

Sports and Exercise Physiology	(Original article)
สิริวิทยาการออกกำลังกายและกีฬา	(นิพนธ์ต้นฉบับ)

ผลทันทีทันใจจากการใช้ความดันโลหิตในห้องแรงดันสูงที่มีอุกซิเจน 100% ต่อการพื้นตัวภายหลังการออกกำลังกายอย่างหนักในนักกีฬา

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บทคัดย่อ

การศึกษาครั้งนี้ได้ศึกษาผลของการพื้นตัวระยะสั้นของร่างกายจากการใช้อุกซิเจนภายใต้แรงดันสูงระดับต่างๆ ภายหลังการออกกำลังกายอย่างหนักในนักกีฬา เครื่องมือและวิธีการวิจัย ในการศึกษาครั้งนี้ใช้อาสาสมัครนักกีฬาภาคบดี ชายทีมชาติไทยจำนวน 8 คน (อายุ 24 ± 2.7 ปี, น้ำหนัก 75 ± 5.9 กิโลกรัม, ส่วนสูง 176 ± 5.5 เซนติเมตร) โดยทำการสูมวิธีการพักฟื้นที่ระดับแรงดันบรรยายกาศ 1.0, 1.3, และ 1.5 เท่าของแรงดันบรรยายกาศปกติ เป็นเวลา 45 นาที โดยระยะเวลาในการพักฟื้นในแต่ละภาระห่างกันอย่างน้อย 1 สัปดาห์ อาสาสมัครต้องออกกำลังกายอย่างหนักแบบไม่ใช้อุกซิเจนเป็นเวลา 120 วินาที ก่อนและภายหลังการพักฟื้นด้วยเครื่องไฮเปอร์เบริกแซมเบอร์ บันจารยาน Modified Wingate Anaerobic Test ผลการทดลอง ข้อสรุป ความดันโลหิต ความเข้มข้นของกรดแคลคติกในเลือดและระดับการรับรู้ความเหนื่อย ไม่พบความแตกต่างระหว่างสี่ตัวแปรข้างต้น ทันทีเมื่อเสร็จสิ้นการออกกำลังกาย หลังการพักฟื้นที่ระดับแรงดัน 1.5 เท่าของแรงดันบรรยายกาศปกติ มีระดับการเพิ่มขึ้นของอัตราการเต้นของหัวใจน้อยกว่าที่การพักฟื้นที่แรงดันบรรยายกาศ 1.3 เท่าของแรงดันบรรยายกาศปกติ (166.50 ± 2.38 และ 176.25 ± 2.23 ครั้ง/นาที) ($p < 0.05$) ค่ากำลังสูงสุดและค่ากำลังเฉลี่ย ของการออกกำลังกายหลังการพักฟื้นที่แรงดันบรรยายกาศ 1.5 เท่าของแรงดันบรรยายกาศปกติ (215.63 ± 8.98 วัตต์/กิโลกรัม และ 163.88 ± 4.49 วัตต์/กิโลกรัม) มีค่าสูงกว่าการออกกำลังก่อนการพักฟื้น (206.75 ± 10.08 วัตต์/กิโลกรัม และ 158.00 ± 3.64 วัตต์/กิโลกรัม) อย่างมีนัยสำคัญ ($p < 0.05$) จึงเป็นไปได้ที่การมีปริมาณอุกซิเจนสูงในระบบไหลเวียนเลือด ทำให้มีการสันดาปพลังงานเพื่อสำรองในกล้ามเนื้อได้มากขึ้น และยังพบว่าค่าระดับการรับรู้ความเหนื่อย ภายหลังการพักฟื้นที่แรงดันบรรยายกาศ 1.5 เท่าของแรงดันบรรยายกาศปกติ มีค่าน้อยกว่า ที่แรงดัน 1.0 และ 1.3 เท่าของแรงดันบรรยายกาศปกติ แต่ไม่มีความแตกต่างอย่างมีนัยสำคัญ

สรุป การพักฟื้นด้วยเครื่องไฮเปอร์เบริกแซมเบอร์ที่แรงดันบรรยายกาศ 1.5 เท่าของแรงดันบรรยายกาศปกติ 45 นาที ช่วยเพิ่มค่ากำลังสูงสุดและค่ากำลังเฉลี่ยได้ดีกว่าการพักฟื้นที่แรงดัน 1.0 และ 1.3 เท่าของแรงดันบรรยายกาศปกติ

