Original Research

Effects of Nasal or Oral Breathing on Anaerobic Power Output and Metabolic Responses

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ABSTRACT

International Journal of Exercise Science 10(4): 506-514, 2017. Nasal and oral exclusive breathing modes have benefits and drawbacks during submaximal exercise. It is unknown whether these responses would extend to anaerobic work performed at high intensity. Nine individuals (males N = 7, females N = 2) performed a standard Wingate Anaerobic cycle test on a cycle ergometer under nose (N) and mouth (M) only respiratory conditions, performed in a counterbalanced order. A 2 (condition: nose, mouth) x 6 (time: 0-5 sec, 5-10 sec, 10-15 sec, 15-20 sec, 20-25 sec, 25-30 sec) repeated measures ANOVA was used to analyze the data with significance accepted at the $p<0.05$ level. No differences between breathing mode were observed for any power output or performance measures associated with the Wingate Anaerobic cycle test. Respiratory exchange ratio (RER) was significantly higher in the oral respiration condition from 10 seconds to 25 seconds during the test ($p<0.05$). On the other hand, heart rate (HR) in the nasal condition was significantly greater during the final two time intervals ($p<0.05$). Nasal breathing was effective in reducing hyperventilation as RER remained below 1.0. However, elevated HR with nasal breathing indicates increased cardiovascular stress associated with this mode. As breathing mode does not affect power output or performance measures during completion of a high-intensity anaerobic test, preference of the participant should be the determining factor if a choice is available.

KEY WORDS: Nose versus mouth, Wingate cycle test, maximal anaerobic capacity, metabolic measures

INTRODUCTION

One of the primary determinants of endurance performance is the maximum rate of oxygen uptake (VO_{2max}), as it sets a ceiling on an individual's ability to take in and consume O_2 and has an effect on consequent energy production during exercise (13). When an individual exercises, O_2 can be taken into the body through both nasal and/or oral passageways. Nasal breathing is innate to human respiration due to the important function of preparing inhaled

air to reach structures of the respiratory system (16). Nasal inspiration has beneficial functions that include converting inspired air to temperatures near that of body temperature; increasing it's humidity; and acting as a filter by extracting contaminants (including dust and bacteria) prior to air passing into the remaining respiratory system (6). If a higher concentration of nitric oxide is formed in the nasal passages and taken up in the lower respiratory tract, it is assumed that nasal nitric oxide will improve respiratory function (17). Therefore, there may be various benefits to nasal versus oral breathing while exercising.

In a study utilizing sport conditioning drills it was reported that restricting nasal breathing had no negative affects on physiological responses (8). It is a common observation that during exercise the mouth is more or less continuously open, and as ventilation increases one shifts from nasal to oronasal breathing (11). The switch from nasal to oronasal breathing during exercise is partly attributed to the relative high nasal airflow resistance and the resultant increased breathing effort sensation (15). This so-called switch is where nasal breathing becomes less optimal. One study reported that cycling at 60% of maximum heart rate with oral breathing resulted in higher levels of oxygen, ventilation volume and respiratory rate produced, as opposed to nasal breathing (3). As work rate and intensity increase, oral breathing seems better suited because it can deliver larger volumes of oxygen to the working body at a faster rate. The relative contributions and physiological determinants to nasal and oral breathing during exercise are still not well understood (1).

In a case study, a competitive triathlete who had adopted a nasal-only breathing strategy during training displayed greater maximal oxygen consumption and time to exhaustion during graded exercise tests performed in a nasal only condition and an oral only condition (4). As the energy contribution supplied at the end of a maximal exertion exercise test is significantly anaerobic, we wondered whether similar findings would be displayed during a classic test for anaerobic capacity. Therefore the purpose of this test was to analyze nasal breathing and oral breathing during completion of the Wingate anaerobic cycle test. Our primary hypothesis was that nasal breathing would be more advantageous than oral breathing, in regards to completing a thirty-second Wingate anaerobic test on a cycle ergometer. We believed nose-breathing to be more controlled as opposed to the mouth where an individual might tend to hyperventilate.

METHODS

Participants
Nine individuals (males N = 7, females N = 2) participated in the study (see table 1 for characteristics). All individuals were considered low risk according to the American College of Sports Medicine Stratification Screening Questionnaire. All participants provided informed consent and procedures were approved by the University of Nevada Las Vegas review board (protocol #885381-2).

Table 1. Participant demographic characteristics (n = 9).

