



Original Research

The Effects of an Elevation Training Mask on VO₂max of Male Reserve Officers Training Corps Cadets

BRIAN G. WARREN[†], FRANK J. SPANIOL[‡], and RANDY A. BONNETTE[‡]

Department of Kinesiology, Texas A&M University-Corpus Christi, Corpus Christi, TX, USA

[†]Denotes graduate student author, [‡]Denotes professional author

ABSTRACT

International Journal of Exercise Science 10(1): 37-43, 2017. The purpose of this study was to investigate the effects of an elevation training mask (ETM) on the VO₂max of male Reserve Officers Training Corps (ROTC) cadets. Fourteen male ROTC cadets (age 20.00 ± 1.8 yrs, height 174.35 cm ± 3.1 cm, weight 76.75 kg ± 11.09 kg, body fat 13.88% ± 4.62%) participated in this study to determine if an ETM would cause a significant increase VO₂max. After the familiarization period, the test subjects were randomly assigned to either the control or experimental group, respectively. The training period lasted seven weeks with each subject participating three days per week. The post-test was performed four days after the final training session. Statistical analysis indicated no significant difference in VO₂max values ($p = 0.34$) between the (control vs. the experimental group). This study concluded that the ETM did not cause a significant increase in VO₂max under the training conditions of this study. However, results may differ if there is an increase in the frequency of exposure to the ETM, as well as an increase in the duration of the training period.

KEY WORDS: Elevation training mask, altitude training, elevation, acclimatization, aerobic performance, VO₂max

INTRODUCTION

There have been a number of novel approaches and modalities utilized for altitude training including: normobaric hypoxia via nitrogen dilution (hypoxic department); supplemental oxygen; hypoxic sleeping devices; and intermittent hypoxic exposure (11). The original method of altitude/hypoxic training required living and training at moderate altitude (1500-4000m) for the purpose of increasing erythrocyte volume, and ultimately enhancing sea-level maximal oxygen uptake (VO₂max) and endurance performance (12). Additionally, altitude training invokes physiological changes that are very similar to those caused by endurance

training. As a result, Wolski, McKenzie, & Wenger (13), have incorporated this training approach to improve aerobic performance.

According to a report by Bonin (2), the importance of oxygen transport and uptake in the body for endurance performance is the reason why altitude training is utilized as a popular method of preparation. Also, the value of training at altitude for sea-level activity appears to garner complete acceptance among some scientists, however, there may be a lack of acceptance present for the individuals who have yet to enjoy the benefits, first-hand. (3).

VO₂max was first described in 1923 as the oxygen intake during exercise at which actual oxygen intake reaches a maximum beyond which no increase in effort can raise it (6). A high VO₂max is typically complimented by success in aerobic performance, and the majority of those who elect to train at higher altitudes assume that the exposure to this environment will yield benefits in this parameter. Conversely, high altitude decreases VO₂max and reduces the workloads at which training occurs. On initial exposure to hypoxia, there is a much greater reduction in VO₂max that occurs in individuals and is apparent as low as 580m altitude (5). At altitude, base training is performed at a slower velocity and lower O₂ uptake compared to sea level, though heart rate is similar and lactate is higher (7).

Furthermore, when exposed to a hypoxic environment, this uptake of oxygen decreases tremendously. The reason for this occurrence is due to the fact that the O₂ concentrations are lower at higher altitudes, thus, requiring that individuals undergo a degree of adaptations before training regimens and performances can approach sea level expectations, particularly for aerobic (predominantly endurance) activities (1). Due to the lower O₂ concentrations at increasingly higher altitudes, a stepwise progression must be taken to ensure a proper physiological response.

Exposure to high altitude, and consequently, low oxygen pressure, leads to a variety of physiological responses which are driven by a hypoxia inducible factor (9). Altitude acclimatization improves capacity for activities at altitude, more specifically, high altitude (8). As adaptation to the altitude occurs, there are studies that show no, or very small amounts of VO₂max recovery. In the cases that there are noticeable levels of recovery, it is due to constant exposure to the change in elevation. This suggests a legitimate adaptation to hypoxia that may result in increased O₂ transport to the muscle resulting in an increase in VO₂max. Furthermore, O₂ carrying capacity can be enhanced due to hypoxia-induced augmentation of total hemoglobin mass/red cell mass after classical altitude training performed from 3-4 weeks at an elevation of at least (≥) 2000m (4).