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คำสำคัญ: ภาวะความดันอากาศสูง, อุกซิเจน, การพื้นตัว

INTRODUCTION

Various methods of recovery after exercise have been introduced, for example, active and passive recovery techniques in order to enhance recovery process have never been completely compensated, for example recovery duration of 25 min reduced about 50% lactic acid level (Gupta, 1996). Hyperbaric oxygenation (HBO_2), by which subjects breathed 100% oxygen under greater than 1 atmospheric pressure (ATA), has been introduced in clinical aspect (Ishii, 2005). Even though this pressurized chamber has been used in various aspects, investigations at HBO_2 on recovery outcomes are still controversial in that there is no consensus on the appropriate level of pressure. For example, breathing of 2.5 ATA in healthy subjects caused more rapid reduction of blood lactate level than 1ATA (Nuntaporn, 2000). While other investigators indicated 1.3 ATA as an appropriate level for HBO_2 intervention for lactate reduction (Ishii Y, et al. 1995) which exerted greater lactate clearance than 1.0 and 2.0 ATA. In animal model, dogs run in hyperbaric chamber at 3 ATA for 45 min caused reduction in blood lactate (Weglicki et al, 1996). It is believed that there must be an optimal pressure level which resulted in the best recovery variable in athletes following strenuous exercise. Since there are very few studies on HBO_2 and recovery of athletes, the present investigation will concentrate on effects of different levels of pressure applied to a constant 100% oxygenation on recovery after vigorous physical training.

MATERIAL AND METHOD

Eight-male Kabaddi National athletes volunteered for this study. Inclusion criteria included those with age between 20-30 yrs, healthy with no history of psychological problems, no history of musculoskeletal, joint diseases, cardiorespiratory problems, no history of seizure, nausea and vomiting, no history of ears, sinusitis. The purposes, benefits and possible side effects which might be occurred during experimental process were explained. Consent forms were signed prior to the test. Subject was excluded when later found to have breathing difficulties during the test, took medicine which may affect on conscious and judgement, could not adjust under hyperbaric condition and had signs of oxygen toxicity (e.g. nausea, muscle twitching, irritability, dizziness and convulsion). This study had been approved by Mahidol University' Ethic Committee on Human Experiment (MU-IRB 2012/055.1906).

Data collections included anthropometry and % body fat (Inbody), cardiac variables of heart rate (Polar Electro-series S810, Kempele, Finland), blood pressure (Omron, Japan), blood lactate (AccuTrend Lactate strips Nova Biomedical, USA.) were performed before and after HBO_2 exposures, before and after exercises. Subjects' instruction was provided to ensure that they had enough water consumption, regular meal of at least 3 hrs before the test. Subject's resting condition was detected after sat quietly at least 15 min. Laboratory condition was set at 25° Celcius, 45-50% relative humidity. First set of data was collected at rest. Subject was then asked to warm-up and stretching followed by cycling with free load for 5 min. Modified Wingate anaerobic test at workload of $0.075 * \text{body weight (kg)}/5$ which enabled subject to continue maximal cycling speed for 2 min (Soavieng et al., 2011), was then started for 2 min. where peak anaerobic power output

(PPO), average anaerobic power output (watts) were derived. Subject was then supine in a HBO₂ chamber in which all possible ignite monitoring devices were taken out. Chamber's pressure was randomly set up at 1, 1.3, 1.5 ATA, with constant 100%O₂ for total treatment duration of 45 min. Investigator was outside the chamber and took close care and supervision at all time via an intercom. Set of data was collected immediately when subject came out from the chamber. Then second modified Wingate anaerobic test was repeated where another set of data was collected. Data were compared using Paired *t*-test to compare differences of blood lactate and performance between 2 exercise tests. Repeated measure ANOVA was used to analyze differences among blood lactate levels and performance after 1, 1.3 and 1.5 ATA interventions. Significant level was set at *p* < 0.05 level.

RESULT

Subjects' characteristics (mean and SD) were 24.13 \pm 2.79 yrs of age, height of 176.00 \pm 5.53 cm, body weight of 75.69 \pm 5.94 kg and body mass index of 20.14 \pm 1.12 kg.m² with % body fat of 23.64 \pm 2.25. Most of the above characteristics are in normal ranges of young Thai population (Physical Fitness Test and Promotion Section Sports Authority of Thailand, 2012). Therefore, investigators successfully recruited normal healthy adults for the present study. Laboratory conditions during 1, 1.3 and 1.5 ATA were controlled (25.08 \pm 0.47, 24.95 \pm 0.05 and 25.14 \pm 0.26 $^{\circ}$ Celcius respectively) which showed no significant difference among conditions.

