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สรีรวิทยาการออกกำลังกายและกีฬา (Sports and Exercise Physiology)

# ผลของการใช้ออกซิเจนร้อยเปอร์เซ็นต์ภายใต้ความดันบรรยากาศสูงที่มีต่อการฟื้นฟูกล้ามเนื้อภายหลังการออกกำลังกาย

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**บทคัดย่อ**

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาผลของการใช้ออกซิเจนร้อยเปอร์เซ็นต์ภายใต้ความดันบรรยากาศสูงภายหลังการออกกำลังกายที่ทำให้เกิดการบาดเจ็บของกล้ามเนื้อ ค่าครีเอทีนไคเนสในเลือดและการฟื้นตัวของกล้ามเนื้อ ทำการสุ่มอาสาสมัครที่มีสุขภาพดี 30 คน โดยการสุ่มเป็นสองกลุ่ม กลุ่มละ 15 คน กลุ่มที่ได้รับออกซิเจนร้อยเปอร์เซ็นต์ความดัน 1.7 เท่าของบรรยากาศปกติ (HBO) (อายุ = 25.3 ± 4.5 ปี น้ำหนัก = 65.8 ± 5.8 กก. ส่วนสูง = 171.4 ± 5.2 ซม.) และกลุ่มควบคุม (CONT) (บรรยากาศปกติ) (อายุ = 25.5 ± 5.0 ปี; น้ำหนัก = 68.0 ± 7.9 กก. ส่วนสูง= 173.5 ± 5.6 ซม.) อาสาสมัครออกกำลังกายโดยการกระโดดในแนวดิ่งสูงสุด (10 ครั้ง x 10 เซต, พักระหว่างเซต 1 นาที ) จากนั้นแต่ละกลุ่มได้รับวิธีการฟื้นฟูภายหลังการออกกำลังกายทันทีเป็นเวลา 60 นาที โดยนอนพักในตู้ที่มีออกซิเจนร้อยเปอร์เซ็นต์และมีความดันบรรยากาศสูง (HBO) หรือนอนพักในท่านอนหงายในห้องบรรยากาศปกติ (CONT) ทำการฟื้นฟูซ้ำอีกครั้ง ที่ 24 และ 48 ชั่วโมงหลังจากการออกกำลังกาย วัดความแข็งแรงสูงสุดของกล้ามเนื้อต้นขา ระดับความเจ็บปวดกล้ามเนื้อ เส้นรอบวงต้นขาก่อนออกกำลังกาย และหลังจากการออกกำลังกายเป็นเวลา 1, 24, 48, และ 72 ชั่วโมง วัดระดับครีเอทีนไคเนส ในเลือดก่อนออกกำลังกายและหลังจากการออกกำลังกายเป็นเวลา 1, 24, และ 48 ชั่วโมง ผลการวิจัยพบว่า ระดับของครีเอทีนไคเนสในเลือดมีค่าสูงสุดที่ 24 ชั่วโมงหลังการออกกำลังกายในทั้งสองกลุ่ม อย่างไรก็ตามกลุ่มที่ได้รับออกซิเจนร้อยเปอร์เซนต์ภายใต้ความดันบรรยกากาศสูง (HBO) มีระดับครีเอทีนที่ต่ำกว่ากลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติที่ 48 ชั่วโมงภายหลังการออกกำลังกาย ($p$<0.05) นอกจากนี้ยังพบว่าความแข็งแรงสูงสุดของกล้ามเนื้อต้นขามีค่าลดลงแต่ระดับความเจ็บปวดและเส้นรอบวงต้นขาเพิ่มขึ้นหลังจากการออกกำลังกายทั้งสองกลุ่ม แต่ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างกลุ่ม สรุป กลุ่มที่ได้รับออกซิเจนภายใต้ความดันบรรยากาศสูงส่งผลลดอาการบาดเจ็บของกล้ามเนื้อได้แสดงให้เห็นจากระดับครีเอทีนไคเนส แต่วิธีการพักฟื้นดังกล่าวไม่มีผลต่อความรู้สึกเจ็บปวดของกล้ามเนื้อ เส้นรอบวงกล้ามเนื้อและความแข็งแรงของกล้ามเนื้อ

