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TRIATHLETE ADAPTS TO BREATHING RESTRICTED TO THE NASAL PASSAGE WITHOUT LOSS IN VO2MAX OR VVO2MAX

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ABSTRACT

This case study investigated the effect of restricting breathing to the nasopharynx versus the oropharynx on the ability to perform maximal and high level steady state running in a highly trained triathlete who previously adapted himself to nasal only breathing during exercise as a means of inhibiting exercise-induced bronchospasm (EIB). The subject was tested using a maximal graded treadmill protocol (GXT) to voluntary exhaustion followed 10 minutes later by a 6 minute steady state treadmill protocol (SS) at 85% of the previously achieved maximal velocity in both breathing conditions. Oxygen uptake was measured via indirect calorimetry and 1 second forced expiratory volumes (FEV_1) were measured with spirometry. In the GXT trials the subject produced a time to exhaustion (TE) of 6:24, a maximal oxygen consumption ($VO2_{max}$) of 3.92 L/min. and a velocity at $VO2_{max}$ ($_{V}VO_{2max}$) of 9.7 mph while breathing only through the nasopharynx (NB). While breathing only through the oropharynx (OB) he produced a TE of 6:15, a $VO2_{max}$ of 3.80 L/min. and a $_{V}VO_{2max}$ of 9.7 mph.. During the 6 minute SS trials running at 8.0 mph, his mean oxygen consumption was 4.16 L/min. in NB and 3.99 L/min. in OB. The subject experienced a 17% reduction in FEV_1 (Pre = 5.03 L/sec., Post = 4.17 L/sec.) following the OB GXT not seen following the NB GXT. This case study confirms the ability of a highly trained competitive triathlete to adapt to breathing restricted to the nasopharynx during running at both a maximal effort and a subsequent high level steady state effort without a loss in performance or peak aerobic capacity, as a means of inhibiting EIB.

Keywords: nasal breathing; running; $VO_{2max;}$ $_{V}VO_{2max}$, exercise-induced bronchospasm; oxygen consumption; triathlete

INTRODUCTION

The vast majority of individuals who engage in heavy aerobic exercise breathe predominately through the oropharynx (OB) while doing so (1). However, those suffering from exercise-induced asthma (EIA) have been shown to greatly reduce symptoms by restricting breathing to the nasopharynx during exercise (2, 3). Exercise-induced bronchospasm (EIB) not associated with classical asthma has been shown to occur at rates of 10-50% among well trained endurance athletes in a wide variety of sports (4). One theory concerning this phenomenon suggests that high ventilation rate breathing through the mouth during heavy aerobic training introduces large volumes of unfiltered, non-humidified and non-temperature regulated air to the bronchi and lungs resulting in tissue damage and the development of EIB as a reactive mechanism (5).

It is possible that this response might be attenuated or eliminated by adapting to a pattern of breathing through the nasal passage (NB) alone. Unfortunately, the available research evaluating the capacity to perform physical work while restricting breathing to the nasopharynx suggests that maximal work capacity is severely limited in comparison with breathing through the oropharynx alone or oronasally in subjects not specifically adapted to breathing restricted to the nasal passage (6). Further, upon initially attempting to breathe only through the nasal passage during exercise individuals sometimes experience air hunger, the sensation that they are not breathing adequately (7). As a result, this approach to preventing or treating EIB is not attractive to either average exercisers due to initial discomfort or to athletes who place a premium on the ability to work at high relative exercise intensities. In spite of the fact that breathing restricted to the nasal passage during heavy exercise is not widely practiced, there are published anecdotal reports of individuals who have chosen to adapt to do so with positive results (7). Such adaptation appears to require several months (7). However, no published scientific report evaluating the relative work capacity of an athlete specifically adapted to breathing restricted to the nasal passage currently exists.

Consequently, when presented with the unusual phenomenon of a highly trained triathlete who claimed to have adapted to breathing entirely nasally while running during all intensities of training and racing, we took the opportunity to examine his case by measuring the effect of a restricting breathing to the nasal passage versus the oral passage on his peak work capacity, maximal oxygen uptake, physiological economy and any change in one second forced expiratory volume via a single case experimental approach.

METHODS

The case study design consisted of a single subject comparison across two experimental conditions.

Subject

The study was approved by the Institutional Review Board at Colorado State University – Pueblo and conducted there at an elevation of 1450 meters above sea level. The subject was a 53 year old male competitive triathlete who had competed in the sport successfully for 31 years (1981-2012) at the initiation of the project. He reported training between 3-5 hours in running along with ~3 hours swimming and 6-10 hours cycling weekly. He had done so habitually since 1981.