There was significant different of heart rate at immediate post-Wingate anaerobic exercise 2 between 1.3 and 1.5 ATA HBO₂ with 45 minutes duration (Table 1) where heart rate of 1.5 ATA was lower than that of 1.3 ATA (*p*<0.05). No significant differences of systolic and diastolic blood pressures, of all conditions, were found among all groups.

Table 1. Vital signs (Means \pm SEM.) including heart rate, systolic and diastolic blood pressures at rest, immediate post Wingate anaerobic exercises 1 and 2 with HBO2 interventions with 1.0, 1.3 and 1.5 ATA and 100%oxygen for 45 minutes duration.

		Oxygen 100%, 45 min with varies pressures (ATA)		
		1.0	1.3	1.5
Heart rate (bpm)	Baseline	62.25 \pm 1.49	64.25 \pm 3.59	61.75 \pm 2.49
	Post-ex 1	170.50 \pm 2.62	172.50 \pm 2.67	165.25 \pm 2.21
	Post-HBO	70.00 \pm 4.49	71.13 \pm 2.85	69.00 \pm 4.41
	Post-ex 2	171.00 \pm 3.09	176.25 \pm 2.23	166.50 \pm 2.38 ^c
SBP (mmHg)	Baseline	110.88 \pm 3.58	107.00 \pm 3.84	111.00 \pm 4.09
	Post-ex 1	146.25 \pm 3.75	142.13 \pm 3.66	151.25 \pm 5.18
	Post-HBO	115.00 \pm 4.50	108.50 \pm 2.82	113.63 \pm 4.25
	Post-ex 2	150.75 \pm 5.37	148.88 \pm 2.43	153.00 \pm 6.94
DBP (mmHg)	Baseline	71.63 \pm 2.69	69.25 \pm 3.36	70.75 \pm 2.39
	Post-ex 1	71.25 \pm 1.25	69.50 \pm 1.55	70.25 \pm 3.19
	Post-HBO	70.00 \pm 3.27	66.00 \pm 2.00	70.13 \pm 1.79
	Post-ex 2	72.50 \pm 2.56	67.25 \pm 2.99	72.22 \pm 3.24

* significant difference from resting condition, $p < 0.05$

^a significant difference between 1.0 and 1.3 ATA condition, $p < 0.05$

^b significant difference between 1.0 and 1.5 ATA condition, $p < 0.05$

^c significant difference between 1.3 and 1.5 ATA condition, $p < 0.05$

Blood lactate concentrations (mmol/L) reveals that 2 min anaerobic exercise bout induced remarkable increase up to 10-12 folds from resting values (Table 2) and these levels were not fully recovered from effects of HBO2 intervention. Immediate post-anaerobic exercises and post-HBO2 shows no significant change among groups and conditions.

Table 2. Blood lactate concentrations at rest, immediate post-anaerobic exercise 1 and recovery from HBO2 (means \pm SEM)

Variables	Time at Collection	Oxygen 100%, 45 min with varies pressures (ATA)		
		1.0	1.3	1.5
Lactate (mmol/L)	Rest	1.66 \pm 0.16	1.41 \pm 0.23	1.23 \pm 0.18
	Immediate post-anaerobic ex 1	12.05 \pm 1.38	11.34 \pm 1.35	12.40 \pm 1.01
	Post recovery	3.91 \pm 0.67	3.63 \pm 0.34	3.34 \pm 0.38

Anaerobic peak power output (PPO; watts) and average power output (watts) shows the significant differences only at 1.5ATA condition where post-HBO2 exposure induces higher anaerobic peak power output ($p<0.05$) and average power output ($p<0.05$) (Table 3).

Table 3. Peak (PPO) and average anaerobic performance from 2 exercises before and after exposed to 1.0, 1.3 and 1.5 ATA HBO₂.

