



Effect of Wearing the Elevation Training Mask on Physiological Performance in Elite Kayaking Girls

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Abstract

Background: The elevation training mask 2.0 (ETM) has been introduced as a novel tool to allow for respiratory muscle training and altitude exposure during exercise that can improve performance and hematological markers in elite and well-trained athletes.

Objectives: The purpose of the present study was to examine the effect of wearing ETM while performing exercise training on erythropoietin (EPO), vascular endothelial growth factor (VEGF), peak oxygen consumption (VO_{2max}), lactate, and 1000-m kayaking performance in elite Kayaking girls.

Methods: Thirty elite Kayaking girls (14 to 18-year-old) were equally and randomly assigned into mask, no mask, and control groups. The mask and no-mask groups completed 8 weeks of repeated sprint training, while the control group performed their routine kayaking training programs. Pre- and post-training tests included EPO, VEGF, VO_{2max} , lactate, and 1000-m kayaking performance.

Results: We showed that 1000-m time trial significantly decreased for mask ($P < 0.001$) and control ($P = 0.035$) groups, and was significantly lower in mask group than control ($P = 0.014$) and no mask ($P = 0.009$) groups. EPO did not show any significant changes for all groups. VEGF was increased significantly for mask ($P = 0.04$) and no mask ($P = 0.014$) groups. Lactate was decreased significantly for mask group ($P = 0.025$). VO_{2max} increased significantly for no mask group ($P = 0.021$).

Conclusions: Performing repeated sprint training while wearing ETM has the potential to enhance performance in Kayak racing.

Keywords: Airflow Restriction, Physical Exercise, Respiratory Muscle Training, Endurance Performance

1. Background

Flat-water Kayaking, as a high intensity endurance event, requires development of both aerobic and anaerobic capacities. Respiratory muscle training (RMT) has become a popular training method among competitive endurance athletes to improve athletic performance outcomes (1, 2). RMT can improve cycling endurance (3), decrease inspiratory muscle fatigue, and improve time trial performance (4).

The Elevation Training Mask v2.0 (ETM) is a commercially fabricated (Training Mask LLC; Cadillac, MI, USA) RMT device that utilises a silicone mask and

flexible neoprene head strap to fix the face during exercise (1). The adjustable “resistance caps” on this device also purportedly provide for between 3,000 and 18,000 ft of “altitude resistance” (1). Wearing the ETM acts as a respiratory training device, enables the user to simulate altitudes ranging from 914 m to 5486 m and is used by elite athletes to simulate the increased expiratory and inspiratory effort required at high elevation (2). It was shown that wearing ETM alone had not a positive effects on lung function, inspiratory muscle strength, or did not induce changes in hemoglobin or hematocrit levels (2). However, wearing ETM while participating

in a 6-week high-intensity cycle ergometer interval training program may improve physical capacity and endurance performance in moderately trained students (2). Combining breathing resistance with exercise training can improve VO_{2peak} (5). We can speculate that wearing ETM while participating in repeated sprint training may benefit endurance athletes by means of specific adaptations in Kayakers. As well, we have hypothesized the role of the hormone erythropoietin (EPO) and vascular endothelial growth factor (VEGF) which are the important factors regulating erythropoiesis and angiogenesis (6-8), respectively, and lactate concentration as an indicator of respiratory muscle performance.

The physiological adaptations that occur during EMT depend on the specific training protocol. However, no study has reported the effects of wearing EMT while exercising on physiological Kayaking performance. It would be of interest to know if wearing ETM would further enhance physiological kayaking performance and by which specific adaptation.

2. Objectives

The purpose of the present study was to investigate the changes of blood EPO and VEGF, lactate levels, VO_{2max} , and endurance performance in elite Kayaking girls.

3. Methods

3.1. Participants and Study Design

Thirty female national level Sprint Kayak athletes (mean \pm SD: age: 14 ± 3 years; height: 1.62 ± 0.67 m; body mass: 50.7 ± 4.8 kg) were recruited for this study. The participants had at least 2 years of kayak specific training experience, trained regularly 5 training sessions of 2h per week, had been training regularly with a Kayak ergometer, and had to be competing at national level. The study took place during the competitive season. They did not have any medical conditions and were free of acute or chronic injuries over the 6 months before the experiment. All of the participants reported that they had not climbed more than 2500 meters in the 6 months prior to the study. Parents and coaches of all participants were asked to give their written informed consent following a detailed explanation about the aims, benefits, and potential risks involved in the investigation. The study was approved by the university ethics review board and human subjects committee with ethics No: IR.UT.SPORT.1399.018.