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**คำสำคัญ**: การหดตัวแบบความยาวของกล้ามเนื้อเพิ่มขึ้น, การใช้ออกซิเจนความดันบรรยากาศสูง, การบาดเจ็บของกล้ามเนื้อ, การพักฟื้น

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สรีรวิทยาการออกกำลังกายและกีฬา (Sports and Exercise Physiology)

# EFFECT OF HYPERBARIC OXYGEN EXPOSURE ON MUSCLE RECOVERY FROM EXERCISE-INDUCED MUSCLE DAMAGE

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## ABSTRACT

This study aimed to investigate the effects of hyperbaric oxygen (HBO) exposure on exercise-induced muscle damage, plasma CK level, and muscle recovery. Thirty healthy males were randomly divided into two groups (n=15/group): HBO (100% $O_2$ and 1.7 ATA) exposure (Age, 25.3 ± 4.5 y; body weight, 65.8 ± 5.8 kg; height, 171.4 ± 5.2 cm) and Control (CONT) (room air) groups (,Age, 25.5 ± 5.0 y; body weight, 68.0 ± 7.9 kg; height, 173.5 ± 5.6 cm). Subjects were asked to perform maximal vertical jump (10 reps x 10 sets, 1-min rest between set) followed by 60-minute recovery of HBO exposure or rest in supine position (CONT) at immediately after exercise. Recovery sessions were repeated at the same time of day on the two subsequent days (24 hr, and 48 hr after exercise). Knee extension peak torque, pain scores, and thigh circumference were measured at baseline, 1, 24, 48, and 72 hr post-exercise. Creatine kinase (CK) level was measured at baseline, 1, 24, and 48 hr post-exercise. The results show that CK levels were peaked at 24 hr post-exercise in both groups. However, an increase of CK in HBO group was significantly lowered compared with CONT at 48 hr post-exercise ($p<0.05$). In addition, muscle peak torque was reduced but pain scores and thigh circumference were increased following exercise in both legs, but no significant difference between groups were observed. Conclusion: HBO exposure had protective effect on muscle damage represented by CK level but it had no effects on muscle soreness, thigh circumference and isokinetic muscle strength.

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**KEY WORDS**: Eccentric exercise, Hyperbaric oxygen, Muscle damage, Recovery

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## INTRODUCTION

Delayed onset muscle soreness (DOMS) is one type of muscle damage that occurs after exercise, especially in people who are not familiar with the exercise.[1] It has been known that eccentric exercise can cause DOMS[2] which can reduce the speed, agility and strength.[3] Using HBO chamber has gained popularity for decades but recently has been introduced to elite Thai athletes aiming to augment recovery following fatigue or injury with little scientific evidence to support. A previous study showed that a single dose of HBO (45 min, 100% $O_2$ at 1.5 ATA) exposure caused a better subsequent high-intensity exercise performance than control and that of the exposure at lower pressure (1.3 ATA).[5] In terms of recovery from injury or muscle damage, some previous studies found that after exercise-induced muscle damage and then recovery by HBO (100% oxygen at 2.0-2.5 ATA, 1 hour) treatment for 3-5 day can fasten recovery of eccentric and isometric muscle torque, compared with control .[6-7] In contrast,, Brooke, 2001[8] found that HBO exposure (100 min, 2.5 ATA) did not have any benefit on muscle recovery after eccentric arm exercise. Since, the effects of HBO on muscle recovery and muscle damage marker were not clear, this study aimed to investigate the effects of HBO on CK level, pain scores, thigh circumference, and knee extension peak torque after exercise-induced muscle damage.

## METHODS

Thirty healthy males aged between 20 and 35 years old were randomly divided into two groups (n=15/group): HBO [Age: 25.3 ± 4.5 yr] and CONT [Age: 25.5 ± 5.0 yr]. Subjects were screened and recruited according to the inclusion and exclusion criteria using questionnaire and medical examination (performed by physician at sports medicine clinic of the Sports Authority of Thailand). Moreover, inclusion criteria included those who did not have any experiences in plyometric training or training for any competitive sports. Subjects who had musculoskeletal disorders, respiratory tract infection, lung disease, claustrophobia, and taking analgesic drug were excluded. All subjects were verbally and written informed about the experimental procedures, and possible risks associated with this study, and, then, signed the informed consent before participating in the study. This study was approved by Mahidol University Institutional Review Board (MU-IRB; 2015/075.1806).