Exercise Testing

The subject completed a maximal graded running protocol (GXT) designed to elicit a peak workload and oxygen uptake within six to ten minutes using a TRUE Commercial Series 8.0 motorized treadmill. The individualized protocol began at 7.0 mph and increased workload by 0.3 mph every 30 seconds until he reached voluntary termination due to exhaustion. Ten minutes after the GXT trials the subject completed a six minute steady state (SS) protocol at 8.0 mph which was performed at 85% of the velocity achieved in the GXT completed during his familiarization trial. The complete testing procedure was performed on successive weeks for familiarization and then in conditions restricting breathing to the nasal passage and oral passage. The oral only breathing condition was created by having the subject wear a nose clip underneath a full face style mask. The nasal only breathing condition was created by using the same mask with the mouth taped shut and an external nasal splint placed on the nose to offset the slight pressure effect created by the mask on the nasal flares. The subject did not consume any medications prior to or during testing. Oxygen consumption was measured using a Medgraphics Ultima PFX metabolic cart. Heart rate was measured using a Polar heart rate monitor. The one second forced expiratory volume (FEV_1) was measured at rest and immediately after the maximal protocol using a Microlife PF100 spirometer. Following familiarization testing the experimental trials were conducted at the same time of day one week apart. The subject was blinded as to work output and physiological responses throughout the trials. The subject carried out similar training in the weeks prior to each testing session and the testing was conducted at the same time and day on subsequent weeks.

Data Analysis

Reported values for maximal oxygen consumption (VO_{2max}) were the highest 30 second averages of breath by breath data obtained during the GXT. The final 2 minutes of data were averaged for the reported SS values. They are reported without a variability measure as they represent a single subject score. The level of exertion reached in each GXT was examined by recording the rating of perceived exertion (RPE) reached after subject self-termination of the protocol using the Borg Scale (6-12); by measuring the maximal 30 second average respiratory exchange ratio (RER) reached in the protocol; and by evaluating the final several 30 second average measurements of oxygen consumption for leveling or dropping prior to the subject's volitional termination of the GXT. The occurrence of exercise-induced bronchospasm was evaluated by comparing pre and one minute post-measures of FEV_1 taken before and after the graded protocol. A drop in value greater than 15% was interpreted as indicative of bronchospasm.

RESULTS

As illustrated in Table 1, during the graded protocols the subject exhibited similar velocity at VO2max ($_VVO_{2max}$), time to exhaustion (TE) and maximal oxygen consumption (VO_{2max}) across the NB and OB conditions.. The peak expiratory exchange ratio (RER) and rating of perceived exertion (RPE) were also very similar and indicative of a maximal effort in both conditions. However, in the NB condition maximal heart rate (HR_{max}), maximal ventilation (VE_{max}), respiratory rate (RR), ventilatory equivalent (VE/VO_2), fraction of expired oxygen (FEO_2) and the pulmonary end-tidal oxygen concentration ($PETO_2$) were all considerably lower. Pulmonary end-tidal carbon dioxide ($PETCO_2$) was higher in NB.

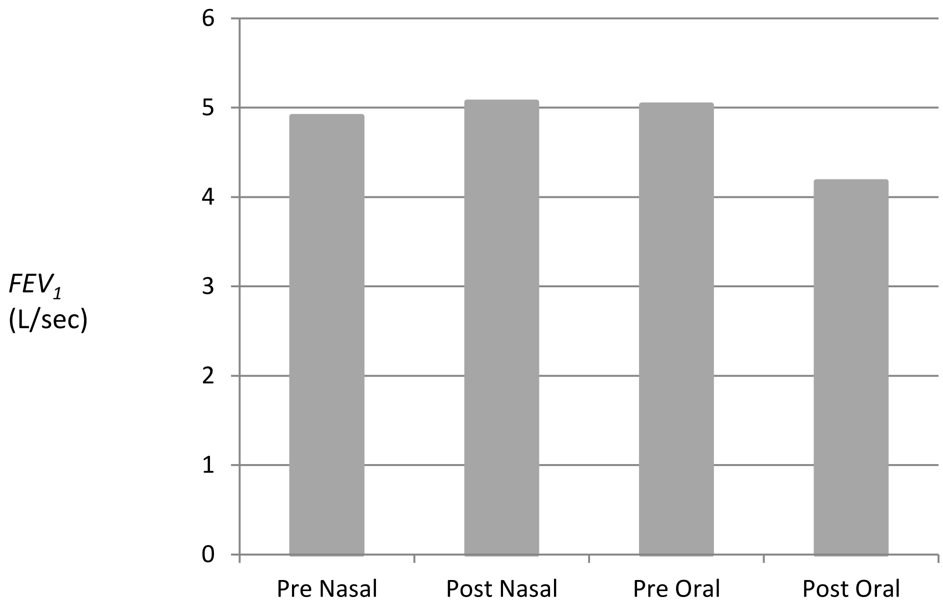
As illustrated in Table 2, during the steady state running trials at 8.0 miles per hour the subject produced a similar VO_2, HR, RER and RPE; as well as similar VE, RR, VE/VO_2, FEO_2, and $PETO_2$ in each condition. However, $PETCO_2$ was higher in the nasal breathing condition.

