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Oral vs. Nasal Breathing during Submaximal Aerobic Exercise

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ORAL VS NASAL BREATHING DURING SUBMAXIMAL AEROBIC EXERCISE

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ABSTRACT

Oral vs Nasal Breathing During Submaximal Aerobic Exercise

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When comparing oral breathing versus nasal breathing more volume of air can be transported through the oral passageway, but nasal breathing can lead to slower respiration rates and cleaner inspired air. The purpose of this study is to find the most efficient mode of breathing during different intensities of submaximal aerobic exercise. There were 9 males and 10 females that completed this study. First test was a VO_2 Max test, 3.0 mph for 3 minutes, with increases in 1.0 mph every minute after that. Using a regression equation running speeds were determined for each individual's submaximal intensities. The desire was to have each individual complete 4 minutes on the treadmill at 50%, 65%, and 80% of VO_2 max. One trial was completed by nasally and other orally. Oral breathing was significantly greater ($p<.05$) in all three intensities (50%, 65%, and 80%) in RR, VE, VO_2/kg, VO_2, and VCO_2. Oral breathing creates greater respiratory rates and allows for greater volumes of air to be transferred to the lungs; combined with greater O_2 consumption and CO_2 expiration this breathing mode met the exercise demands more proficiently. With greater respiratory and metabolic demands met in oral breathing it provided the more suitable breathing mode for intensities greater than 50% VO_2 max. Steady state did not seem to be reached in nasal breathing during the short 4 minute stages. There were beliefs that anaerobic contributions during the nasal breathing mode allowed for measures to create similar responses.

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Chapter 1

Introduction

Respiration is a fundamental physiological process that warrants exploration in finding the most efficient breathing mode during exercise. There are multiple modes in which an individual can breathe: through the mouth, nose, a tracheostomy tube, or combinations of these modes. In healthy individuals, breathing will occur predominantly through the nasal cavity at rest and combination of oronasal breathing during exercise. At rest, over 90% of inspiration occurs nasally (Camner and Bakke, 1980). Oral breathing will exchange greater volumes of air at maximal intensities. During varying intensities of exercise there are advantages and benefits for different modes of breathing. Finding the most effective breathing mode at submaximal intensities is the desire for the proposed study.

At rest nasal breathing dominates respiration and at maximal intensities of exercise oral breathing is required; however, it is unknown which specific breathing modes are preferred at differing submaximal intensities. Although moderate submaximal exercise would not dictate one breathing mode completely, it is possible that one mode could work more efficiently than the other. Determining the favorable intensity of each breathing mode could yield further information to an increase in aerobic performance in individuals. There is a gap in the research investigating submaximal intensities. Research has been conducted at rest and at maximal values, but limited studies have been conducted examining moderate workloads. One such study by Hall et al. (2006) found at 60% of maximal oxygen consumption (VO_2 max) that oral breathing produced significantly higher oxygen consumption (VO_2), ventilation (VE), and respiration rate

(RR) than nasal breathing. With VO_2 being higher in oral breathing is that primarily from different volumes of air being transported to lungs or is there a work capacity difference between the two breathing modes? RR and VE should create lower values in nasal breathing, but VO_2 is the variable that should warrant greater examination. Determining the intensity nasal breathing begins to inhibit athletic performance and moment to incorporate oral breathing is the underlying mechanism to investigate.

This investigation is a replication of an unpublished study by LaComb et al. (2014). Nasal vs oral breathing was examined during treadmill running in 18 healthy college students. Moderate intensities of 50, 65, and 80% of each individuals VO_2 max were the work rates completed at 5 minute stages. There was a significant higher response ($p<.05$) in oral breathing in RR, ventilatory equivalent for oxygen content (Veq/O_2), ventilatory equivalent for carbon dioxide content (Veq/CO_2), end tidal concentration of O_2 (ETO_2), and end tidal concentration of CO_2 ($ETCO_2$) at all workloads. Absolute VO_2 (L/min) was significantly higher at 80% for nasal breathing ($p<.05$). RR represented nasal breathing having slower, deeper breaths to maintain the same work rates. Oral breathing occurred in shallow, quick breaths; probably due to the need to receive more O_2 into the lungs and higher CO_2 values in the body. CO_2 is the driving force for respiration and the study provided evidence that oral breathing had greater Veq/CO_2 and $ETCO_2$. It is likely that more prevalent CO_2 concentrations led to a higher perception to require more breathing, enticing the higher respiration rates. The Veq/O_2 levels were significantly lower in nasal breathing, providing evidence that in nasal breathing per volume of air there was less O_2 content in the air than oral breathing. Less O_2 content will result in a decrease in exercise performance. The last stage there was a greater VO_2 in nasal breathing. With nasal breathing producing greater VO_2 at the last intensity it could be postulated that O_2 was utilized better or demands were much higher causing a greater work output to maintain the intensity. All intensities produced lower Veq/O_2 values in nasal breathing, creating the assumption that nasal breathing required more work to be completed by the body. Greater O_2 demand was necessary to produce the ability to work at the desired 80% max intensity.

Therefore, oral breathing seems to be more efficient at the 80% intensity, but have mixed conclusions with regards to the other intensities and further investigation is warranted. The study previously mentioned needs to be reexamined, due to the equipment used during investigation. There have been previous studies measuring the switching point between nasal and oronasal (combined nose and mouth) breathing. No airways were restricted and allowed for normal transfer from nasal to nasal and oral to occur. The effects of breathing nasally are comfortable at lower intensities, but generally at 35-41 L/min total ventilation (VE) individuals switch from breathing nasally to oronasal breathing (Ninnima et al. 1980, Campbell 1984). Multiple studies have tried to find the exact switching point but deviations in study results show that there is no set point due to wide variance in individuals' breathing patterns. The size of the nasal airway was the greatest contributor to the switching point as found by Ninnima (1980). The larger the nostrils and size of the nasal cavity the longer the individual was able to breathe through the nose. An individual with a nasal airway less than .4 cm^2 was known to have airway impairment and unable to sustain nasal breathing beyond the desired work capacity, which occurred in roughly 12% of the subjects (Warren 1988).