Additionally, exposure and adaptation to high altitude decreases Hb O₂ affinity which has been explained to favor O₂ delivery to tissues. When exposed to hypoxia, the magnitude of the decrease in Hb O₂ affinity depends on the acid-base status (Bohr Effect and Haldane Effect), whereas during acclimation to hypoxia, the change in Hb O₂ affinity depends on the total concentration of organic phosphates in the red blood cells, specifically 2, 3 diphosphoglycerate

(2,3-DPG) and ATP (14). As of late, altitude training's effect on aerobic capacity as well as endurance performance upon return to sea level remains ambiguous (8).

Recently, simulated altitude training has become increasingly popular for its convenience as opposed to a cold environment, harsh terrain, and low oxygen pressure that often accompanies high altitude training (1). Although there have been other apparatuses, such as snorkels, designed for simulating higher altitude conditions, it is desirable to have an economical device which can easily be worn while the user engages in physical activity that possibly facilitates acclimatization prior to entering higher altitude. Thus, acclimatization can possibly be accomplished without the necessity of the user being physically located at such an environment (10).

An elevation training mask (ETM) is a patented pulmonary resistance training device that is the only one of its kind on the market, currently. This device covers the user's mouth and restricts air intake into dual channels and has an additional vent for the discharge of exhaled air (10). Additionally, the mask includes a variety of adjustable resistance caps, as well as three adjustable flux valves. Therefore, the individual can progressively increase the resistance to simulate 3,000 - 18,000 feet above sea level.

Furthermore, with correct application, breathing devices such as the aforementioned may increase oxygen saturation in the body which could possibly produce profound effects on long- term endurance, speed of recovery from training, and ultimately, VO_{2max} . Thus, the purpose of this study is to investigate the effects of an elevation training mask on the VO_{2max} of male ROTC cadets. It is important to note that the claims that this mask can actually simulate altitude have been refuted among researchers, even with limited research available. It was hypothesized that there will be no significant difference between VO_{2max} in cadets that wore the ETM during the study and the cadets that did not.

METHODS

Participants

Fourteen male ROTC cadets participated in this study to determine if the ETM is a viable training tool to increase VO_{2max} . A larger sample size was desired, however, this was the greatest number of participants available. Also, no females were chosen in this study due to pre-existing obligations that would create conflict with data collection. The study received approval by the TAMUCC Institutional Review Board. Descriptive statistics for the cadets can be seen in Table 1.

The participants were evenly assigned to either the control or experimental group in a randomized fashion. Pre-test and post-test 1.5 mile run times (along with age) were used to estimate VO_{2max} for each participant. The 1.5 mile run was chosen for this sample due to ease of administration and similarity to their present training.

Table 1. Descriptive Statistics for Male TAMUCC ROTC Cadets.*

	All (n=14)	Control (n=7)	Experimental (n=7)
Age (yrs)	20.00 ± 1.80	19.29 ± 0.95	20.71 ± 2.21
Weight (kg)	75.68 ± 9.55	77.08 ± 11.67	74.29 ± 7.55
Height (cm)	174.36 ± 3.10	176 ± 7.14	172.72 ± 7.61
Body Fat (%)	13.61 ± 3.60	14.21 ± 3.61	13.01 ± 3.77

*Values are recorded as mean ± SD

Protocol

Prior to participating in the study, age and enrollment in the ROTC program were verified: and the purpose, procedures, requirements, risks, and how the results will be used was explained. The subjects were required to complete a Physical Activity Readiness Questionnaire, as well as an informed consent form.

After the study was explained and all documents were collected, the participants were assigned a number which served as their identification during the data collection process. A screening criteria to participate in this study was to have an estimated VO_2max of 45 mL/kg/min⁻¹ (or higher) for the pre-test. The baseline value was chosen because it is the average VO_2max for this demographic. However, there were two subjects that did not meet the minimum qualifications, but were less than 1 mL/kg/min⁻¹ under the requirement. Therefore, they were allowed to participate in the study. Upon completion of the pre test, each subject was taken through a familiarization period to gain an understanding of the elevation training mask's purpose, numerous resistance levels that simulate increases in elevation, and progression in which the resistance would be increased.