**Exercise-induced muscle damage:** Subjects were asked to perform maximal vertical jump (10 reps x 10 sets, 1-min rest between set) and instructed to jump with kneel down before jumping at an angle of 90 degrees. This type of exercise has been used successfully to induce skeletal-muscle damage in previous studies.[12, 28]

**Treatments:** The 60-min exercise recovery including 1) HBO (100% $O_2$ and 1.7 ATA) exposure and 2) CONT (rest in the supine position) with normobaric oxygen (room air) exposure. Room temperature was controlled 25˚C and 45-50% relative humidity. Subjects were recovered at immediately after exercise, and repeatedly

exposed to hyperbaric oxygen in HBO group or rested in supine position in CONT group at 24, and 48 hr post-exercise.

**Variables measurement**: Knee extension peak torque, pain scores, and thigh circumference were measured at baseline, 1, 24, 48, and 72 hr post-exercise. Blood samples (5ml) were taken from the antecubital vein at baseline, 1, 24, and 48 hr post-exercise for CK analysis using Biosystem diagnostic kits (Barcelona, Spain). Maximal isokinetics knee extension peak torque was tested at 60˚/second. Subjects were seated on the Cybex (Humac® Norm muscle dynamometer) with torso, pelvis and upper leg (quadriceps muscle) secured to reduce extraneous body movements. Chair settings, dynamometry attachment and joint angles were recorded and maintained same on each trial occasion. The CybexHumac Norm® was calibrated according to manufacturers' instructions before each test to account for limb weight and the influence of gravity on torque (Moore, 2012). Pain score (Numeric rating scale; NRS 0-10) (Williamson, 2005 [4]; Tippawan, 2012 [29]) was used to evaluate the perception of pain during performing squat (90˚ degrees of knee flexion for 5 sec). Thigh circumference measurements were taken at the mid-thigh point between the lateral condyle of the femur and greater trochanter with the participants in a standing position.

**Statistical Analysis**

Data were presented as mean ± SEM or otherwise indicated. Normality of data distribution was tested by using Shapiro-Wilk test. Two-way ANOVA (Mixed model: within subject × between group) was used to test main effects of treatment, and interaction. For pain scores, Mann Whitney U test was used to test the difference between groups and Friedman test was used to test the effect of times. Statistical significance was set at $p<0.05$ and all data were analyzed using SPSS version17.

## RESULTS

Subjects' characteristics were not significantly different when observed in two groups ($p>0.05$) (Age: HBO = 25.3 ± 4.5, CONT = 25.5 ± 5.0 yr; Body weight: HBO = 65.8 ± 5.8, CONT = 68.0 ± 7.9 kg; Height: HBO = 171.4 ± 5.2, CONT = 173.5 ± 5.6 cm). Significant time effects of CK (Figure 1), pain scores (Figure 2), thigh-circumferences (Table 1), and knee extension peak torque (Figure 3) were observed ($p<0.05$). CK levels of HBO and CONT at baseline and at 24 hr post-exercise was not significantly different but peaked CK level of HBO at 24 hr post-exercise [450.1 ± 116.43 (U/L) tended to be lowered compared with peaked CK of CONT group (824.53 ± 116.43 (U/L)] ($p=0.09$). At 48 hr after exercise, CK level (329.47±173.72U/L) was significantly lowered compared with CONT (754.9±779.4 U/L) ($p <0.05$) (Figure 1). Pain scores (Figure 2) were peaked at 24 hr post-exercise in both legs and groups. Additionally, at 72 hr post exercise CONT group had significantly higher pain scores compared with baseline (Figure 2). Thigh circumferences (Table 1) of left leg at 24 hr after

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exercise was significantly greater than those at the baseline ($p<0.05$). Percentage changes of peak torque (Figure 3) of both legs were reduced at 24 hr in both groups and there were significantly reduced at 1, 24, 48 and 72 hr when compared with baseline ($p<0.05$). However, there were no significant differences interactions between group and time in quadriceps peak torque, and thigh-circumferences between HBO and CONT groups.