	Age (yr)	Height (cm)	Body mass (kg)
Average ± SD	24.44 ± 7.60	171.68 ± 6.94	74.27 ± 14.56

Protocol
All procedures were performed in the Exercise Physiology laboratory at the University of Nevada, Las Vegas. All descriptive characteristics were measured and recorded before testing was performed. Metabolic data was recorded from computerized software attached to the metabolic analysis system (Moxus, Applied Electrochemistry Incorporated, Pittsburgh, PA) as well as the cycle ergometer (Wattbike Ltd, Nottingham, UK). Prior to testing participants were outfitted with a heart rate monitor (H7, Polar, Oy, Findland) and respiratory mouthpiece.

Participants performed a standard Wingate Anaerobic Test on the cycle ergometer to which they chose a comfortable seat height with a predetermined resistance (7.5% of body mass). Standard procedures called for maximal effort while pedaling on the cycle ergometer for 30 seconds. Procedures were taken under two conditions, nose (N) and mouth (M), performed in a counterbalanced order. At least 30-min of rest was provided between bouts.

Under the N condition, participants had athletic tape placed over their mouth in order to prevent any oral breathing. For the M condition, the nose was plugged with a standard laboratory noseclip and respiratory headgear was attached to the head in order to secure metabolic data. The participant was allowed a warm up consisting of 3 minutes of unloaded pedaling. Immediately following the warm up participants performed as many cycle revolutions on the ergometer as possible. The sampling rate on both the metabolic analysis system and on the cycle ergometer was set to time intervals of 5 seconds.

Statistical Analysis
A 2 (condition: nose, mouth) x 6 (time: 0-5 sec, 5-10 sec, 10-15 sec, 15-20 sec, 20-25 sec, 25-30 sec) repeated measures ANOVA was used to analyze the data. If a significant main effect occurred for condition, a 2-tailed paired t-test was used to determine significance. If a main effect for time occurred, a one-way ANOVA was utilized to determine where differences occurred between time points. The statistical significance of this study was set at $p < 0.05$.

RESULTS

No differences between oral or nasal conditions were noted with respect to any power output parameters or performance measures associated with the Wingate Anaerobic cycle test (see table 2).

While no interaction between time and condition was observed for respiratory exchange ratio (RER), ($p = 0.27$), significant main effects for time ($p = 0.01$) and condition were found ($p = 0.028$). Post hoc analysis showed that RER was significantly higher in the mouth only respiration condition from 10 seconds to 25 seconds during the Wingate Anaerobic Cycle test (see figure 1).

Table 2. Power output and performance variables in subjects who completed Wingate cycle tests under conditions of mouth-only and nose-only respiration.

Variable	Mouth	Nose	p-value
Peak Power (W)	694.9±176.8	734.7±172.1	0.36
Mean Power (W)	503.1±125.1	513.6±122.6	0.58
Estimated Energy (kcal)	16.2±3.6	16.5±3.5	0.56
Revolution count (#)	64.1±4.4	63.7±3.0	0.74
Mean Speed (km.h^{-1})	51.4±5.1	51.7±4.8	0.66
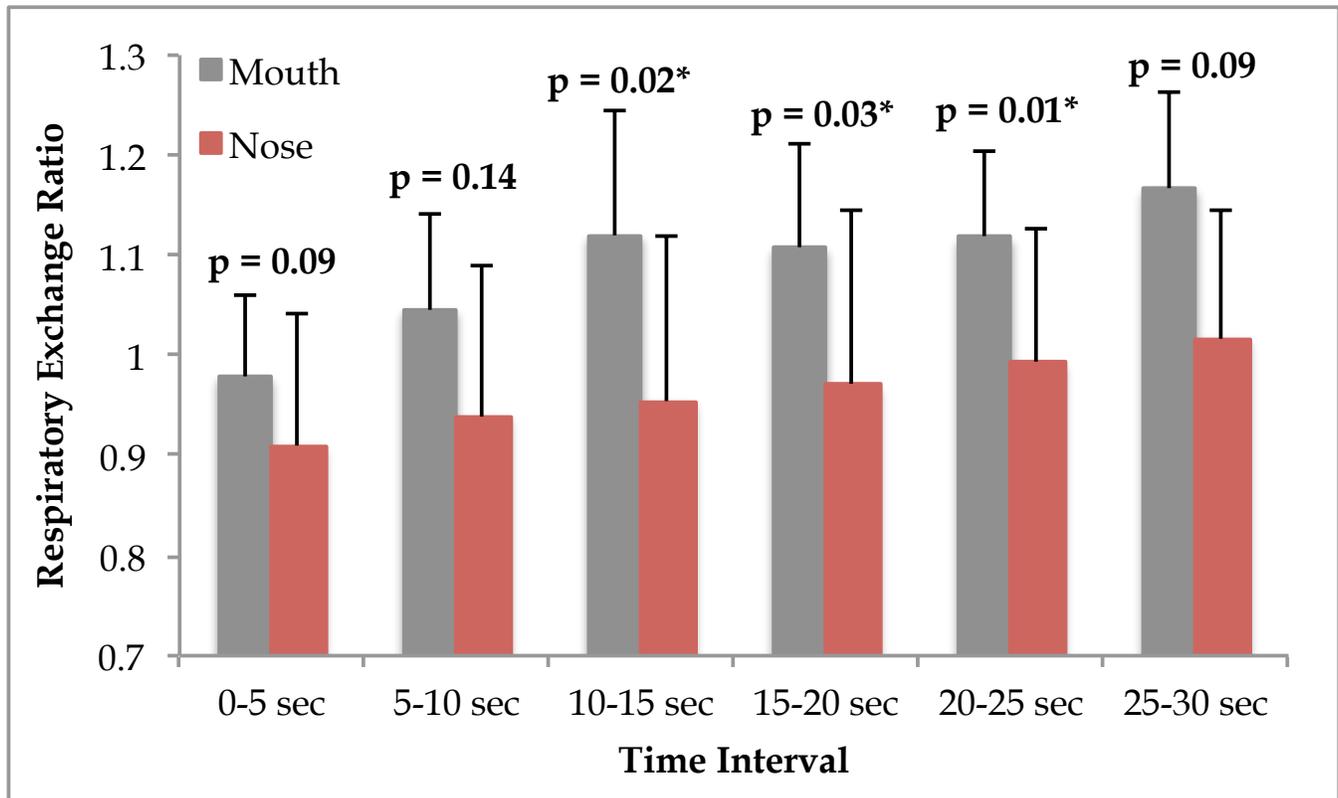
Figure 1. Respiratory exchange ratio during the Wingate Anaerobic cycle test in participants (n = 9) who performed testing under oral and nasal conditions. Significance is shown in the figure and accepted at p≤0.05.