Furthermore, the training period of the study covered seven weeks, with each subject participating 3 days per week. Additionally, the training regimen was pre-determined by the ROTC in advance. Due to conflicts of interest, the training protocol was not modified. In conjunction with each training session, there was a warm-up and cool-down period. The first training session consisted of one moderate-distance run that was approximately 2 miles and was performed in an interval style with 60 seconds of slow jogging followed by a 10 second sprint. The second day had participants rotate through an 8-station body weight circuit. The longest run was always on the third training day, which required the cadets to run approximately 4 miles at a steady pace.

At the onset of training, the resistance of the ETM was set to simulate 3,000 feet above sea level. On the first training day of weeks 2, 3, and 4, the resistance was increased at intervals that simulated 3,000 feet increases in elevation. Therefore, at the beginning of week 4, the

resistance was set to simulate 12,000 feet above sea level. Unlike weeks 1-4, resistance was not increased during weeks 5, 6, and 7 in an effort to minimize risks and also to determine if any adaptations would occur at this already-high level of resistance. This specific progression was chosen due to its linear fashion over time. However, there are numerous progressions one can administer with this mask to see if training outcomes will differ.

Approximately 4-5 days after cessation of the training period, post testing (1.5 mile run for time) was performed to reduce the chance of diminishing adaptations that may have occurred during training, as well as to minimize any adaptations that may be elicited due to the presence of higher oxygen concentration once again. Also, this was an all-male study, therefore, no gender differences were required to be noted and discussed. Finally, the last procedure was to accept or reject the null hypothesis based on the data collected.

Statistical Analysis

Data was analyzed using Microsoft Excel and SPSS 19 software. A *t*-test for independent samples was calculated to determine any differences between the control and experimental group's pre-test and post-test $VO_2\text{max}$ values. Statistical significance was accepted at $p \leq 0.1$.

RESULTS

This study concluded there was no significant difference between the pre-test and post-test $VO_2\text{max}$ values (control vs. experimental) ($p = 0.34$). Therefore, the ETM was shown to not be a viable training tool to increase $VO_2\text{max}$ under the specific parameters of this study. A summary of results can be seen in Table 2.

DISCUSSION

Members of the United States Armed Forces are constantly searching for means to improve all facets of their performance. More specifically, they attempt to discover methods to enhance aerobic endurance. The purpose of this study was to investigate the effects of an ETM on the $VO_2\text{max}$ of male ROTC cadets. These findings suggest training utilizing an ETM did not significantly increase in $VO_2\text{max}$ values for male ROTC cadets.

Currently, the research on the effects of implementing this piece of equipment during training seems to be limited to the company's website. The available research on other altitude training methods has shown positive physiological adaptations in those who participated in the hypobaric chamber training; however, it is important to mention that the majority of the positive changes were not significantly different when compared to pre-test data.

The biggest limitation during this study would be the total amount of exposure to the ETM during the training period. The participants that wore the mask only did so for one hour a day for three days. Due to the amount of time required for adaptive responses to occur, wearing the ETM for three hours each week may be considered by most, insufficient. In conjunction with the lack of exposure during the 7 week training period, a small sample size may have

affected the results. Also, the subject's level of motivation was considered another limitation if they did not perform to the best of their ability. It was to be suspected, but not proven, that the subject remained highly motivated in an attempt to achieve optimal performance. Additionally, there may have been possible CO₂ re-breathing if all air was not fully discharged from the mask with each breath. This re-breathing of CO₂ could potentially limit the workload leading to a detriment in performance.

Table 2. Summary of pre and posttest VO₂max, along with absolute and relative % change of VO₂max for all participants involved in the 7 week training.