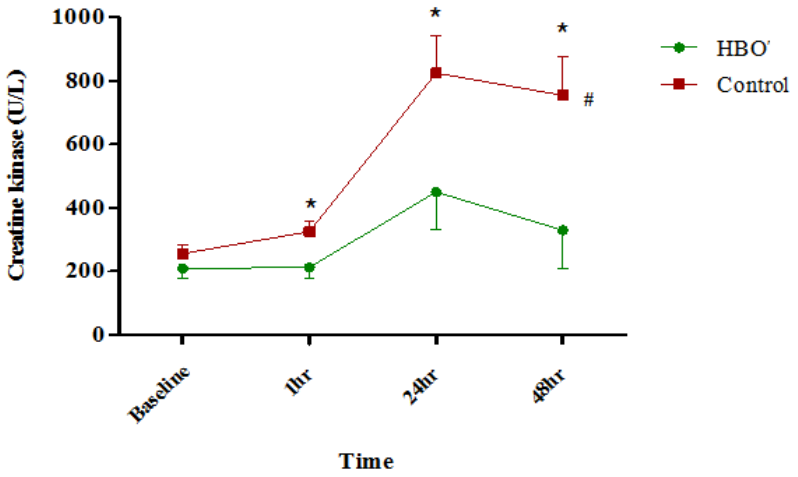


**Figure 1.** Mean (± SEM) plasma creatine kinase levels at baseline, and after exercise (1, 24, and 48 hr). *Significant difference when compared with baseline ($p<0.05$), # Significant difference when compared with HBO groups ($p<0.05$).

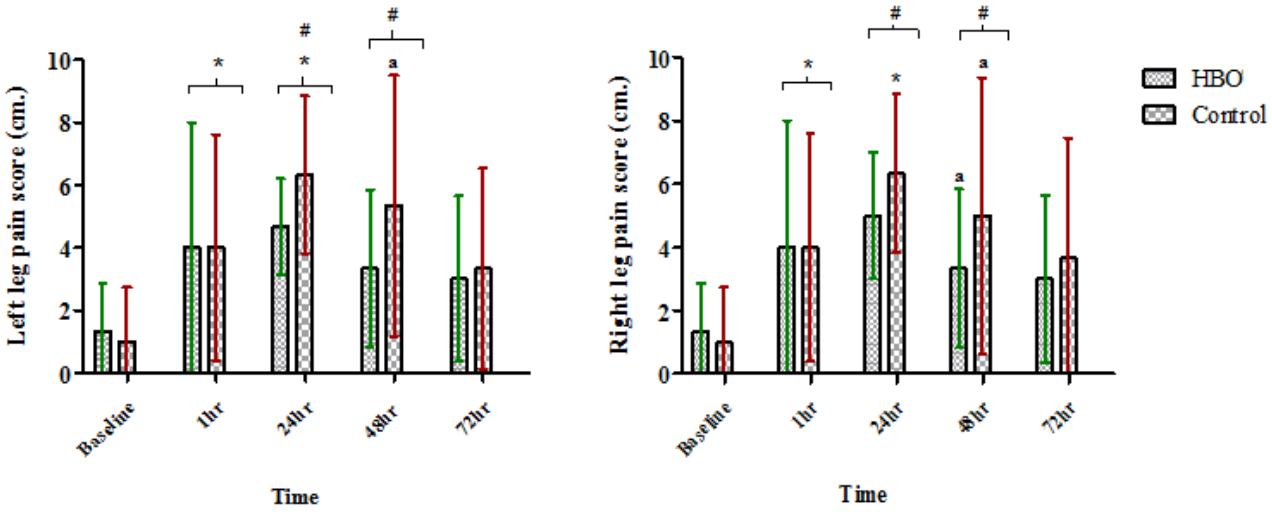


**Figure 2** . Median (±range) pain scores of right and left legs. *Significant difference when compared with baseline ($p<0.05$). #Significant difference when compared with 72 hr post-exercise ($p<0.05$),

[a] Significant difference when compared with 24 hr post-exercise ($p<0.05$).