With respect to heart rate (HR), no interaction was evident (p = 0.74), but significant main effects were observed for time (p = 0.001) and condition (p = 0.028). Post hoc analysis revealed that HR in the nasal condition was significantly greater during the final two time intervals compared to respiring through the mouth (see figure 2).

A significant time x condition interaction was observed for the ventilatory equivalent of oxygen (VeqO2) (p = 0.001). VeqO2 was significantly higher in the oral condition from 10 seconds through the remainder of the test (see figure 3).
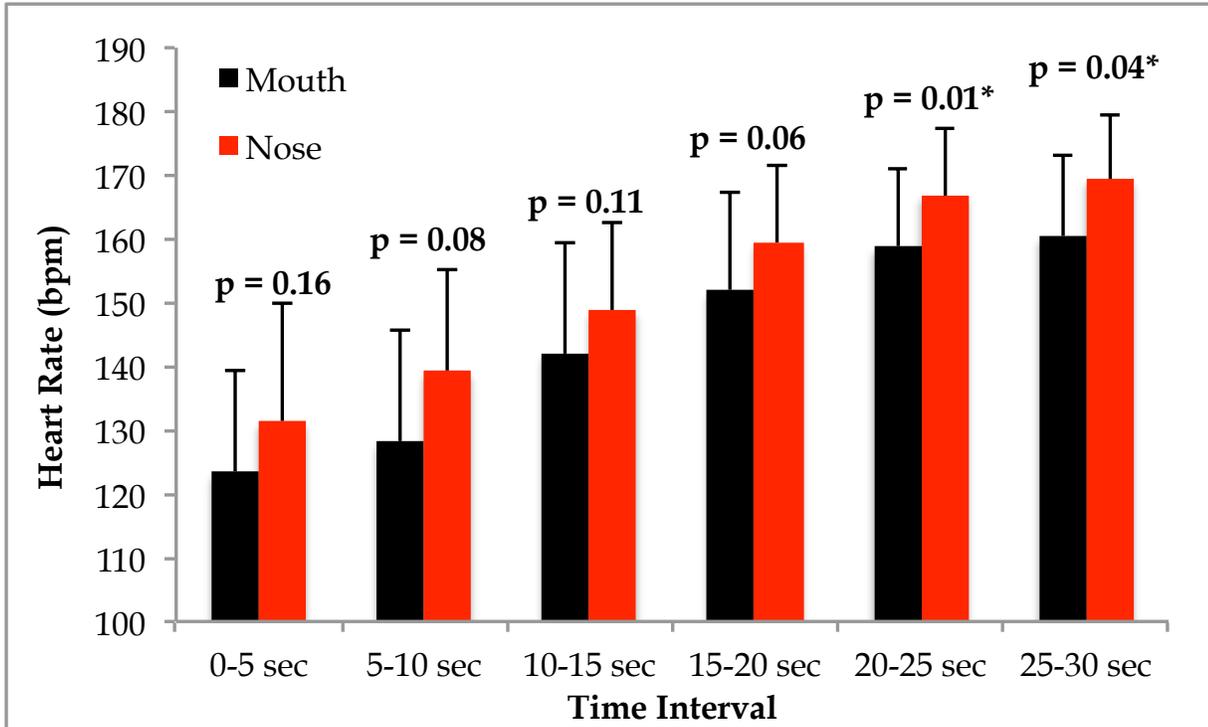
Figure 2. Heart rate response to the Wingate Anaerobic cycle test in participants (n = 9) who performed testing under mouth only and nasal only conditions. Data are displayed as mean and standard deviation. Significance is shown in the figure and accepted at p≤0.05.