Nasal breathing has also been shown to be beneficial during the post exercise period. Mangla and Menon (1980) observed asthmatics and non-asthmatics during oral vs nasal breathing. They found a significant lower ($p<.05$) with post exercise forced expiratory volume (FEV_1) rates in nasal breathing compared to oral breathing in both groups. When the participants were directed to breath only through their nose there was a markedly different post-exercise bronchoconstrictive response. It was suggested that nasal breathing could reduce exercise-induced asthma or bronchoconstriction in all individuals. Breathing nasally increases flow rates of air throughout the lungs.

Nasal versus oral breathing can lead to different physiological responses in the body. Oral breathing will produce a greater volume of air to be utilized by the human body. Nasal breathing can clean the air, produce Nitric Oxide, and produce the same amount of work at easier work rates. The proposed study will compare the physiological effects of nasal versus mouth breathing at multiple work rates between 50% - 80% of VO_2 max, to see which mode of breathing is more efficient and most suitable in a diverse population with varying habitual daily activity levels. The findings of this study may lead to further awareness if varying intensities are completed more efficiently with specific breathing modes. Acclimatizing to nasal breathing, could further advance individuals in their abilities to breathe more efficiently and produce improved performances compared to mouth breathing.

Purpose

The purpose of the study is to find the most efficient breathing mode at different submaximal intensities. Secondly, the specific work intensity of which breathing mode is more efficient for oxygen consumption.

Research Question

Research Hypothesis: Nasal breathing will have lower respiratory values while maintaining metabolic rates between 50% and 65% of an individual's VO_2 max during aerobic exercise, but oral breathing will provide greater metabolic responses at the 80% VO_2 max.

Limitations

The ability to test forced expiratory volumes (FEV_1) at the end of each stage is a limitation in this study. There would be a benefit to examine the effect of maximal exhalations at the completion of each stage. During pilot tests, there were 30-40 second delays before completing the exhaled maneuvers. Specifically, the mask has three knobs that would have to be unscrewed, two tubes taken out, and the respiration mask to have two latches disassembled before giving the subject the spirometer. For best results the spirometer test should occur <10 seconds of cessation of exercise.

Another limitation is finding nasal breathers that have adapted or acclimatized to nasal breathing. Through recruitment, it may be difficult to not be biased and state nasal breathing adaptation or practice is desired, but findings subjects with experience in nasal breathing will likely be difficult. Did not want to measure adaptation of nasal breathing, but that would be an effect and create a limitation on the study. Last limitation would be the ability to measure nasal resistance. On site we do not have anything to obtain accurate nasal passageway measurements.

Significance

The significance of this study is to examine the physiological responses of individuals at 50%, 65%, and 80% while breathing through the nose only and the mouth only. Benefits of this study has the potential to help endurance athletes in maximizing work capacity, help individuals with respiratory problems, sleep apnea, bronchoconstriction, and general population in living a healthier life. Familiarization to nasal breathing could further advance individuals in their abilities to breathe more efficiently and improve performances compared to breathing orally.

Chapter 2

REVIEW OF RELATED LITERATURE

Empirical Literature Review

Primary function of the nose is to smell; role of mouth is to chew and digest food. Each serve primary functions for survival, but the main focus in the present study is their role in breathing. Breathing or ventilation is gas exchange from the outside environment to the alveoli. The nose has numerous functions: olfaction, sensation, immunology, mucociliary clearance, filtration, warm and humidify, and nasal cycle with airflow dynamics (Jones et al., 2001).

Olfaction is the sense of smell, or the ability of the nose to sense odor in the nasal cavity. Humans can detect more than 10,000 odors. Smell is recognized by chemical receptors sensing the air passing through the nasal cavity. Epithelial tissue in the nose picks up the smell and transmits signals through the olfactory nerve to the brain. Most smells are then deciphered into the different sensations of smell we possess. There can be an irritation or burning sensation which occurs from branches of the trigeminal nerve and glossopharyngeal nerve that send information to the spinal trigeminal nucleus, thalamus and somatosensory cortex.

Immunology functions of the nose produce mucus and secrete immunoglobulins. The nose has its own self-defense because of the coarse hairs (vibrissae) and secretions it creates. The nose protects the lungs from allergens, toxicants, and other bacteria with its immunology properties. Mucociliary clearance promotes mucus and cilia functions: to filter, trap toxicants and transporting airborne particles. Particles greater than 30µm are removed as they are too large and inhibit respiration rate, along with the majority of particles as small as 12µm which are also filtered (Jones et al., 2001). Humidification occurs within 80% of the air before it reaches the lungs. Air is heated through conduction, convection and radiation with blood flow in the opposite direction to incoming airflow, in response allows for greater efficiency of warming the air (Swift, 1982). Overall this process can warm the air up to 3°C in the nasal cavity.

The nasal airway represents 2/3 of the total airway resistance to the lungs! Due to the elaborate properties of the nose to filter and humidify foreign particles, it also inhibits air traveling to the bronchioles. During every 3-7 hours each nostril will congest and decongest. It is unclear what causes this mechanism. This specific response is the greatest limiting factor to nasal breathing. Overall, the nasal cycle allows for inhalation and exhalation, air being transported in and out of the body, completing the entire ventilatory cycle.

Mouth physiology includes a wider array of functions. The largest contribution the mouth plays upon the human body is mechanical digestion of food. Other key roles that take place within the mouth include: speech, chemical digestion, taste, drinking, facial expressions, social bonding (kissing), and respiration. The mouth produces all noises, sounds, and speech, our fundamentals for communication. Exterior parts of the mouth contribute to facial expression such as smiling and frowning. Social interaction between the vast populations of the world is primarily due to the combination of talking and facial mannerisms. Humans break down food by mechanical and chemical digestion. Through mastication, the process of chewing, our teeth break down substances that are easier for our body to digest. Chemical digestion is an aid to chewing, where saliva dissolves and furthers the process in helping humans digest food. Saliva is secreted by the salivary glands, which produces salivary amylase. Salivary amylase is an enzyme that starts the digestion of starch into dextrin and maltose.