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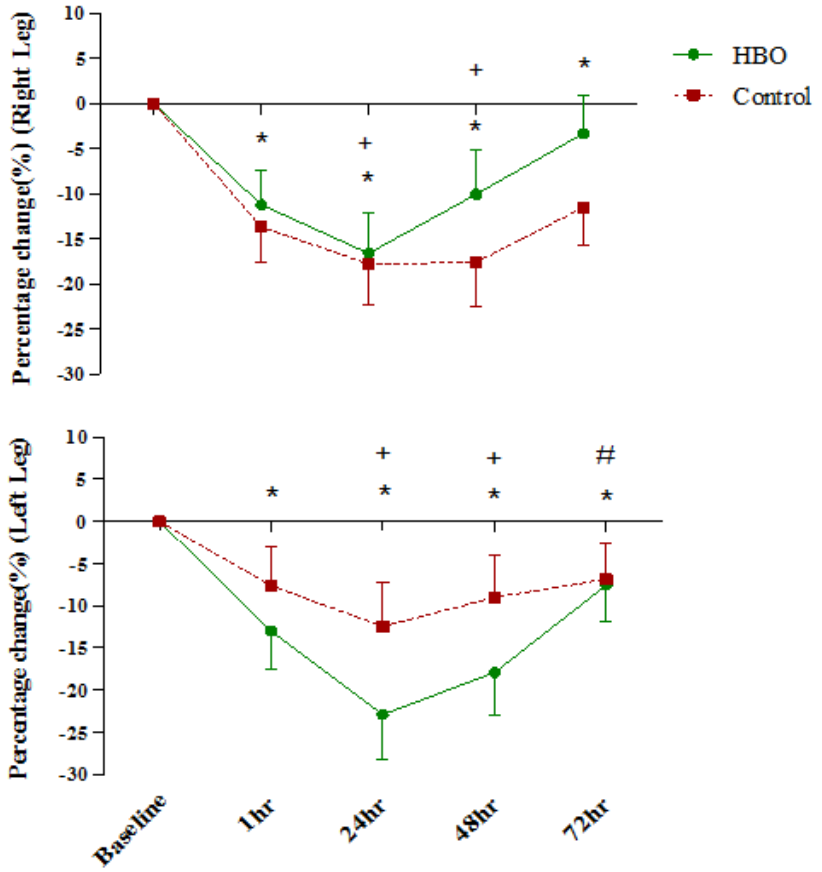


**Figure3.** Mean (±SEM) of percentage change of peak torque of right and left legs at 60˚/s of HBO and Control.

* Significant difference when compared with baseline, + Significant difference when compared with 72 hr post-exercise ($p$<0.05), # significant difference when compared with 1 hr post-exercise ($p$<0.05).

**Table1.** Mid-thigh circumferences (cm.) at baseline, 1, 24, 48, and 72 hr after exercise.

| Time | Right | | Left | |
|---|---|---|---|---|
| | HBO | CONT | HBO | CONT |
| Baseline | 49.6 ±2.9 | 51.0 ±4.3 | 48.8 ±2.9 | 49.9 ±3.7 |
| 1hr | 49.7±3.2 | 51.5 ±4.3 | 49.2 ±2.5 | 50.4 ±3.8 |
| 24hr | 49.9 ±2.9 | 51.6 ±3.8 | 49.4 ±2.7* | 50.5 ±3.2* |
| 48hr | 49.7 ±3.2 | 51.5 ±3.8 | 49.1 ±2.9 | 50.4 ±3.4 |
| 72hr | 49.5 ±2.9 | 51.4 ±3.9 | 49.3 ±2.6 | 50.4 ±3.2 |

*Significant difference compared with baseline ($p$<0.05).

## DISCUSSION

The present study demonstrates that the effects of HBO on recovery of quadriceps peak torque, mid-thigh circumference, and pain score were not different compared to CONT. However, HBO treatment may have some protective effect against muscle damage since the presence of CK was reduced at 48 hr post-exercise.

