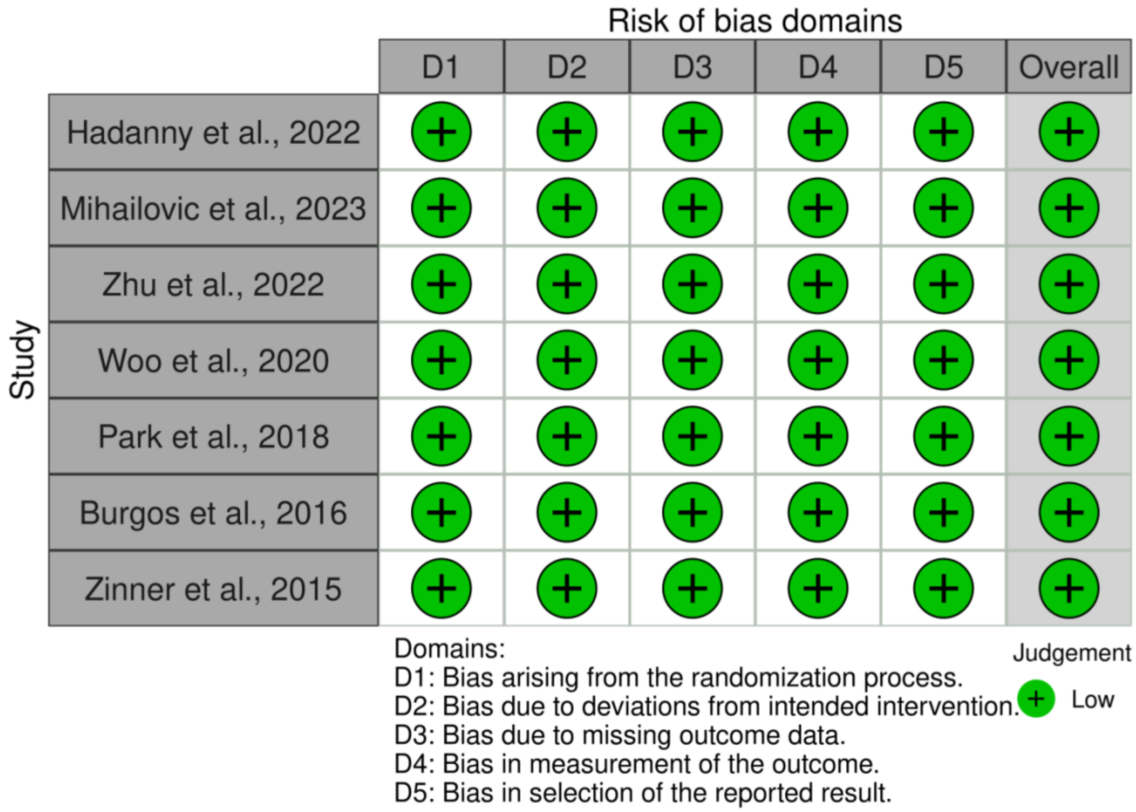

Figure 2. Risk of bias quality assessment using ROB2

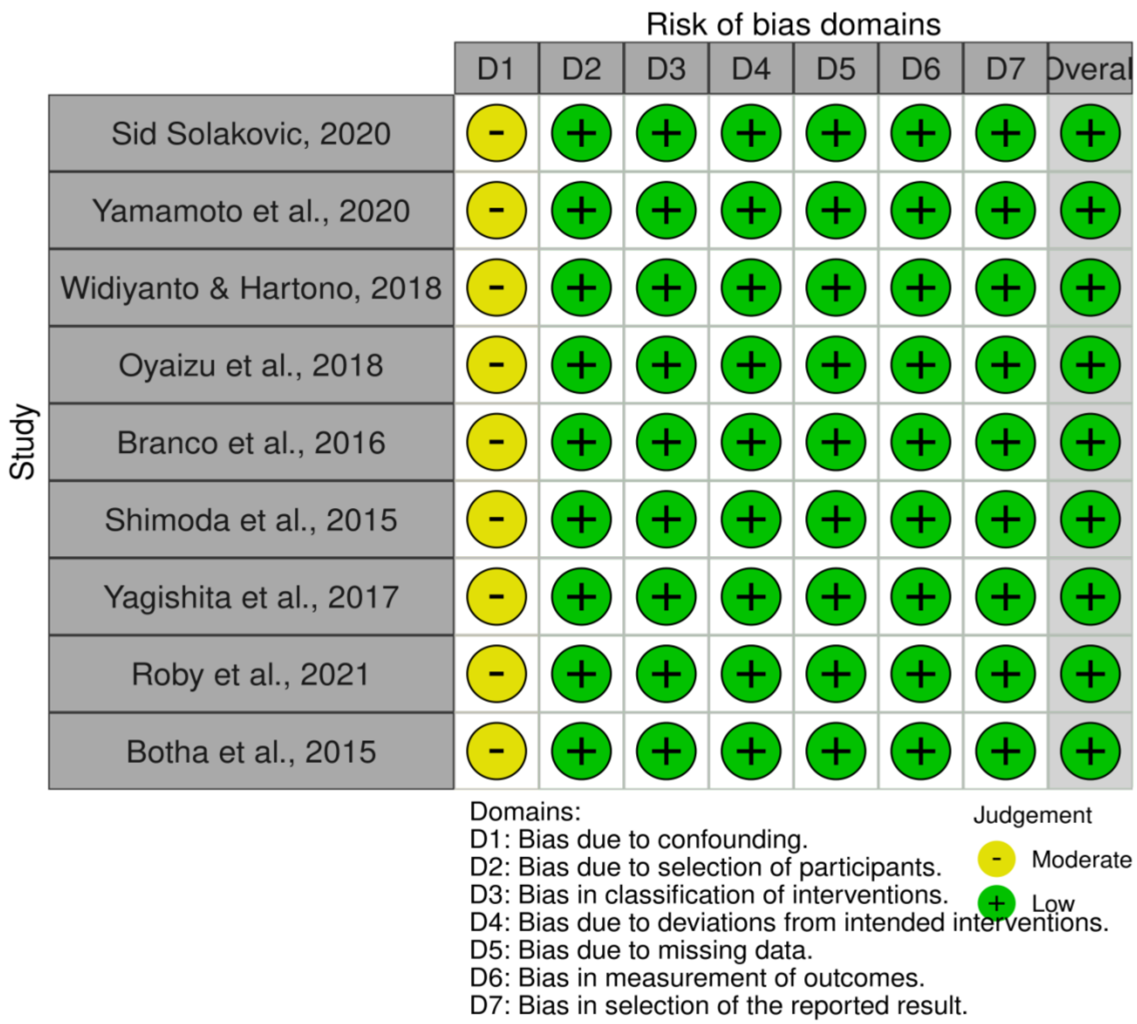

Figure 3. Risk of bias quality assessment using ROBINS-I

Table 1. Characteristics of included studies

Author/ Year	Study Design	Sample Size	Population	Intervention	Comparator	Changes in athletic performance (e.g., speed, strength, endurance).	Improvement in recovery times post-exercise or injury.	Measures of oxygen saturation, blood lactate concentration, muscle soreness, and recovery biomarkers	Changes in pain and inflammation.	Findings
Hadanny et al., 2022 [21]	Double-blind, randomized, placebo-controlled trial	37	Healthy, middle-aged master athletes	Hyperbaric Oxygen Therapy (HBOT) – 40 sessions, 2 absolute atmospheres (ATA), 100% oxygen for 1 hour	SHAM – 1.02 ATA, breathing air for 1 hour	Improved VO_2Max and VO_2AT	Not directly measured	Significant improvement in VO_2Max and mitochondrial function	Not measured	HBOT improved performance and mitochondrial respiration
Mihailovic et al., 2023 [22]	Randomized crossover trial.	12	Trained male cyclists	Post-exercise hyperbaric oxygenation (HBO) with 97% O_2 at 1.3 ATA pressure for 75 minutes.	Passive recovery	Cycling power output increased	HBO improved heart rate variability (HRV) recovery and reduced perceived exertion (RPE).	No difference in blood lactate concentration	HBO significantly improved perceived recovery status the day after testing.	HBO facilitates better post-exercise recovery, potentially improving subsequent athletic performance.