During respiration the oral cavity has far less resistance than the nasal cavity. At higher demands of exercise it is normal to have a higher VE in the oral cavity than nasally. During congestion of an airway, there can be different responses of respiration functions. In children with enlarged tonsils and adenoids, there was a decrease in the maximal inspiratory pressure and muscles function (Pires et al. 2005). Congestion of the nasal airway produced weaker maximal inspiratory forces and lower muscle output making it far more difficult to breathe nasally. If an individual has a stuffy nose, experiences congestion, or has extra resistance in the nasal passageway it will inhibit ventilation through the nose. Milanesi et al. (2014) investigated adults who were solely mouth breathers as children. Over years of chronic mouth breathing and adaptation to relying on the oral cavity for all breathing, there were significantly lower inspiratory and expiratory maximal pressure ($p<.05$) through the mouth when compared to nose. These years of oral breathing, severely limited the adults when tested on forced inspiratory and expiratory capabilities. From overuse or lack of using the nasal cavity, oral breathing was weaker than individuals that who were not chronic oral breathers. Overall findings from this cross sectional study of individuals, over the 10 years of optional breathing, capabilities of producing the same amount of air flow in each passageway has altered. This represents the effect of chronic mouth breathing over time and decrease in performance with overused thoracic muscles.

Respiration

Air enters the body through the nose or mouth, then travels down to the pharynx, through the trachea and into the bronchioles. Transported air into the bronchioles will enter the alveoli by diffusion. Diffusion of the O_2 molecules will exit the alveoli and enter the blood in response to the lower pressure gradient in the alveoli to the capillaries. O_2 in the blood is transported mainly through hemoglobin. Hemoglobin is and iron containing molecule that transports up to four O_2 molecules in red blood cells. During circulation of O_2 through the body, the molecules will be extracted and utilized by the tissues. The work capacity will determine the demands for O_2 consumption. Higher demands will utilize and extract more O_2 from the blood than lower intensities. O2 will be used to fuel the muscles by creating adenotriphosphate (ATP) during continuous exercise. The O_2 has served its primary purpose of supplying energy for the tissues, which turns CO_2 to the focus for the other key part of respiration.

CO_2 combines with H_2O in the blood to form carbaminohemoglobin (H_2CO_3) with the aid of the enzyme, carbonic anhydrase. The H_2CO_3 yields bicarbonate (HCO_3) and hydrogen ion (H+). CO_2 is transported as HCO_3 primarily through the body. Once O_2 reaches the tissues, the pressure of O_2 decreases, limiting the demand, and reversing the previous mentioned reaction. Excess H+ (leftovers of Hb + O_2, with O_2 being utilized by tissues) will react with readily available CO_2 in the form of HCO_3 to create H_2CO_3. The H_2CO_3 will then yield H_2O and CO_2 which is then available for diffusion back to the alveoli.

As O_2 is utilized, CO_2 levels will increase due to waste from the tissues. Higher CO_2 levels, stimulate chemoreceptors which signal for greater activation of respiration, causing an increase in RR. When completing the cycle, CO_2 will eventually be transported out of the capillaries and back into the alveoli. Resulting in CO_2 being transported out of the body by expiration.

During quiet breathing expiration is completed as a passive response. Breathing does not occur in response to forced actions of the respiratory muscles, but rather stimulation of the chemical sensations of the body upregulating the process. Inspiration occurs with forced contractions of the diaphragm and intercostal muscles. The phrenic nerve causes activation of the diaphragm and downward movement of the abdomen. Due to CO_2 levels driving respiration rates, increasing passive breathing would help lower total work completed upon the body. During higher intensities, CO_2 levels are elevated, therefore increasing RR and higher demands made on the body. This idea will be discussed later as lower CO_2 rates are desirable to allow for the body to work easier and more efficiently. Utilizing passive breathing as successfully as possible could help improve the body's energetics.

The O_2 enters the lungs, diffuses into the blood to the muscles, then CO_2 is diffused back to lungs then out of the pharynx. For optimal aerobic performance, the goal is to utilize O_2 as efficiently as possible. The greatest athletes in the world are able to consume more O_2 in their muscles while keeping CO_2 levels low. Once the respiratory exchange ratio (RER), ratio between CO_2 out and O_2 going in, moves above 1.1 that value is great enough to meet the criteria for volitional fatigue in a maximal exertion (VO_2 max) test.

CO_2 is the driving force for respiration. The general population will tend to breathe orally during exercise, which allows for faster, shorter breaths. Shallow breaths lower CO_2 levels, leading to upregulation, and increase the response of the CO_2 receptor sensitivity. Shallow breaths will likely lower oxygenation or limit the capacity of O_2 consumption. These effects will induce a hyperventilation response, also triggering a sensation of dizziness and possible fainting could occur. Nasal breathing has shown to produce lower end tidal concentration of CO_2 than oral breathing (Chinevere et al., 1999; LaComb, 2014). Training or increasing the work capacity while nasal breathing could lower the CO_2 demands. Decreasing CO_2 levels could increase the threshold of maximal exertion.

Oral vs Nasal Breathing in Aerobic Exercise

Exercise physiologists focus on health and fitness in modern populations in an acute and chronic perspective. In the realm of respiration there are many unanswered questions in the wide spectrum of oral vs nasal breathing. Research has been completed at rest and during maximal bouts. There is minimal research looking at submaximal intensities, particularly during running.