The exercise-induced muscle damage protocol used in the present study was sufficient to induce muscle damage in both groups indicated by the rising of CK level which peaked at 24 hr after exercise similar to previous study. [9, 10]

The decline of muscle strength [11, 9] and the increases of pain score, and mid-thigh circumference [10, 12]have been shown after exercise-induced muscle damage and these were similar to the present study. The lower muscle strength at 1 hr post-exercise in the present study may result from muscle fatigue by decreases of alpha-motor neuron or muscle response, leading to the decrease of muscle output [15,16] and the mechanism of DOMS including muscle fibre damage and breakdown of muscle protein lead to inflammation and pain. Eccentric-biased downhill running which caused muscle damage resulted to 10-30% deficit offorce loss compared with concentric exercise.[13,14] However, the decline of peak torque at 24-48 hr may result from muscle soreness by ultra-structural muscle damage and muscle membrane disruption.[16]Although muscle pain tended to be lowered in HBO group, there was no effects of HBO exposure on muscle pain, and isokinetic peak torque in the present study. Previous studies which used higher oxygen pressure (100% oxygen at 2.0-2.5 ATA for 60 min/day) at repetitive doses (3 times) reported that HBO therapy can prevent the loss of strength after exercise when compared with non treatment group[7, 20]. Haapaniemi,[17] concluded that HBO treatment had benefit for recovery at least 48 hr post-exercise by raising levels of high energy phosphate compounds and stimulation of aerobic oxidation in mitochondria. HBO treatment may allow a better replenishment of high-energy phosphate bonds by increased oxygen delivery to tissue which may prevent tissue damage. [18] In addition, it was suggested the HBO treatment can increase plasma oxygen pressure and benefit to areas of damage, especially, in the muscle-tendon junction [19]or the ligament[7].

Stauber.,1989[13]has concluded that tissue disruption and swelling due to the extracellular fluid accumulation following muscle damage may induce inflammation and pain. The accumulation of metabolites increases the osmolality of the cell and permeability resulting in edema. Edema increases mechanical stress and compress capillary, impairing oxygen transports and waste removal, as well as muscle soreness.[5]In the present study, muscle soreness was recovered to baseline at 72 hr in both groups. Ebbeling and Clarkson[21] have shown that muscle soreness usually decreases within 5 to 7 days following quadriceps eccentric exercise (300 eccentric repetitions *Vs.* 180 eccentric repetitions of maximal effort over 30 min). After exercise induced muscle damage resulted to increases mid thigh circumference on the non-dominant legs in both

groups andthis was peaked at 24hr post-exercise. This was similar to the previous study[22] showing that leg volume increased at 24, 48, and 72 hr post-exercise.Shift of fluid into the muscle is related to the intensity of exercise and high intensity exercise increases the volume of intramuscular water content.[23] In this study, swelling, especially, of the left (non-dominant) leg in both groups was significantly observed following jumps or knee extension exercise similar to Howatson.,2008.[24] Plasma CK level is one of indicators of muscle damage [25,26] and normally peaked at 24-48 hr post-exercise. An increase of this enzyme level usually indicates cellular necrosis and tissue damage following muscle injuries. Inthe present study, all subjects were healthy and had normal CK levels before exercise. In addition, all subjects were untrained, therefore the rising of CK levels in two groups likely resulted from the exercise protocol. CK in both groups were changed significantly over time and peaked at 24 hr post-exercise similar to the previous studies [8,27]. In the present study, the lower of CK in HBO at 48 hr post-exercise compared with CONT may result from vasoconstriction effect due to an increase of $PO_2$ and oxygen in capillary blood flow. These may decrease transudation and diapedesis including increase reabsorbing of fluid and waste product.

## CONCLUSION

HBO exposure (100% $O_2$ at 1.7 ATA for 60 min) at immediately after exercise, 24, and 48 hours after exercise had some protective effect on muscle damage indicating by significant lowering the level of CK compared to CONT. The CK level was decresed at 48 hr post-excercise may be resulted from vasoconstriction effect due to an increase of $PO_2$ and oxygen in capillary blood flow and increase reabsorbing of fluid and waste product. However, HBO had no significant effect on muscle peak torque, muscle soreness and thigh circumference.

### Limitation

Limitation which must be noted in the present study is the counter movement jumps were not controlled especially the angle of knee joint during downward or eccentric phase of jumps, although the subjects were instructed to bend their knees approximately at 90 degree. However, perceived exertion during jumps including heart rate at the end of exercise were not different among groups.

### Further study

For the further study, the exercise induced muscle soreness protocol should be set relative to the strength level of the individuals e.g. 1RM of leg extension and the measured variables should include other muscle damage and inflammatory markers e.g. myoglobin, and Interleukins.

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