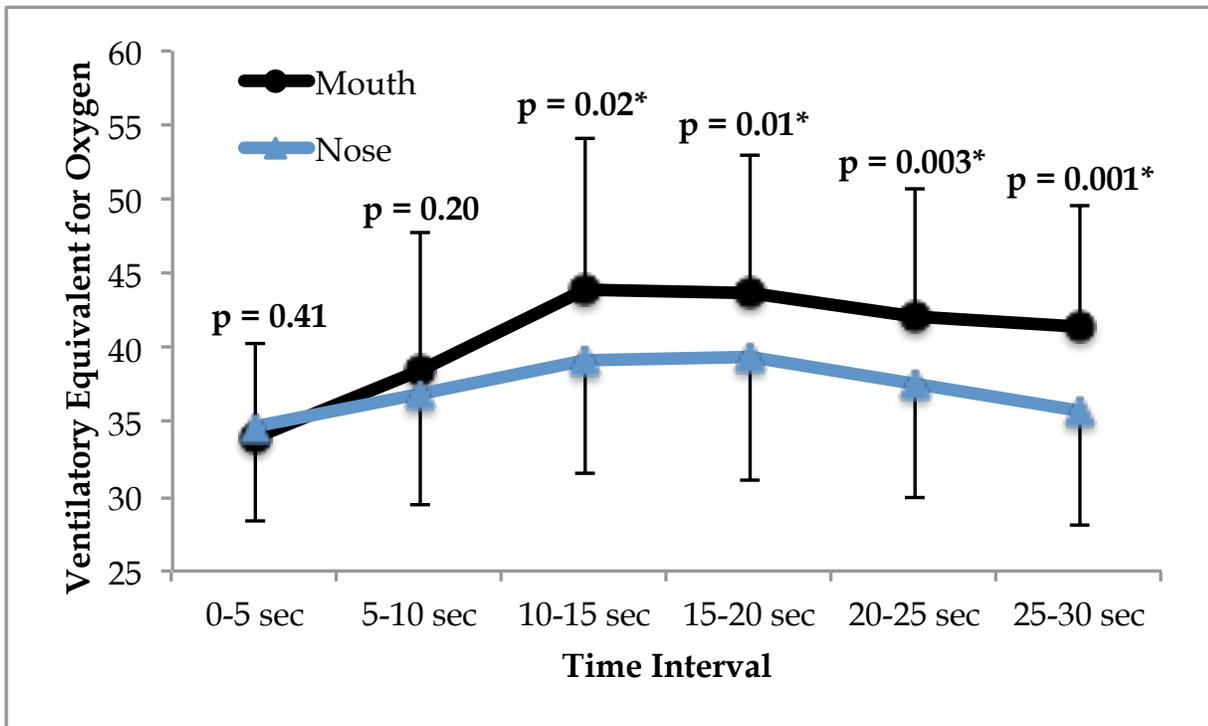
Figure 3. The ventilatory equivalent for oxygen response throughout the Wingate Anaerobic cycle test in subjects (n = 9) who performed under mouth and nose-only breathing conditions. Significance is shown in the figure and accepted at p≤0.05.

With respect to relative oxygen consumption, we observed no interaction (p = 0.57) or main effect for condition (p = 0.14). There was a main effect for time (p = 0.001), with oxygen consumption increasing throughout the duration of the test (see table 3). Additionally, no interaction (p = 0.11) or main effect for condition (p = 0.26) was noted for the ventilatory equivalent for carbon dioxide. While a significant main effect for time was initially noted (p = 0.04), pairwise comparisons revealed no significant differences at any time interval (p>0.05).