Submaximal Intensities

Subjects were examined during 10 minutes at rest and 10-15 minutes on a cycle ergometer. One test was completed using the Hans Rudolph facemask that sanctions oral breathing only. On each subject's second laboratory visit they were fitted with a nose facemask. The protocol on the cycle was to maintain constant pedal rate, then a slow increase in resistance was administered until the subject reached a level just under 60% of the maximum heart rate estimated by age. Once work rate was found, they continued at that constant resistance for 10-15 minutes. During the nasal test, the protocol was similar with slow increases of resistance until work rate was congruent to the first test. One note from the author of this study is there might have been learning effects having the subjects complete the study first orally, as subjects were more comfortable possibly with familiarity to the test. Hall et al., (2006) found a significant increase in VO_2, VE, and RR during exercise in oral breathing when compared to nasal breathing. The possibility of the subjects learning or becoming familiarized with the protocol allowed for better utilization of O_2, lower breath frequency and less total volume of air expended per minute. During nasal breathing there was greater energy efficiency than during oral breathing. Work rate and resistance were held constant on the cycle ergometer, leading to easier demands accomplished by means of nasal breathing in this sample size of 50 recreational college students.

Investigation in a different realm of the study, Hall et al., (2006), measured gender and anthropometric measures for conclusions to the elicited responses. Males had greater nose volumes, less resistance for air to enter in through the nasal passageway. The larger volumes allowed for greater VO_2 and VE. There was a significant difference between genders in VO_2 and VE during rest and exercise, for both test conditions of oral and nasal breathing ($p<.05$). Bennett et al. (2003) found that females were significantly lower at VE at rest, VE at 60%, and FEV_1 ($p<.05$). Men had less nasal contribution to breathing during exercise of all intensities. Males were able to produce greater volumes of air to be exchanged and expired out of the body, but the results showed less nasal contribution of total breathing through the nasal cavity. Based off of these findings, the males in the study should have greater nasal resistance than the females. The airway sizes were probably smaller or had physical limitations to nasal breathing with the reported low values of nasal contribution to breathing. In summary, males produce greater VE and VO_2, due to the strength in the musculature of the diaphragm and lungs.

During the same study, a regression equation produced stronger predictors for lean body mass and body mass index (BMI) scores to levels of exercise. The greater VO_2 in an individual would lead to a greater predictor of the actual lean body mass and BMI score. Nose volume was a strong predictor for VO_2, VE, and RR at a resting state. RR was found to be the lone variable during exercise to be an accurate predictor from nose volume. Lean body mass% was an accurate predictor from nose volume, VO_2, VE, and nasal RR. Overall, they found that natural selection has started to take place and there were strong relationships between nose volume, body size, and VO_2.

Another cycle ergometer investigation conducted looked at nasal contribution, but allowed access to oral breathing when desired. Comparing: at rest up to 60% (in 10 % increments) of working capacity max, the investigators examined the nasal contribution of breathing at each intensity. Caucasians were severely limited compared to African Americans in respect to nasal contribution of breathing. African Americans produced 25% greater maximal inspiratory flow readings (Bennett et al., 2003). At 20% and 60% of max physical working capacity the Caucasians had significantly less nasal contribution to breathing than African Americans ($p<.05$), along with a strong tendency at 40% working capacity of ($p=.06$). Caucasians were proposed to be more susceptible to toxic particles due to their lack of nasal inspiration compared to African Americans.

With knowledge of the previous research of oral vs nasal breathing at submaximal intensities, there were gaps in the research at the upper threshold of submaximal running. LaComb et al. (2014) in an unpublished study looked at treadmill exercise in college subjects at 50%, 65%, and 80% of their relative max. The current investigation will mimic these procedures with a more reliable system.

Results provided evidence that RR was much lower in nasal breathing than oral breathing. The ventilatory equivalents for oxygen (Veq/O_2) and carbon dioxide (Veq/CO_2) were greater in oral breathing. Ventilatory equivalent describes the ratio of VE to O_2 intake or to carbon dioxide output. The end tidal oxygen (ETO_2) and end tidal carbon dioxide (ETCO_2) were also greater in all stages of oral breathing compared to nasal breathing. ETO_2 is concentration of O_2 during the end of expiration. ETCO_2 is the concentration of CO_2 released at the end of expiration. Due to the greater O_2 content per volume of air, Veq/O_2 at all intensities suggest that oral breathing was more efficient, but greater CO_2 content expired seen in ETCO_2 and Veq/CO_2 during oral breathing leads to opposing conclusions. Greater ETCO_2 and Veq/CO_2 values lead to higher CO_2 values. When CO_2 concentrations are at high enough levels, it creates a limiting factor in respiration. Higher CO_2 rates could initiate hyperventilation and volatile fatigue from a test. When the CO_2 and O_2 ratio, RER, reaches levels above 1.1, which is an acceptable measure for maximal exhaustion in an individual. RER rates were never in the 1.1 range, but there were trending up towards 1.0.

The VO_2, heart rate (HR), and ratings of perceived exertion (RPE) were similar between oral and nasal breathing. Oral breathing did produce higher ventilatory equivalents and end tidal concentrations of both molecules portraying greater utilization and expired concentrations of O_2 and CO_2, respectively. During exercise greater O_2 utilization is optimal, but greater expiration of CO_2 leads to hyperventilation and volatile fatigue. With that tradeoff it is not conclusive that oral breathing was more efficient. Overall, nasal breathing is an adequate mode of breathing for all submaximal intensities.

At 80% of an individual's max, oral breathing is more efficient as found from the small population in the research.

The metabolic cart, respiration masks, respiratory tubes, and treadmill used during the study were all over 15 years old. Reliability of the previous results are in question as 2 subjects data were exclude due to results that were outliers during the initial study and large variability in results of the interpreted data. A small validity study was completed between the two metabolic carts that reside in the Exercise Physiology lab at UNLV, MPE 312. The Orca metabolic cart was compared to the Moxus metabolic cart using the relative respiration masks that were specific to each system were used while maintaining the same treadmill use. Six subjects were asked to complete the same VO_2 max test on the Moxus metabolic cart as a comparative study to the Orca metabolic cart. From the six individuals, VO_2, VO_2/kg, and VCO_2 were all significantly different ($p< .05$) showing that there is a reliability issue between the two systems. The VE and RER were trending to be different. It is recommended that replication of the study on the newer, metabolic system be completed.