Finally, the subject exhibited a decrement of 17% in FEV_1 following the maximal graded protocol while breathing orally (Pre = 5.03 L/sec., Post = 4.17 L/sec.) which met our criteria as evidence of exercise induced bronchospasm; however he exhibited no meaningful differences in FEV_1 across the nasal breathing trials, as illustrated in Figure 1.

Table 1 - *Maximal GXT Results*	***Nasal Condition***	***Oral Condition***
Velocity at $VO2_{max}$	9.7 mph	9.7 mph
Maximal Oxygen Consumption	3.92 L/min	3.80 L/min
Time to Exhaustion	06:24.0	06:15.0
Maximal Heart Rate	168 bpm	173 bpm
Respiratory Exchange Ratio	1.26	1.32
Borg Rating of Perceived Exertion	20	20
Maximal Ventilation	160.5 L/min	187.6 L/min
Respiratory Rate	50	60
Ventilatory Equivalent	41	50
Fraction of Expired Oxygen	17.16%	17.75%
Pulmonary End-Tidal O_2 Concentration	91 mmHg	95 mmHg
Pulmonary End-Tidal CO_2 Concentration	39 mmHg	35 mmHg

Table 2 - *Steady State Run Results*	***Nasal Condition***	***Oral Condition***
Running Velocity	8.0 mph	8.0 mph
Oxygen Consumption	4.16 L/min	3.99 L/min
Heart Rate	156.5 bpm	149 bpm
Respiratory Exchange Ratio	1.09	0.94
Borg Rating of Perceived Exertion	15	15
Ventilation	135.87 L/min	136.42 L/min
Respiratory Rate	42	43
Ventilatory Equivalent	33	34
Fraction of Expired Oxygen	16.40%	16.62%
Pulmonary End-Tidal O_2 Concentration	88 mmHg	89 mmHg
Pulmonary End-Tidal CO_2 Concentration	40 mmHg	31 mmHg

Figure 1 - *Pre and Post GXT FEV_1 across Breathing Conditions*



DISCUSSION

The subject self-reported that he began adopting a nasal-only breathing approach during cycling and running in conjunction, with daily use of a Neti Pot in 2006, as a means of overcoming post exercise coughing, exercise induced wheezing and the frequent sinus and upper respiratory infections he had experienced throughout his athletic career to date. He further reported that after a period of approximately six months spent gradually adapting to the nasal only breathing approach at all levels of training and racing intensity, his post exercise coughing had stopped occurring, the wheezing symptoms he experienced while running stopped occurring and his incidence of upper respiratory illness was dramatically diminished. This continued until the time of our study as well. During the adaptive period he gradually shifted from his customary oronasal breathing pattern to a breathing pattern restricted to the nasal passage at progressively increasing training intensities as his feeling of air hunger diminished at each level of intensity while breathing nasally. He described this process as taking approximately 6 months, after which he was able to run a mile in 5:32, the best time he had recorded over the previous decade, while limiting his breathing to the nasal passage and without undue feelings of air hunger.

The subject's highest relative VO_{2max} recorded during our study was 49.8 ml/kg/min at peak ventilations of 160.7 L/min and respiratory rate of 50 breaths per minute. This peak ventilation value greatly exceeds the peak ventilation of 40 liters/min reported for normal subjects breathing in a nasally restricted manner prior to switching to oronasal or oral breathing in a similar graded exercise testing situation (8), providing further evidence that a significant adaptation to nasally restricted breathing had occurred in our subject's case. In addition, his VO_{2max} suggests a well above average aerobic capacity for his age and gender (9) implying that successful adaptation to a nasal only breathing strategy may be possible even for an athlete with higher than average cardiorespiratory capacity.