Zhu et al., 2022 [23]	Randomized Controlled Trial (RCT)	18	Experimental group: 8 athletes Control group: 8	4-week micro HBO intervention at 1.3 ATA, conducted 4 times per week for 1 hour each session. Pressure: 1.3 ATA. Time: 60 minutes per session.	Control group with natural recovery (no HBO intervention).	Not directly measured	Significant reductions in oxidative stress (lower MDA and PC) and increased antioxidant enzyme activity (higher T-AOC, SOD, CAT) in the experimental group after 4 weeks.	Decreases in markers of muscle damage (CK)	Not directly measured	HBO intervention significantly reduced oxidative stress (MDA and PC) and improved antioxidant enzyme activity (SOD, CAT, and T-AOC) in skeleton athletes. There was a reduction in exercise-induced muscle damage (lower CK levels) in the experimental group.

Sid Solakovic 2020 [24]	Prospective cohort study (6-month observational study)	72	Young male recreational bodybuilders, aged 20-30, using anabolic steroids, with and without hyperbaric oxygen therapy (HBOT)	20 sessions of hyperbaric oxygen therapy along with anabolic steroid use.	Only anabolic steroid use without HBOT	There were no significant strength improvements in the HBOT group compared to the non-HBOT group. The only significant difference was seen in the bench press	HBOT showed some benefits for recovery after gym efforts, although not as significant as the effects of anabolic steroids on strength gains	LDL cholesterol decreased significantly in the HBOT group over 6 months, while it increased in the non-HBOT group. Systolic blood pressure was higher in the HBOT group.	Not directly measured	The use of anabolic steroids has a detrimental effect on cardiovascular health in young recreational bodybuilders. While hyperbaric oxygen therapy (HBOT) did not significantly improve muscle strength over the control group, it did show potential cardiovascular benefits, particularly in reducing LDL cholesterol and systolic blood pressure. Recovery: HBOT showed some promise in aiding recovery, although not at a level that would compensate for the damaging effects of anabolic steroid abuse.
Woo et al., 2020 [25]	Randomized controlled pilot study with repeated measures	18	Healthy males (aged 20-30)	Participants underwent 60 minutes of HBOT breathing 100% oxygen at 2.5 ATA after acute exercise.	Normobaric normoxic conditions	Not directly measured	Decreased CK and LDH	Decreased inflammation markers (IL-6, fibrinogen)	Not directly measured	HBOT could be a potential intervention to alleviate post-exercise inflammation and muscle damage, especially after training in hypoxic environments.

Yamamoto et al., 2020 [26]	Experimental animal study	445 male Wistar rats	Male Wistar rats subjected to muscle contusion injury	Hyperbaric oxygen (HBO) therapy (2.5 ATA 100% oxygen for 120 minutes daily for 5 consecutive days)	No treatment (NT) group and inhibitor groups (ROS inhibitor NAC and NOS inhibitor L-NAME)	Not measured	HBO accelerated recovery of muscle healing and angiogenesis compared to the NT group.	Increased nitric oxide (NO_3^-), VEGF, bFGF, and HIF1α levels after HBO treatment, indicating enhanced angiogenesis and muscle recovery.	HBO-treated rats showed reduced inflammation and increased blood vessel formation.	HBO treated rats have observed to be recovered faster compared to control group.
Widiyanto & Hartono, 2018 [27]	Randomized pretest-posttest control group design	30	Male students aged 19-23 years from the School of Sport Sciences, Surabaya State University	Group 1: Hyperbaric oxygen (HBO) recovery at 1.3 ATA after the Running-based Anaerobic Sprint Test (RAST) Group 2: HBO recovery at 1.8 ATA after RAST Group 3: Active recovery (jogging) after RAST	HBO 1.3 ATA	Not measured	HBO 1.3 ATA showed the most effective recovery, suggesting that increased oxygen supply to muscles improved lactate metabolism and recovery from fatigue, but there were no significant differences in fatigue index between treatments.	HBO 1.3 ATA showed the most effective recovery, suggesting that increased oxygen supply to muscles improved lactate metabolism and recovery from fatigue, but there were no significant differences in fatigue index between treatments.	HBO 1.3 resulted in the lowest fatigue index (6.7 watts/second) compared to HBO 1.8 and active recovery.	Hyperbaric oxygen at 1.3 ATA is more effective than both HBO 1.8 ATA and active recovery in lactate removal, promoting better recovery post-exercise. However, there were no significant differences in fatigue reduction across the recovery methods.