Maximal Intensities

Morton et al. (1995) wanted to compare the VO_2 max between oral and nasal breathing. Due to the greater size of the oral airway, the authors' postulated that oral breathing will produce greater values. This study asked individuals to complete five VO_2 max tests. The first test was to acclimatize to the apparatus and protocol, along with completing the necessary questionnaire to determine if the individuals were susceptible to any asthma related issues. The other four tests were conducted with different breathing modes: nasal only (Hans Rudolph allowing nasal breathing while the mouth was taped closed with duct tape), oral only (Hans Rudolph face mask where the nose was clamped), oral and nasal (Hans Rudolph face mask with no restrictions, and mouth valve (Hans Rudolph 2-way non-rebreathing valve). The VO_2 max protocol included walking on the treadmill for two minutes at the brisk pace of 6.5 km/hr. The intensity increased each minute over the next 5 minutes until it reaching a maximal speed of 12 km/hr. After this, exercise intensity was increased by grade at 2% each subsequent minute until volitional exhaustion was reached.

The average VE scores at VO_2 max breathing nasally were reduced by 38.2%, 35.1%, and 35.0% compared to orally in mouthpiece, Hans Rudolph mask, and oral ad nasal groups respectively. Large values for reduction in VE. The metabolic values were not as substantial, as VO_2 max values were 13.6% (mouth valve), 11.6% (oronasal), and 10.3% (oral breathing only) higher in oral breathing compared to nasal breathing. The VE, ET O_2, VO_2, RR, running time and ventilation per vital capacity% (VE/VC %) were all significantly lower in nasal breathing compared to the other three groups ($p< .05$). ETC O_2 was significantly higher in the nasal breathing trial. HR was the only variable investigated that did not produce a significant difference.

Explanations for the VO_2 max differences were discussed. The HR changes were minimal and since SV was not likely to be altered between the breathing modes, assumptions could be made that cardiac output was not the limiting factor for VO_2 scores. The other possibility was the a-v O_2 difference. An increase in a-v O_2 difference would allow for greater VO_2 values in oral breathing. During nasal breathing there was a decrease in ETO_2 and increase in $ETCO_2$. Morton et al. (1995) proposed that saturation of oxygen (SaO_2) would be much lower during nasal breathing due to the air remaining in the lungs for a longer period of time in response to the decreased respiration rate with nasal breathing. It was suggested that lower SaO_2 of the arterial blood would result in lower VO_2 values, however this measure was not obtained during the investigation. Oral breathing was postulated to have greater extraction and utilization of O_2 during exercise.

Michailow et al. (1976) found a difference in VE between nasal and oral breathing of 51-62%. The explanation for this observed phenomenon was that individuals in the study had miniscule nasal airways and large mouths. Michailow et al. (1976) also reported a VO_2 difference of 33.3% between nasal and oral breathing. Morton et al. (1995) took the study one step further by examining if there was a training effect according to the guideline established by the Journal of Sports Medicine (50-85% of VO_2 max or 65-90% of maximal heart rate required to produce an increase in cardio-respiratory endurance). Specifically looking at the HR at 12 km/hr in each subject, during nasal breathing only the mean HR was equal to 87.7% of their maximal HR. Morton et al. (1995) did present findings that ventilatory adjustments were made to allow for nasal breathing to attain mean VO_2 max scores of 86.5% - 90% of VO_2 max found from other breathing modes. In the proposed study, working at 80% of VO_2 max is pushing the upper ventilatory threshold for an individual breathing nasally only.

Another VO_2 max study comparing oral vs nasal breathing was completed comparing the effects of nasal splints. The investigation was conducted by Chinevere et al. (1999) and explored the nasal splinting effects on a progressive running protocol. Each individual completed five running trials with speed at 3.13 m/s for males and 2.68 m/s for females, then grade increased 2.5% every 2 minutes until exhaustion. Trials consisted of different modes of breathing: nasal only, oral only, nasal and oral, nasal dilator, and nasal dilator and oral. VE, Veq/O_2, and RR for all nasal and nasal dilator modes of breathing were significantly lower than the other three modes. Veq/CO_2 was significantly lower for nose vs oral, and nasal dilator vs nasal, and nasal dilator vs oral breathing. $ETCO_2$ was significantly higher in nasal versus oral, oronasal, nasal dilator and oral, and in nasal dilator versus oral breathing. Nasal breathing revealed a significantly lower HR all other breathing modes. HR being significantly lower shows that nasal breathing only was not able to complete the same workload as other modes of breathing. The authors postulated that lowered maximal HR values showed a limitation of breathing nasally at VO_2 max. The individuals were not able to complete the same amount of work, not allowing the body to reach the same HR while breathing nasally.

Switching Point

There have been studies by Ninnima et al., 1980; Campbell, 1984; Saibene et al., 1978; James et al., 1997, measuring the switching point between nasal and oronasal breathing. The original belief of researchers was that nasal breathing occurs at rest and oral breathing occurs during high intensity exercise. There was small room for a combination, but deemed there was a set switching point between the two breathing modes. The first research measured individuals wearing a facemask and the switch point was determined as the time when the mouth was kept open for more than 20 seconds. Other studies classified the switching point as a noticeable increase in VE during the protocol. The effects of breathing nasally are comfortable at lower intensities, but generally at 35-41 total ventilation (VE) individuals switch from nasal only breathing to oronasal breathing (Ninnima et al. 1980; Campbell, 1984). In effort to find the specific switching point, the findings are more reliant on the individuals' breathing patterns and nasal airway size. Without a defined VE rate for all humans, there is a relative intensity for the specific switching point that maximizes the work capacity of the individual.