Variables	Time at Collection	Oxygen 100%, 45 min with varies pressures (ATA)		
		1.0	1.3	1.5
PPO (watts)	1 st Anaerobic ex 1 (pre HBO ₂)	209.00 \pm 9.54	213.75 \pm 9.81	207.13 \pm 10.03
	2 nd Anaerobic ex2 (post-HBO ₂)	205.63 \pm 9.79	211.50 \pm 7.09	215.88 \pm 8.92 ^d
Average power (watts)	1 st Anaerobic ex 1 (pre HBO ₂)	155.13 \pm 4.41	158.75 \pm 3.94	158.75 \pm 3.77
	2 nd Anaerobic ex2 (post-HBO ₂)	157.75 \pm 5.24	161.50 \pm 5.32	164.13 \pm 4.56 ^d

^d significant difference between pre- and post-HBO₂, $p<0.05$

Figure 4.1 Heart rates obtained from interventions with 100%oxygen at 1.0, 1.3 and 1.5 ATA. Data were collected at immediate post-exercise 2 and 45 min recovery.

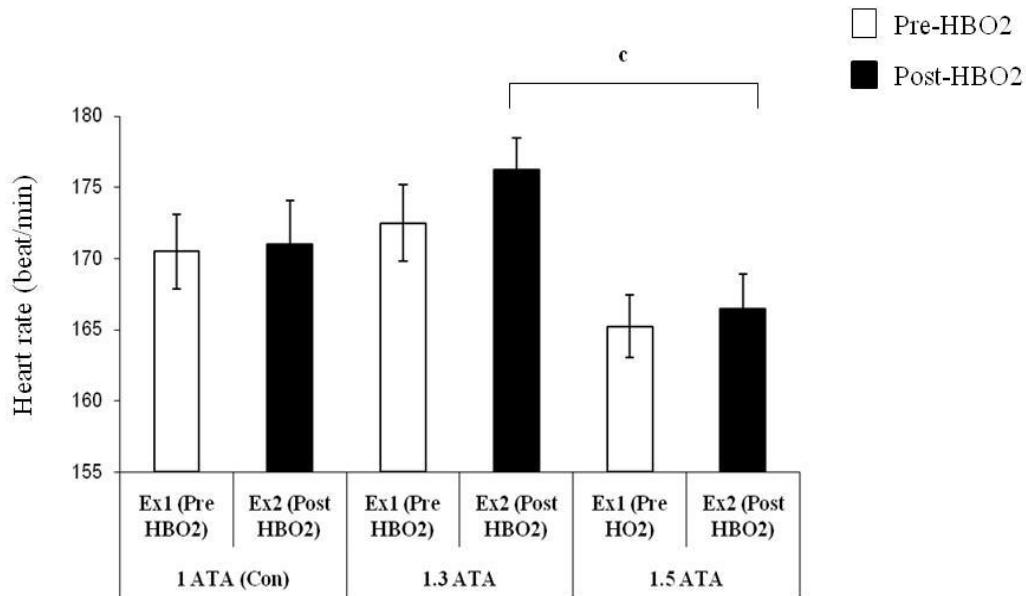


Figure 4.2 Peak anaerobic powers obtained from interventions with 100%oxygen at 1.0, 1.3 and 1.5 ATA. Data were collected at immediate post-exercise 2 and 45 min recovery.