The participants were randomly and equally assigned into three groups (10 participants each): Mask group, no mask group, and a control group. The mask group performed repeated sprint training while wearing ETM

according to ETM manufacturer settings during all training sessions (2). The mask was set to simulate an altitude of 914 m (week 1), 1829 m (week 2), 2743 m (week 3 and 4), 3658 m (week 5, 6, 7, and 8) (2). The no mask group performed repeated sprint training without wearing ETM. The control group performed their normal training program without wearing ETM.

Within 10 days after completion the training protocol, all participants performed the exercise test with the same protocol but under normal conditions. Each testing session included a standard warm up of 3-min paddling at $\sim 85\%$ maximum Heart Rate (HR_{max}) followed by two 15 s accelerations interspersed with 45 s rest and two standing starts of 24 strokes with 45 s rest between each ending with 3 min of paddling at $85\% HR_{max}$ and standard cool down of 3 min of paddling at $85\% HR_{max}$ (9). The main body of each of sprint kayak training sessions consisted of repeated sprint training.

VO_{2max} Test VO_{2max} test was conducted on electronically braked cycle ergometer (Monark 894E; Stockholm, Sweden). VO_{2max} was calculated by averaging of the highest 2 consecutive 15 s averages. HR was continuously measured using a Polar heart rate monitor (Polar A1, Polar Electro, Kempele, Finland).

3.2. Time Trial test

Kayak athletes were familiar with the use of ergometer and the 1000-m kayaking time trial protocol to assess rowing performance. They performed the graded exercise test according to the study of Kerr et al. (10) on a rowing ergometer (Concept IID, Morrisville, USA). The warm-up was followed by a 1000-m effort with the participants encouraged to adopt a self-selected stroke rate and to maximize force on the ergometer paddle to complete the 1000-m in the fastest time (10). All kayak athletes started this test at the same time and their time was recorded.

3.3. Blood Analysis

Venous blood samples (10 mL) were collected by venipuncture of the antecubital vein into serum separator or EDTA-coated tubes before and after the exercise training protocol. Plasma and serum samples were aliquoted and stored at $-80^{\circ}C$ until analysis. The biomarkers were measured by enzyme-linked immunosorbent assay kits according to the manufacturer's instructions: serum EPO (IBL international GmbH, Hamburg, Germany) and plasma VEGF (IBL international GmbH, Hamburg, Germany). Lactate was measured using the Lactate Pro 2 Analyzer (Arkray, Tokyo, Japan).

3.4. Statistical Analysis

The commercial software Statistical Package for the Social Sciences (SPSS) for Windows, version 25.0 (SPSS Inc., Chicago, IL, USA) was utilized for all statistical analyses. Results are presented as means \pm standard deviation (SD). Data normality was tested using Shapiro-Wilk test. Mean values were compared using Student's *t*-test. Comparison among groups was performed by two-way ANOVA with Fisher's Least Significant Difference (LSD) test as post-hoc test. The significance level was established at $P < 0.05$.

4. Results

As shown in Table 1, 1000-m kayaking record was significantly decreased for the mask group ($P < 0.001$). EPO did not show any significant changes for all groups. VEGF was increased significantly for the mask ($P = 0.04$) and for the no-mask ($P = 0.014$) groups. Lactate was decreased significantly for the mask group ($P = 0.025$). VO_{2max} increased significantly for the no-mask group ($P = 0.021$).

Two-way ANOVA test showed a significant interaction for only 1000-m kayaking record ($P = 0.014$). LSD post-hoc test showed that after the exercise training protocol, 1000-m kayaking record was significantly lower in mask group than control ($P = 0.014$) and no-mask ($P = 0.009$) groups, respectively.

5. Discussion

The present study investigated the effects of wearing ETM while participating in repeating sprint training on EPO, VEGF, lactate, VO_{2max} , and 1000-m kayaking record in the elite Kayaking girls. The main findings of this study were that in Kayak athletes who trained with or without ETM device, VEGF levels increased and EPO level showed no change. Training with ETM improved 1000-m kayaking record, and decreased lactate levels, while training without ETM increased VO_{2max} .