Saibene et al. (1978) conducted one of the original investigations of the switching point during exercise. During tests on 63 young cadet males, the switching point was determined when their mouth was kept open for 20 seconds during exercise. The protocol included riding a cycle ergometer for 3 minutes stages at work loads of 98, 131, 163, and 196 W. Pedaling frequency was 66 rpm which was held constant due to aid of a metronome. A marker was switched by a lady that sat behind the oscillograph desk when the individual met the criteria of the switching point. Oronasal breathing could have occurred much earlier with pursed lips or the individual kept their mouth open in preparation for greater demands of exercise, but did not use oral breathing. The method to obtain the switching point is questionable; however the results were similar to findings in research developed many years later. This study found 44 l/min was the VE that the switching point occurred. This was relatively high compared to what is believed to be the switching point today.

Ninimaa et al. (1980) conducted a cycle ergometer test that exercised subjects through 0 -70% (10% increments) of their physical working capacity. The findings were 37% and 50% of total work capacity and 21.8 and 25 mL/kg/min VO_2 in females and males, respectively were the switching points between the breathing modes. The methods to find the switching point can happen at low levels of exercise. In the research provided the switching point was found at low intensities, but lacked thorough investigation about the set switching point being the necessary moment oral breathing or cessation of exercise would result. For the general population nasal breathing is not commonly practiced.

The percentage of work capacity was lower than anticipated, a small percentage of subjects could withstand work at 196 W on a cycle ergometer breathing nasally only (Saibene et al., 1978). Ninimaa et al. (1980) noted roughly 20% of the subjects were able to complete all submaximal intensities breathing nasally with work output up to 110 W. Nasal breathing can be more comfortable for certain individuals with less nasal resistance and an adequate mode of breathing during all submaximal exercise. The switching point had a high predictive value (69.8%) to ratings of perceived exertion of breathing and total VE in nasal breathing.

Ninimaa (1981) replicated the cycle ergometer protocol, but tested oronasal distribution of respiratory airflow. The findings of this study were that the switching point occurred at 45 L/min and accounted for 61% of total VE at high respiratory volumes. The nasal inspiration of oral breathers exceeded expiration by 2 L/min at rest, but the difference increased to 13.5 L/min at a VE of 81.5 L/min. With work from the previous study there was bias towards early shifting of oronasal breathing and the need for oral breathing earlier. The replicated study showed nasal breathing was adequate at rest and comfortable. During the higher demands of exercise oral breathing was dominant as was suspected.

A study was conducted by James et al. (1997) examining the switching point in various ages during a submaximal exercise test. The results were as follows: 7-72 years old, nasal only (13.5%), nasal shifting to oronasal (40.5%), oronasal only (40.5%), and oral only (5.4%). The majority (81%) of runners breathed nasally at lower levels and switched to an oronasal breathing pattern. Nasal airway resistance decreased significantly with age (p < .001). Adults ages 17-30 that started breathing nasally with exercise switched to oral ventilation at a lower percentage of the earlier measured maximum ventilation (10.8%) than older subjects (31.8%). Ventilation patterns during exercise in children ages 7-16, displayed more variability than adults. Overall with the wide variety of subjects, with mixed genders, age, and ethnicity, there were no accurate predictors between the switching point or ventilation rates.

Competitive Race

Ninimaa (1983) studied 984 participants in a 10 km fun run. Subjects were videotaped using a Sony Betamax SLO 340 at the 9000 m mark while running towards the camera. Elapsed time was also recorded on the recorder. The degree of mouth opening based off of video playback were determined in 7 characteristics': mouth closed, lips possibly sealed, mouth open, mouth open teeth not occluded, mouth open not sure if teeth occluded, moth open and closed in rhythm with breathing, and subject discarded. Of the 917 people that were able to be analyzed, 96.3% of them were classified as oronasal breathers. The video recorder found 3 individuals to be predominantly nasal breathers. The three nose breathers (all males) ran at a much slower pace than the average male. There were no findings between larger openings of the mouth, correlated with running speed and increased pulmonary ventilation as the study hypothesized. .

High Intensity Exercise

In an abstract, recently published by Meir et al. (2014) nose plugs were worn to see the physical demands in oral vs nasal breathing. There were no differences in the time to completion, blood lactate, VE, HR, and RPE when wearing the nose clip. The individuals were able to achieve the same amount of work while completing all out shuttle runs independent of which breathing mode they were using. Exercise consisted of only 20m shuttle runs lasting less than 30 seconds, there were no differences in performance or respiratory values in the study.

Walking Intensities

During a six minute walking test in children SaO_2 were lower in the oral breathing group compared to the nasal breathing group. Children with oral breathing showed significant increase in RR; decreased saturation rates and lower ratings on the Borg scale (Boas et al., 2013). Milanesi et al. (2014) found subjects that were diagnosed as oral breathers or nasal breathers as children. Subjects were 18-30 when completing the study, but were diagnosed having a specific characteristic of predominantly breathing nasally or orally. After a 6 minute walk test, the study produced significantly lower maximal expiratory pressure in oral breathers compared to nasal breathers ($p<.05$). After years of chronic mouth breathing, the group produced much weaker expiratory pressure. This study provided evidence pointing to a detriment for breathing mostly through the mouth as a child and never adapting or initiating the attempt to breathe nasally.

Step Test

Individuals assessed during a step test breathing nasally versus orally were measured by Richerson and Seebohm (1968). Nasal resistance decreased as the step test became more difficult. In effort to look at the mechanism for this action: norepinephrine, epinephrine, phentolamine HCL, guanethidine, and stellate ganglion block were given on separate occasions. Norepinephrine and epinephrine elicited no response to exercise. Phentolamine and stellate ganglion block were found to severely congest and close the nasal airway (Richerson and Seebohm, 1968) and the step test was ceased due to the problems of nasal congestion. Most subjects did experience increased nasal airway openings 15 to 30 minutes following the step test.

Nasal Size and Resistance

The nose provides 2/3 of the resistance in the respiratory tract (Swift, 1988), consequently the size of the nasal cavity is the largest contributor to the switching point. The larger the nostrils and size of the nasal cavity the longer, individuals were able to breathe through the nose (Ninimaa et al., 1980). An individual with a nasal airway less than 0.4 cm^2 was known to have airway impairment and unable to sustain nasal breathing beyond the desired work capacity, which occurred in roughly 12% of the subjects (Warren 1988). If the nasal passageway is smaller than 0.4 cm^2 then the individual will rely on oral breathing.