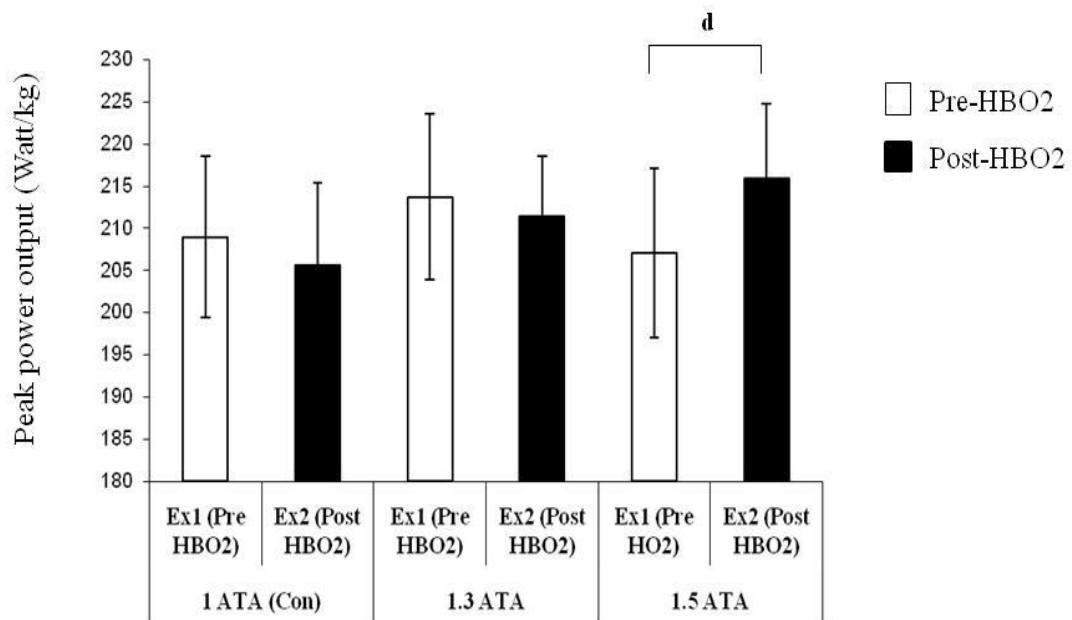
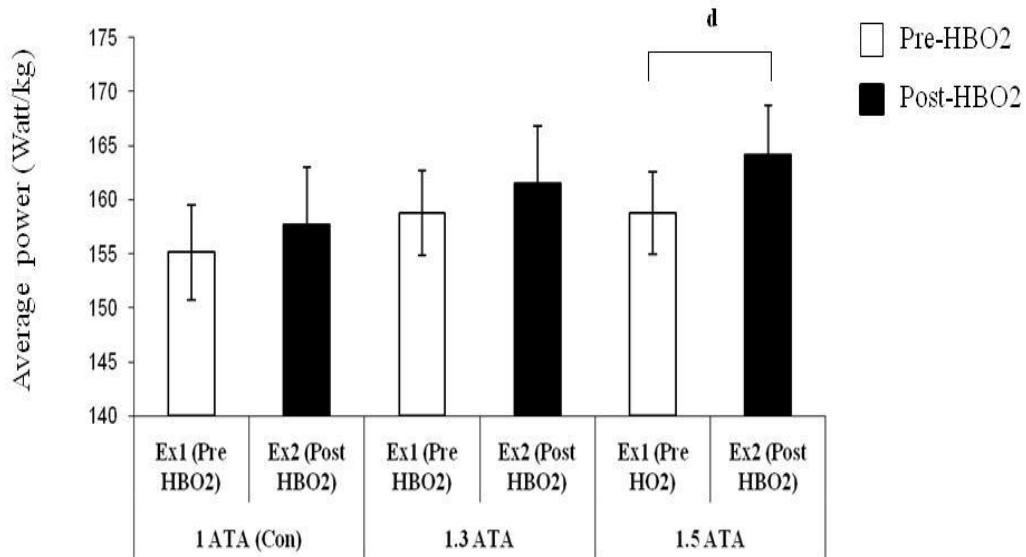


Figure 4.3 Averaged anaerobic powers obtained from interventions with 100% oxygen at 1.0, 1.3, and 1.5 ATA. Data were collected at immediate post-exercise 2 and 45 min recovery.



4.5 Rating of perceive exertion (RPE)

Rating of perceive exertion (RPE) was sequentially estimated at 3 occasions: immediate post-exercise 1, post-hyperbaric chamber exposure and immediate post-exercise 2. Results showed no significant difference among all groups at 1.0 (15.75 ± 0.37), 1.3 (15.38 ± 0.56), and 1.5 (14.25 ± 0.75) ATA conditions. Post-hyperbaric chamber exposure revealed the reduction in RPE (7.87 ± 0.52 , 7.50 ± 0.33 , and 6.87 ± 0.13 in 1.0, 1.3 and 1.5 ATA respectively), however, no significant difference among groups was detected.

DISCUSSION

This study was aimed to investigate and compare the acute effects of hyperbaric oxygenation (HBO_2), with different pressures, on recovery after high-intensity exercise. The major findings were PPO and average power output in post- HBO_2 was greater compare to Pre- HBO_2 at 1.5 ATA. In addition, average power output at Post- HBO_2 in 1.5 ATA was greater than Post- HBO_2 at 1.0 and 1.3 ATA. Linossier Dormois *et al.* (2000) reported hyperbaric oxygen exposure enhanced anaerobic performance. The proposed mechanism was via increasing high energy phosphate in muscle after aerobic exercise (Todd A.Astorino *et al.*, 2003). Hyperbaric oxygen exposure with breathing of 100% oxygen under conditions of elevated atmospheric pressure increases the oxygen content in central and peripheral cellular level and improves acid-base balance system (Welch HG *et al.*, 1982).