Of additional interest is the way in which this subject was able to adapt to breathing entirely through his nasal passage during heavy ventilation without distress. The ability to do so seems counterintuitive as nasal breathing increases the resistance to flow considerably (10). In spite of his level of adaptation, this anatomical difference still limited his ability to produce the same ventilation nasally versus orally at maximal levels of work, although not during the high steady state work. The relative hypoventilation the subject demonstrated in NB appears to have been offset by an increased oxygen extraction from each breath, as seen by a lower expired oxygen fraction (FEO_2). This parallels the findings of Morton, et al who also reported a lower FEO_2 coupled with lower ventilation (VE) at maximal work load while breathing nasally (6). This phenomenon appears to result primarily from a reduced respiratory rate, possibly allowing greater transit time for gas diffusion. Morton et al. also reported lower VE/VO2 ratios in their subjects when breathing nasally which they described as indicating better ventilatory efficiency in this condition. Our subject demonstrated the same outcome, although his maximum ventilation was not reduced as much as those of the subjects not specifically adapted in the Morton study, suggesting that part of the effect of adapting to nasal only breathing during exercise is an increase in peak ventilation while breathing nasally, possibly as a result of improved respiratory muscular function created by the increased resistance of breathing in this condition while exercising.

Our subject also reported initially experiencing air hunger as he attempted increasing work intensities while in the process of adapting to breathing nasally, sensations which gradually disappeared. While we found no published data on this phenomenon during exercise, other researchers have demonstrated that an increased end tidal pulmonary carbon dioxide concentration ($PETCO_2$), produced by artificially creating hypoxia at rest, is associated with increased air hunger (11). However, the air hunger response disappears with sustained exposure to artificial conditions that keep $PETCO_2$ elevated over time in ventilated subjects (12). In addition, nasal breathing at rest also increases $PETCO_2$ (13). Our subject also demonstrated an increased $PETCO_2$ during both maximal and steady state exercise in NB. This observation may explain the increased sense of air hunger he described while initially adapting to nasal breathing. Further, his subsequent loss of this sensation after continued exposure to the nasal breathing approach, suggests that the same mechanism that drives the development of air hunger at rest while breathing nasally may continue to operate during exercise and may also be equally subject to down regulation with continued exposure.

Consequently, our findings support the notion that this athlete was able to adapt to a breathing strategy which restricted him to breathing only through his nasal passage during exercise without loss in $VO2_{max}$ or $_{V}VO_{2max}$. In the process he was able to overcome his previous limitations to training and performance resulting from difficulties with breathing while running and reduce his ongoing frequency of upper respiratory illness. In this case the subject appears to have retained a vulnerability to bronchospasm while running at maximal velocity and ventilation rate and breathing orally, which does not occur while breathing nasally in the same conditions. This finding is of great interest due to the elevated rate of bronchospasm documented among well-trained athletes (4).

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REFERENCES

1. Veli, N. Oronasal airway choice during running. Respiration Physiology 1983; 53(1): 129–133.
2. Mangla PK, Menon MP. Effect of nasal and oral breathing on exercise-induced asthma. Clinical Allergy 1981:11(5): 433-9.
3. Shturman-Ellstein, R., Zeballos, R J, Buckley JM, Souhrada, JF. The Beneficial Effect of Nasal Breathing on Exercise-Induced Bronchoconstriction. American Review of Respiratory Disease 1978; Vol. 118, No. 1 : pp. 65-73.
4. Rundell KW, Jenkinson DM. Exercise-Induced Bronchospasm in the Elite Athlete. Sports Medicine. 2002; 32(9): 583-600.
5. Anderson SD, Kippelen P. Airway injury as a mechanism for exercise-induced bronchoconstriction in elite athletes. Journal of Allergy and Clinical Immunology 2008; 122, (2): 225–235.
6. Morton AR, King K, Papalia S, Goodman C, Turley KR, et al. Comparison of maximal oxygen consumption with oral and nasal breathing. Australian Journal of Science and Medicine in Sport 1995; 27(3): 51-5.
7. Williams, L.. Yoga for Runners. Bloomsbury Pub: 2014.
8. Saibene F, Mognoni P, Lafortuna CL, Mostardi R. Oronasal breathing during exercise. Pflügers Archives, 1978; December (1), Volume 378, Issue 1: 65-69.
9. Shvartz E, Reibold RC. Aerobic fitness norms for males and females aged 6 to 75 years: a review. Aviation, Space, and Environmental Medicine, 1990; 61(1): 3-11]
10. Pertuze J., Watson, A., Pride N.B. (1991) Maximum airflow through the nose in humans. Journal of Applied Physiology 1991; 70:1369-1376.
11. Banzett RB, Lansing RW, Evans KC, Shea SA. Stimulus-response characteristics of CO2-induced air hunger in normal subjects. Respiratory Physiology 1996; 103(1):19-31.
12. Bloch-Salisbury E, Shea SA, Brown R, Evans K, Banzett RB Air hunger induced by acute increase in PCO2 adapts to chronic elevation of PCO2 in ventilated humans. Journal of Applied Physiology 1996; 81(2):949-56.
13. Tanaka Y, Morikawa T, Honda Y An assessment of nasal functions in control of breathing. Journal of Applied Physiology 1988; 65(4):1520-4.