No previous study was investigated the effects of RMT on EPO, VEGF and performance parameters simultaneously. Therefore, this makes direct comparisons to previous literature more difficult. We compared our results with the findings of previous studies that examined the effect of altitude training or simulated altitude training (hypoxia training). Our results indicate that the increase of VEGF depends of the training method adopted which is in line with previous studies. Similar to previous study (11), authors showed that exercise is effective in VEGF stimulation when it is combined with hypoxia. VEGF also increased during intermittent hypoxic training (8). Asano et al. (12) showed that serum VEGF

levels increased in swimmers after 3 weeks of endurance training at moderate terrestrial altitude (1886 m). Results obtained by Park and Lim (13) indicated a rise of serum VEGF in swimmers following 6 weeks of a combination of continuous, interval and resistance training in hypobaric hypoxic conditions (in a simulated altitude of 3000 m). On the contrary, in groups which trained in normoxia, there were no changes in VEGF-A level (8). Thus, both repeated sprint training and hypoxic training could stimulate VEGF improvements explaining our results.

On the other hand, the present study showed that EPO did not change significantly after training with and without ETM, which is similar to a previous study where EPO did not change during "intermittent hypoxic training" (8). However, EPO increased after "live high - base train high - interval train low" and "live high - train low" conditions (8) and following several hours of hypoxic exposure (14, 15). The lack of EPO response to hypoxic and normoxic training can be associated with the inefficiency of hypoxic training with ETM to elicit hematological changes, which was confirmed in cyclists and swimmers (16, 17). Thus, longer periods of exposure to hypoxia are likely needed to obtain an increase in EPO levels, probably, being the best option the concept of "live high-train low". Thereby, training with ETM was effective for VEGF increment and ineffective for EPO increment. Therefore, our finding indicated that ETM did not induce hypoxia and the Kayaking athletes should perform new respiratory training methods that induce a sufficient hypoxic dose.

We also reported a significant reduction in lactate levels in the mask group. In line with the present data, Jagim et al. (18) showed that blood lactate values after sprint during the ETM condition was lower as compared without ETM condition in recreational weight lifters (18). On the other hand, previous studies reported no significant changes in lactate after continuous exercise with mask and continuous exercise without mask (19), 2, 4, and 6 weeks of high intensity cycle ergometer training using ETM (2), and 6 weeks of training with ETM, and intermittent hypoxic training (IHT) (20).

These results partially confirm our finding in lower lactate levels after repeated sprint kayak training. However, the differences between the results of these studies may be due to the different training protocols and sport modalities, as well as to background of anaerobic training.

The increase of VO_{2max} in no-mask group indicates that repeated training exercise is able to enhance exercise capacity. Repeated sprint with higher maximal aerobic power and VO_{2max} are positively related to 1000-m time trial performance. Additionally, it has been demonstrated that physiological characteristics, such as higher maximal

Table 1. The Effects of the Three Intervention on 1000-m Kayaking Record, EPO, VEGF, Lactate, and VO_{2max}

Parameters	Mask Group (n = 10)			No Mask Group (n = 10)			Control Group (n = 10)		
	Pre	Post	P Value	Pre	Post	P Value	Pre	Post	P Value
1000-m kayaking record (s)	157.1 ± 4.0	149.9 ± 4.0	< 0.001	156.6 ± 6.7	155.7 ± 5.1 ^b	0.095	156.3 ± 5.0	155.4 ± 155.4 ^b	0.06
EPO (mU/mL)	7.3 ± 4.6	7.35 ± 3.6	0.595	6.5 ± 1.7	5.9 ± 2.1	0.091	5.4 ± 1.0	5.3 ± 1.4	0.920
VEGF (pg/mL)	121.2 ± 28.5	135.5 ± 14.9	0.040	114.5 ± 20.9	132.4 ± 8.9	0.014	126.5 ± 15.1	134.2 ± 8.7	0.084
Lactate	9.2 ± 1.4	8.0 ± 2.1	0.025	9.7 ± 3.6	7.5 ± 1.2	0.111	7.7 ± 1.4	9.6 ± 2.1	0.059
VO _{2max} (mL.kg ⁻¹ .min ⁻¹)	46.3 ± 8.7	48.6 ± 5.2	0.180	41.3 ± 7.9	47.6 ± 10.0	0.021	41.8 ± 4.4	45.1 ± 8.0	0.128

^a Values are expressed as mean ± SD.