In addition, using HBO_2 can increase exercise performance in athletes owing to high oxygen content help to improve muscle contraction which could lead to increase maximal oxygen consumption ($\text{VO}_{2\text{max}}$) and exercise endurance. In the present study, blood lactate concentrations showed no significant difference after

anaerobic exercise and HBO₂ exposure. Plet *et al.* (1992) found lower /no different in blood lactate concentrations in hyperoxic- compared to normoxic-inhalation conditions. The underlying mechanism might be related to re-synthesis of glycolytic energy system in fast twitch motors (type IIa and type IIb) in muscle during high-intensity anaerobic exercise. These findings confirm that hyperoxia increase phosphate storage in muscle. Additional, muscle biopsy studied in 5 healthy male who regularly exercise showed that Pcr (phosphocreatine) in 60% O₂ inhalation was less reduction compared to normoxic-inhalation condition (Heller J. *et al.*, 1998; Welch H.G. *et al.*, 1982).

The effect of hyperoxia has been extensively studied on performance, maximal cardiorespiratory capacity and blood acid/base balance especially during recovery period. It has been used in sports and exercise for recovery. In this study, hyperoxia increased anaerobic exercise performance in athletes. There was significant difference of heart rate immediate post Wingate anaerobic exercises 2 between 1.3 and 1.5 ATA HBO₂ with 45 minutes duration (Table 1) where heart rate of 1.5 ATA was lower than that of 1.3 ATA ($p<0.05$). These findings may be due to breathing with high oxygen content at 1.5 ATA increased plasma and muscular oxygen content that lead to less reduction in (a-v)O₂ differences. Therefore, heart rate was lower as the need of blood supply is reduced. (Boerema *et al.*, 1960; Sheridan and Shank., 1999; Jack H. *et al.*, 2008) However, no significant differences of systolic and diastolic blood pressures, of all conditions, were found among all groups. Blood lactate concentrations had also showed no different between conditions.

This study investigated the acute effects of hyperbaric oxygenation (HBO₂), with different pressures during recovery period. The results have shown that 45-min recovery at 1.5 ATA HBO₂ showed more advantages than 1.0 and 1.3 5 ATA HBO₂. However, the duration of remain elevated partial oxygen (PtO₂) in muscle is still unclear whether or not it can remain for few minutes or hour (Sheridan and Shank. 1999). Therefore, hyperbaric oxygen exposure could enhance high-intensity, short-duration performance for example sprint 200-400 meters. The further study will be focused on long term exposure to hyperbaric oxygenation on performance since the acute effect has been shown to have potential advantages during recovery in athletes.

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สรีวิทยาการออกกำลังกายและกีฬา	(นิพนธ์ต้นฉบับ)
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ACUTE EFFECTS OF DIFFERENT PRESSURES USED IN HYPERBARIC OXYGEN CONDITIONS ON RECOVERY PROCESS AFTER INTENSIVE EXERCISE IN ATHLETES

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ABSTRACT

This study aimed to find out the acute effects of hyperbaric oxygenation (HBO₂), with different pressures, on recovery after high-intensity exercise. Male national Kabaddi athletes (n = 8, age 24 ± 2.7 yr, body weight 75 ± 5.9 kg, height 176 ± 5.5 cm) were recruited. Subjects were exposed to three randomized HBO₂ conditions of 1, 1.3, 1.5 atmospheric pressure (ATA), at least 1 week apart, with a treatment duration of 45 min. Subjects performed 120 sec anaerobic tests (modified Wingate) pre and post HBO₂ exposure. Blood pressure, blood lactate, and ratings of perceived exertion (RPE) were not significantly different between the three experimental trials. Immediate post-exercise heart rate after recovery at 1.5 ATA increased less than at 1.3 ATA (166.50 ± 2.38 and 176.25 ± 2.23 bpm) ($p < 0.05$). Peak power output (PPO): 215.63 ± 8.98 watt/kg and average power: 163.88 ± 4.49 watt/kg after HBO₂ exposure was significantly higher than pre-exposure: 206.75 ± 10.08 watt/kg and 158.00 ± 3.64 watt/kg, respectively, at 1.5 ATA (45 min) $p < 0.05$. This is probably the result of the high concentration of oxygen in the circulatory system synthesizing energy reserves in the muscle. It was found that at 1.5 ATA, pressure, RPE values were lower than the 1 ATA and 1.3 ATA, but not significant ($p > 0.05$). The acute effect on short-term recovery, using oxygen under high pressure, produces higher peak and average power output than normal atmospheric pressure and is more effective at 1.5 ATA than 1.3 ATA.

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