The nose acts as a filter in respiration, preventing the penetration of toxic particles and gases to the lower respiratory tract. In different modes of breathing (nasal vs. oral) there may be differing effects of amounts of toxicant doses to the lungs. Different ethnic groups have anatomical differences, leading to certain populations to have improved responses of nasal breathing over others. Chinese individuals have greater nose cross sectional area than Indians and Caucasians (Zhu et al., 2011). Bennett et al. (2003) found that Caucasians had less nasal contribution in breathing during submaximal exercise than African Americans ($p < .05$). Maximal inspiratory flow was 2.1 L/s for Caucasians and 2.8 L/s in African Americans. Adaptation has played a key role in nasal airway size. Depending on where the individual is located and climate, there may have been adaptations to the nose. A tall, long nose with downward directed nares will help in cooler climates, allowing for more time and space for the air to be warmed and humidified. The longer nose experiences greater turbulence of airflow and has a greater surface area for exposure of harmful toxicants to the mucus membranes. A broader nose will more than likely reside in a more humid climate, to scatter and dissolve particles before it enters the lower respiratory tract (Churchill et al., 1999).

Bennett et al. (2007) completed another study that mimicked the gender comparison of nasal contribution to breathing. This change was looking at different ages: children and adults. Children will have lower nasal contribution to breathing at rest and during exercise than adults. Children however, have significantly decreased nasal deposition efficiency for 2-μm particles under light exercise breathing conditions compared to adults. Based off of these findings, children are less efficient at nasal filtering for larger particles and higher flow conditions. These results suggest that the lungs of children may be exposed to higher concentrations of inhaled, ambient particles than adults.

Exercise decreases nasal airway resistance within 30 seconds and could persist from 5-30 minutes. Immediately the nasal airway creates a response to exercise. Allowing for this response creates the ability for nasal breathing at high demands of exercise in short time constraints. That would cause an issue if nasal resistance would not decrease until 5-10 minutes after the initiation of exercise. Due to the immediate physiological response nasal breathing is proposed to be more efficient during low to moderate levels of exercise intensity. Nasal airway resistance drops in proportion to exertion, with a 39% reduction at workload of 75 watts and 49% after 100 watts (Forsyth et al., 1983). This response is primarily a result of reduced blood flow and blood content of the nasal mucosa. This mechanism may be adaptive to allow improved ventilation or redistribution of nasal blood to the muscles, heart, and skin (Schulz and Horvath, 1989). Increased blood flow to other parts of the body during exercise will help utilize the necessary molecules for optimal performance.

Decongestant sprays are great psychological aids for aerobic competitors. Allowing the nose to feel free of any resistance pre-race or before a training session. Decreasing resistance will increase the ability for air to travel into the nasal passageway and into the lungs. Benninger et al. (1992) compared the effect of a nasal spray on aerobic performance. During a cycle ergometer test there were no differences during the exercise testing. The VO_2, HR, VE, and FEV_1 all produced no statistically significant differences. Pre-exercise nasal resistance was lower in the nasal spray condition than all other test groups. The nasal spray, oxymetazoline hydrochloride, provides no aerobic benefits, but decreases nasal resistance immediately (Benninger, 1992). In a separate study measuring peak nasal inspiration flow by means of doses of oxymmetazoline, higher doses resulted in less nasal resistance (Clarke et al., 1994). The drug works, but it plateaued showing the similar results as the previous study in terms no exercise response.

Nasal VE accounted for 27% at 90% of the maximal attainable power (Fregosi and Lansing, 1995). Wheatley et al. (1991) found that 36% of total VE at maximal work occurs nasally. Despite majority of work accomplished by oral breathing, up to 1/3 of the work is completed by nasal breathing. Nasal VE and integrated nasal flaring EMG activities increased linearly with intensity up to 60% of the max power (Fregrosi and Lansing, 1995). However, both variables plateaued at 60% of work capacity. This leads to analyze that nasal breathing can be an adequate mode of breathing up to 60%. At that point, there is a plateau effect, due to the inability of the nasal airway to expand or increase volume of air anymore. As humans we are restricted on how large the airway can become. In the sample provided in this study, individuals were not able to increase their abilities of nasal VE or nasal flaring past 60% of their work capacity, but up to that point was a sufficient mode of breathing. Conclusions based off of these findings include the exponential rise in nasal VE and nasal flaring represent the turbulent flow produced in the nasal airway. Nasal airway is restricted in the full capacity of the body's needs. There are limitations and once those limitations are met, oral breathing is necessary for a switch to occur.

Nasal Reflexes

The brainstem, autonomic, and systemic reflexes that regulate nasal airways regulate our breathing. They are in control of every sensation and reflex that occurs through the mucosal passages of the bronchioles. Sympathetic reflexes are active in the nasal mucosa in forms of baroreceptors. Baroreceptors control blood pressure and blood flow. Nasal resistance decreases immediately after exercise, as the intensity of exercise increases there will be an even greater decrease in resistance of the passageway. Sympathetic vasoconstriction in the nasal cavity is a response of the sympathetic effect to maintain flow of oxygenated blood to the muscles (Baraniuk and Merck, 2008). The response for vasoconstriction will occur during high work rates. In an opposite spectrum, a normal parasympathetic response is vasodilation. The parasympathetic nervous system works as an antagonist to the sympathetic nervous system. The efforts of the parasympathetic nervous system are to decrease blood pressure, decrease heart rate, and promote a rested state. If both systems are stimulated simultaneously, the sympathetic will override.

Nasal and sinus patency increases from exercise and adrenergic agonists. Richerson and Seebohm (1968) found that intravenous infusion of epinephrine and norepinephrine did not stimulate a response to exercise. There was a significant blockade with topical phentolamine and stellate ganglion block. It was presumed that phentolamine played a key role in a blocking effect in the sympathetic nerve ending. Stellate ganglion block resulted in sympathetic paralysis and promoted a sympathetic nerve discharge. Blocking the sympathetic effect increased nasal resistance and induced congestion in the participants.