^b Significantly different as compared with mask group (P < 0.05 and P < 0.01, respectively).

aerobic power and VO_{2max}, are better related to 1000-m time-trial performance (9).

Training without ETM increased VO_{2max} that indicate that ETM did not play an important in improving exercise capacity by means of VO_{2max} and did not act like a hypoxia stimulator. Thus, VO_{2max} is affected by the type of training, not the ETM2 condition. This finding is in line with Biggs et al. (21) who showed that high intensity interval training is a viable method to increase VO_{2max}, but ETM may not lead to greater overall improvements. In addition, Devereux et al. showed high intensity interval training with and without ETM reported significant improvement in VO_{2max} (22). Also, Porcari et al. (2) in moderately trained participants showed that 6 weeks of high intensity cycle ergometer training using ETM did not improve VO_{2max} more than did the control condition. To highlight is the fact that the current study did not found increase in VO_{2max} using a non-sport specific test (cycle ergometer) while the sport specific performance (time in 1000-m kayaking) was improved. However, research has indicated that simulated altitude should be 2000 to 3000 meters to provide obvious changes in physiological changes and increased aerobic performance (23). Although the simulated altitude in the present study was ranged from 914 m to 3,658 m, factors other than altitude, such as training with ETM duration, may also play an important role in the conflict between studies.

The training protocol used in the present study was repeated sprint training which is a potential useful tool for monitoring training in Sprint Kayak athletes. Such information may be used to guide coaches and sports scientists on appropriate programs to develop elite kayak athletes in each of the specific Sprint Kayak events. Such data may help to inform Sprint Kayak coaches and coaches in similar sports involving aerobic and anaerobic metabolism when designing appropriate targeted training sessions that meet the specific physical and physiological aspects for individual athletes or events.

We also showed that training without mask, by increasing VEGF and VO_{2max}, did not improve endurance performance. These data in addition to the mask condition

data implies that lactate levels (clearance) could be more determinant than VO_{2max} and VEGF levels in predicting endurance performance. Our finding is in line with those of Bassett et al. (24), which had shown that the speed of lactate threshold is the best physiological predictor of endurance performance.

On the other hand, lack of positive effects of ETM on VO_{2max} and EPO may be due that the mask can cause some psychological discomfort, exercise intolerance, and inadequate hyperventilation that led to arterial hypoxemia (1).

A strength of the present study that we included a no-mask group that trained without mask and a control group that continued his training routine. A limitation of the present study is the insufficient duration for ETM exposure. Future studies should increase the simulated elevation and should compared this device with other approaches.

5.1. Conclusions

Wearing ETM while training may be effective in increasing VEGF, decreasing lactate, and improving anaerobic endurance performance of elite female kayaking athletes. Furthermore, using ETM inhibited increases in VO_{2max} and EPO. These findings should be interpreted with caution. Training without ETM is able to improve VO_{2max} but not performance. This study confirms that ETM is not a stimulator of hypoxia but could be useful to promote anaerobic adaptations. Future researches should continue investigating the exercise adaptations when using ETM.

5.2. Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of the University of Tehran.

Footnotes

Authors' Contribution: F. A. study concept and design, collected the clinical data, drafting of the

manuscript; A. G. study concept and design, drafting of the manuscript, analysis and interpretation of data; S.A. statistical analysis and revised the manuscript; H. A.A. participated in designing the evaluation and helped to draft the manuscript; H.C. re-evaluated the clinical data, administrative, technical, and material support; C. J. L. participated in designing the evaluation, performed parts of the statistical analysis; D. J. P. study supervision and revised the manuscript. All author read and approved the final manuscript.

Conflict of Interests: H.C. is one of the editorial board members.

Ethical Approval: This study is approved by the university ethics review board and human subjects committee with ethics No: IR.UT.SPORT.1399.018.

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Informed Consent: Parents and coaches of all participants were asked to give their written informed consent following a detailed explanation about the aims, benefits, and potential risks involved in the investigation. Informed consent was obtained from all subjects involved in the study.

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