Oyaizu et al., 2018 [28]	Animal study (rat model)	Approx. 400 rats	Male Wistar rats	Hyperbaric oxygen treatment (HBO), 100% O2 at 2.5 ATA for 2 hours/day for 5 days post-muscle contusion	Non-treatment (NT)	HBO improved muscle isometric strength at 7 days after injury compared to NT group	HBO reduced muscle volume and wet weight in the early phase and accelerated muscle regeneration.	Increased tissue oxygenation and oxygen saturation. Decreased hypoxia in injured muscles for 30 hours post-HBO. Higher recovery in twitch/tetanic muscle strength	HBO reduced inflammation by suppressing circulating macrophages in the acute phase and accelerating macrophage invasion into injured tissue later on. IL-6/STAT3 pathway stimulated early post-injury	HBO reduced inflammation, improved oxygenation in injured muscle, and accelerated muscle regeneration. HBO resulted in higher muscle strength and faster satellite cell proliferation/differentiation, and reduced swelling compared to the NT group.
Park et al., 2018 [12]	Randomized controlled trial (RCT)	10 (all male)	Healthy male college athletes (amateur soccer players)	Low-pressure hyperbaric oxygen (HBO) treatment at 1.3 ATA pressure for 30 minutes before and after maximal exercise	Control group (no HBO treatment)	Not measured	Faster heart rate recovery in the HBO-treated group after maximal exercise, suggesting enhanced recovery from intense physical exertion	HBO treatment after maximal exercise reduced lactate levels after 30 minutes of recovery, indicating improved removal of fatigue substances.	Not measured	Low-pressure HBO treatment post-exercise positively impacted recovery markers, specifically lactate clearance and heart rate recovery, without significantly affecting antioxidant capacity. This supports its potential utility in enhancing post-exercise recovery in athletes.

Branco et al., 2016 [13]	Randomized cross-over design.	11	Brazilian jiu-jitsu athletes	Hyperbaric oxygen therapy (OHB) for 1 hour and 40 minutes, with oxygen provided at a pressure of 2.39 ATA. Control condition: Passive recovery for 2 hours.	Passive recovery.	Not measured	Higher RPR scores at 2 hours and 24 hours post-training in the OHB condition.	Lactate Concentration: No significant. Rating of Perceived Exertion (RPE): No significant difference. Hormonal and Cellular Damage Markers: No significant differences observed	Not measured	while OHB might not influence objective recovery measures, it could improve athletes' perception of recovery.

Burgos et al., 2016 [29]	Randomized controlled trial.	12 .	Young soccer players (18.6 ± 1.6 years) from the Chilean National Soccer Championship.	Groups: Hyperbaric Hyperoxia (HH) training group (2 ATA, 100% O2). Normobaric Normoxia (NN) training group (1 ATA, normoxic air). Duration: 3 weeks. Training: 30 minutes of endurance exercise on a cycle ergometer at 75% VO2max, 5 times per week.	Normobaric Normoxia (NN)	Not measured	VO2max and PPO improved in the HH group with a moderate effect size. No significant differences in VO2max or PPO between groups before and after training using traditional statistical methods.	No significant changes in oxidative stress markers or antioxidant capacity in either HH or NN groups. NN group showed significant increases in blood lactate post-exercise compared to HH group. NN group experienced significant reductions in HCO3− and BE after training sessions, unlike the HH group.	Not measured	HBO2 endurance training improved endurance performance without increasing oxidative stress markers. The results suggest potential benefits of hyperbaric oxygen training on endurance performance, but further investigation is needed to confirm these findings.