Control			Experimental		
Volunteer ID#	VO ₂ pretest (mL/kg/min ⁻¹)	VO ₂ posttest (mL/kg/min ⁻¹)	Volunteer ID#	VO ₂ pretest (mL/kg/min ⁻¹)	VO ₂ posttest (mL/kg/min ⁻¹)
1	51.96	51.01	3	51.08	51.56
2	49.94	53.30	4	45.60	46.54
5	50.85	51.48	6	44.55	48.09
8	49.60	51.08	7	50.7	50.16
11	46.18	46.75	9	50.17	51.64
12	46.24	44.32	10	52.95	52.87
14	44.08	46.75	13	52.79	54.34
	VO ₂ pretest (mL/kg/min ⁻¹)	VO ₂ posttest (mL/kg/min ⁻¹)	Absolute change in VO ₂ (mL/kg/min ⁻¹)	Relative % change in VO ₂	
C	48.41 ± 2.91	49.24 ± 3.28	0.83 ± 0.37	0.017 ± 0.13	
E	49.69 ± 3.33†	50.74 ± 2.70‡	1.05 ± 0.62	0.02 ± 0.19	
Control vs. Experimental			1.50 ± 0.03	0.235± 0.57	

* Values are reported as mean ± SD

**Control = did not receive treatment; Experimental = received treatment

† Experimental group shows no significant difference from control group after pretest (*p* = 0.46)

‡ Experimental group shows no significant difference from control group after posttest (*p* = 0.34)

Over time, studies such as this may influence the potential development of other devices that simulate training at higher altitudes, allowing individuals to decide which particular instrument will be the most user-friendly and beneficial for their specific demands. It is suggested that studies in the future broaden the scope of the current investigation by examining individuals that train with an increased frequency of exposure to the ETM over an extended duration of time. Also, the adjustment of the resistance caps can be done so in a multitude of ways, possibly eliciting various outcomes. In addition to the aforementioned modifications, blood analysis may allow the researcher to observe physiological changes that occur, if any, at the cellular level. Doing so may result in different outcomes and expand the knowledge of the overall effectiveness, or lack thereof, of this apparatus.

ACKNOWLEDGEMENTS

Data was collected and analyzed with permission from the Kinesiology faculty and ROTC command from Texas A&M University-Corpus Christi. Appreciation goes out to all ROTC cadets that participated; Dr. Frank Spaniol for his guidance and assistance throughout the study; and the TAMUCC Kinesiology Department for purchasing the masks.

REFERENCES

1. Bernadot D. Advanced sports nutrition. 2nd ed. Champaign: Human Kinetics; 2012.
2. Bonin D. Altitude and hypoxia training-a short review. *Int J of Sports Med* 18(8): 564-570, 1997.
3. Dick FW. Training at altitude in practice. *Int J Sports Med* 13(S1): S203-S205, 1992.
4. Friedman-Bette B. Classical altitude training. *Scan J of Med Sci Sports* 18(1): 11-20, 2008.
5. Hahn AG, Gore CJ. The effect of altitude on cycling performance: a challenge to traditional concepts. *Sports Med* 31(7): 533-557, 2001.
6. Hawkins M, Raven PB, Snell PG, Stray-Gundersen J, Levine BD. Maximal oxygen uptake as a parametric measure of cardiorespiratory capacity. *Med Sci Sports Exerc* 39(1): 103-107, 2007.
7. Levine BD, Stray-Gundersen J. A practical approach to altitude training. *Int J Sports Med* 13(S1): S209-S212, 2007.
8. McArdle WD, Katch FI, Katch VL. Exercise at medium and high altitude. Exercise physiology: nutrition, energy, and human performance. Baltimore: Lippincott Williams & Wilkins; 2010.
9. Risso A, Turello M, Biffoni F, Antonutto G. Red blood cell senescence and neocytolysis in humans after high altitude acclimatization. *Blood Cells Mol Dis* 38(2): 83-92, 2007.
10. Welnetz RJ. Altitude mask simulator. Retrieved from <http://www.google.com.br/patents/US58448589>. 1998.
11. Wilber R. Current trends in altitude training. *Sports Med* 31(4): 249-265, 2001.
12. Wilber R. Application of altitude/hypoxic training by elite athletes. *Med Sci Sports Exerc* 39(9): 1610-1624, 2007.
13. Wolski LA, McKenzie DC, Wenger HA. Altitude training for improvements in sea level performance: is there scientific evidence of benefit? *Sports Med* 22(4): 251-263, 1996.
14. Yalcin O, Cabrales P. Increased hemoglobin O₂ affinity protects during acute hypoxia. *Am J Physiol Heart Circ Physiol* 303(3): H271-281, 2012.