Table 3. Oxygen uptake collapsed across oral and nasal conditions in participants who completed the Wingate Anaerobic test (n = 9).

Time Interval (sec)	VO2 (ml.kg^{-1}.min^{-1})
0 - 5	16.0±4.3[a]
5 - 10	20.6±5.0[ab]
10 - 15	21.8±3.8[b]
15 - 20	24.5±4.8[bc]
20 - 25	27.9±5.6[cd]
25 - 30	30.5±6.5[d]

**Time intervals with the same letter are statistically similar to each other.

DISCUSSION

The main purpose of this study was to investigate how the different breathing mechanisms of the nose and mouth affected power output and metabolic measures during performance of an anaerobic capacity test. It was hypothesized that nasal breathing would be more advantageous than oral breathing, due to its effect on respiratory control. Based on RER data we found that nasal breathing did significantly reduce hyperventilation, however this made relatively little difference on power output and performance measures.

Previous literature has suggested that oral breathing during submaximal exercise allows for greater ventilation to meet the oxygen consumption demands of physical activity (3). Hall asked participants to perform exercise on a cycle ergometer at 60% of their maximum heart rate and concluded that oral breathing resulted in a higher ventilation volume and uptake of oxygen in comparison to nasal breathing (3). Conversely, oral-only breathing during speaking tasks has been shown to cause vocal cord dehydration that results in increased pressure needed for verbal communication and increased vocal effort (12). While not directly associated with the exercise task in the current investigation, it is possible that some of these mechanisms (i.e. vocal cord dehydration, increased pressure and effort) could adversely affect mouth-only breathing during exercise.

On the other hand, nasal breathing filters large particles from the surrounding environment and may help to deliver air with fewer contaminants to the respiratory system (2). Additionally, nasal breathing increases the humidity of the inspired air and may make it more pleasurable to the lungs for utilization (6). Finally, because of its effect as a potent vasodilator, NO produced during nasal breathing could be beneficial during exercise (7). Yasuda et al. showed that while NO increases two-fold during cycle exercise at 60W performed in a nasal

breathing condition compared to mouth only respiration, no differences were observed with respect to cardiorespiratory measures (17).

It should be noted that we determined some limitations with the current study. A convenience sampling of the student population was obtained, and therefore the results may not be generalizable to individuals outside of this setting. Another drawback that we noted upon completion of the study was a relatively wide range of fitness levels among the participants. Because of this some participants anecdotally reported muscle soreness due to the activity and this may have affected the subsequent trial. Another limitation is that nitric oxide production was not evaluated, reducing our ability to mechanistically explain respiratory results.

Given the limitations noted above, future investigations are warranted. Subsequent studies should measure and report nitric oxide produced during oral and nasal exercise bouts. Additionally, extending sampling times into the recovery period may provide additional insight into the differences between oral and nasal breathing. Also, controlling for fitness or training level, or testing specific populations (such as athletes from sports that tend to prefer only mouth breathing, or only nasal respiration) could provide to be beneficial.

The results of the current investigation provide mixed results with respect to which mode of breathing is the most advantageous during an anaerobic capacity test. While research indicates that psychological stress could increase hyperventilation (14), we feel that the very short nature of the anaerobic bout somewhat limits this influence. However, as we did not obtain respiratory measures immediately prior to the tests, this opens an interesting area for future study. Nevertheless, from a respiratory control perspective, we believe that nasal breathing was effective in reducing hyperventilation as RER remained below 1.0, whereas the oral breathing condition returned RER values that are similar to those found at the end of maximal exertion (VO_{2max}) treadmill tests (9). Additionally, the ventilatory equivalent for oxygen data supports nasal breathing as a more efficient mode given that the same amount of mechanical work could be completed at a lower metabolic cost compared to oral respiration. However, heart rate during the later stages of the Wingate Anaerobic cycle test was significantly higher during nose-only breathing. Previous investigations utilizing lower intensity exercise have found no difference with respect to the heart rate response between breathing modes (3, 5, 17). It is possible that as the exercise intensity increases to maximal or near-maximal, that exclusively nasal breathing results in greater cardiovascular stress. This possibility warrants further investigation.

To our knowledge, cardiorespiratory measures under the conditions of oral-only, or nasal-only breathing have not been reported for an anaerobic exercise bout. Therefore, the results presented here represent novel data in this relatively limited area of research. As there are benefits and drawbacks associated with either type of breathing mode, the ultimate preference is at the discretion of the participant (10). As breathing mode does not affect power output or performance measures in completion of a high-intensity anaerobic exercise test, the preference of participant should be the determining factor.

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