Zinner et al., 2015 [30]	Randomized, counterbalanced, single-blind, within-subject design.	10	Male endurance athletes	Normoxic exercise and normoxic recovery. Normoxic exercise and hyperoxic recovery. Hypoxic exercise and hypoxic recovery. Hypoxic exercise and hyperoxic recovery.	Comparison of effects between the different recovery and exercise conditions.	Not measured	Arterial Hemoglobin Saturation: Higher during hyperoxic recovery compared to normoxic or hypoxic recovery conditions. Muscle Activity: Integrated muscle electrical activity was not significantly influenced by the oxygen content Tissue Oxygenation: Significant difference in tissue saturation index between NoNo and HoHOX/NoHOX conditions ($P < 0.05$, d = 0.93).	Blood Lactate Concentration: Elevated after warm-up and higher in HoHo compared to NoHOX before the second interval (d = 1.0). pH Levels: Fell continuously after the first interval, most notably during HoHOX (d = 4.08).	Not measured	Hyperoxic recovery during normoxic or hypoxic exercise can be beneficial, as it prevents a decline in performance and improves arterial oxygen saturation without significantly affecting muscle activity or tissue oxygenation.

Shimoda et al., 2015 [31]	Randomized single-blind experimental study	20	Physically fit males aged 21-24 years	Hyperbaric oxygen (HBO) therapy – 100% oxygen at 2.5 ATA for 60 minutes	Normoxic treatment – At 1.2 ATA for 70 minutes	Torque during maximal isometric plantar flexions (FT) was significantly higher in the HBO group	RMS values were higher in the HBO group.	Not measured	Not measured	Hyperbaric oxygen therapy appears to help maintain muscle force production and reduce the progression of muscle fatigue during repeated contractions, suggesting it could be beneficial for preventing excessive muscle fatigue in activities involving repeated exertion.
Yagishita et al., 2017 [32]	Before-after study	44 patients (39 male, 5 female)	Athletes with acute ankle sprain (mean age 23.2 years, range 13-36 years)	Hyperbaric Oxygen Therapy (HBO2) at 2.5 ATA for 60 minutes/session	Baseline measures (pre-intervention)	Not measured	Significant reductions in pain (both at rest and during walking) and edema, suggesting faster recovery post-exercise or injury.	Not measured	Significant reductions in pain at rest and during walking were observed after each HBO2 session. Edema was also significantly reduced, measured both by foot and ankle volume and subjective VAS evaluations.	Significant reduction in ankle volume post-HBO2 (mean reduction of 11.3 cm^3/session, $p<0.001$) VAS scores decreased for pain at rest, pain while walking, and subjective edema evaluation (all $p<0.05$) HBO2 therapy shows short-term reductions in pain and edema in acute ankle sprains

Roby et al., 2021 [33]	Case series with random assignment to treatment groups	8 participants (5 males, 3 females)	High school student-athletes diagnosed with acute sport-related concussions	HBO2 Therapy: 100% oxygen at 1.5 atmospheres Hyperbaric Air Therapy (HBA): Medical-grade air at 1.5 atmospheres Oxygen Therapy (O2): 100% oxygen under normobaric conditions	HBO2 therapy, HBA therapy, and O2 therapy	Not measured	HBO2 Therapy: Average time to return to activity was 13.7 ± 5.1 days. HBA Therapy: Average time to return to activity was 13.0 ± 5.7 days. O2 Therapy: Average time to return to activity was 19.0 ± 16.5 days.	Not measured	HBO2 Group: Symptom reduction ranged from 77.8% to 93.5%. HBA Group: Symptom reduction ranged from 81.1% to 87.5%. O2 Group: Symptom reduction ranged from 83.3% to 95.7%.	HBO2 therapy and HBA therapy were associated with quicker reductions in symptoms compared to O2 therapy. All groups returned to activity in similar timeframes, but HBO2 and HBA therapies demonstrated notable symptom reductions, suggesting potential benefits in reducing post-concussion symptom burden
Botha et al., 2015 [34]	Retrospective case series, post-intervention data analysis	42	Professional rugby players Injury Type: Hamtring injuries classified as Grade 1 (mild) or Grade 2 (moderate)	HBOT: 1-hour sessions at 2.4 ATA (atmospheres absolute), conducted three times a week, for up to 11 total sessions	Traditional rehabilitation protocol (21 days for Grade 1, 42 days for Grade 2 injuries)	Not measured	Significant reductions in recovery time for Grade 1 and Grade 2 hamstring injuries.	Not measured	Pain was managed using the Visual Analog Scale with rehabilitation tailored to ensure discomfort remained below 2/10.	The study suggests that combining HBOT and PRP with traditional rehabilitation significantly reduces recovery times for hamstring injuries in professional rugby players. Further research is needed to confirm these findings and explore the mechanisms behind these results.