During asthma attacks nasal breathing can induce bronchodilation. With nasal breathing, sniff and gasp-like maneuvers can reverse the sensation of breathlessness. Stopping an asthma attack with nasal breathing and initiated reflex techniques could make the difference of life or death. Complete bronchoconstriction will stop air passing through the bronchioles. The only airway available would be the nasal passageway. Increasing nasal breathing during this mechanism can lower the asthmatic response and alleviate further problems. Zomori et al., (2000) showed reversal of apnea by means of sympathetic activity and contribution of gasping and sniffing to resuscitate the individuals. Adrenergic reactions mediated by catecholamine secretion and allowed regular breathing to transpire.

Nasal Dilator Strips on Nasal Breathing

Nasal dilator strips are banned by athletic committees, due to the effect they have as an ergogenic aid on aerobic based sports. The purpose of the nasal dilator strip is to decrease the nasal cross sectional area by dilating the nostrils. A nasal dilator strip stiffens the lateral nasal vestibule walls. Having less resistance in the passageway will allow for greater exchange of air. Another positive benefit for nasal strips is prevention of nasal flaring, where the nostrils decrease in size or completely close the airway. The dilator strips help individuals with sleeping and reduce nasal airway resistance.

The benefits of nasal strips could enhance nasal breathing over any other mode of breathing. The strongest indicator of augmented breathing due to nasal strips is VE. Decreasing resistance of the nasal passageway should increase the total VE in the nasal passageway when wearing a nasal dilator strip. While using a nasal dilator strip in Oriental subjects the nose contributes to 80% of VE during mild exercise and drops to 45% during near maximal treadmill running (Liu and Mafarlane, 2001). During lower intensities the nasal contribution of breathing is much greater than during higher intensities. At submaximal intensities or roughly 30 mL/kg/min in healthy individuals Chinevere et al. (1999) found VE to be quite similar when comparing oral vs nasal breathing.

There have been mixed results with performance enhancements on VO_2 max as a result to wearing the nasal dilator strip. A few studies showed small improvements (MacFarlane and Fong, 2004; Gehring et al., 2000; Griffin et al., 1997), while others found no difference (Chinevere et al., 1999; O'Kroy, O'Kroy et al., 2001; Overend et al., 2000; Nunes et al., 2011). Nasal dilator strips will likely enhance aerobic performance in a few individuals, but has not been found to produce significant benefits in all people.

The SaO_2 is the percent of O_2 that is saturated with hemoglobin. The normal SaO_2 rate is between 95-100%. Exercise-induced arterial desaturation was increased due to the use of a nasal dilator strip (Martin and O'Kroy, 1993). With greater nasal breathing as a response to use of a nasal dilator strip, the saturation rates were lower in individuals using the ergogenic aid. The lower RR (LaComb, et al., 2014; Chinnevere et al., 1999) during breathing must translate to less arterial O_2, therefore utilizing more O_2 when they become available which results in a decreased saturation rate.

A different performance based benefit found when wearing the nasal strips is ratings of perceived effort was significantly reduced with the strip (MacFarlane and Fong, 2004; Tong et al., 2001). In respect to aerobic performance there are slight advantages to using a nasal dilator. An aid that will keep the nasal airways dilated can improve performance, but minimal improvements are seen at best. Both studies used a placebo, but anecdotal experience with nasal dilator strips has shown that the nasal airways are kept open. There might have been a psychological benefit to the strip because the individuals knew which strip was decreasing the nasal resistance.

Using a nasal dilator strip on anaerobic tests the results are mainly negative. Tong et al. (2001) found a reduction in ventilatory muscle fatigue, but increases in maximal power output. Macfalane and Fong, (2004) found no significant difference between short anaerobic power and long term anaerobic power tests. Boggs (2008) found no significant difference in the blood lactate concentration. Anaerobic effects with use of a nasal dilator do not provide the same possible benefits when compared to aerobic benefits.

For individuals given an opportunity to train with a dilator strip, VO_2 performance can improve and might lower their perceived work rate. Results are mixed, but elite endurance athletes any benefit with the minimal performance increase. Training with nasal dilators and adaptation to nasal breathing would be an advantageous physiological adaptation. For individuals that may have issue breathing nasally, a nasal dilator strip could be an excellent alternative to improve nasal respiration.

Respiratory Problems

Nasal vs oral breathing has been explored in numerous respiratory illnesses. Nasal breathing shows benefits and can lead to prevention or reduce the problems in individuals with respiratory illnesses. Certain issues that have been researched include: bronchoconstriction, asthma, COPD, sleep apnea, and snoring. Researching the effects of nasal vs oral breathing in individuals with all of these diagnoses is not an area in which I am educated or desiring to do, but if I can find a basis for increased performance in nasal breathing in moderate exercise conditions, that could strengthen the effects toward helping these subjects out.

Bronchoconstriction is a constriction of airways in the lungs from smooth muscle contractions. This definition is broad and fits many mechanisms. The constriction occurs from tightening of the smooth muscle that surrounds the bronchioles, with normal responses of coughing, wheezing, and shortness of breath. Nasal breathing can reduce the effect of exercise induced bronchoconstriction with athletes (Parson and Mastronarde, 2005). Despite the conditioning or activity level, all individuals should have a concern for bronchoconstriction. High demands of exercise with oral breathing can increase the likelihood of the response. Overuse of the thoracic muscles and diaphragm cause fatigue and problems within the bronchioles. During high intensity coupled with oral breathing, there is a greater likelihood for bronchoconstriction. When air travels through the oral cavity only, it skips by the nasal mucosa completely, never being filtered, warmed or humidified before entering the respiratory tract. Increasing nasal breathing is one suggested immediate response to limit the bronchoconstrictive responses in over 10% of the general population.

Exposure to cold air increases resistance in the pharynx, specifically through the mouth. Breathing in cold air, can alter the capacity of the oral cavity during exercise. Nasal breathing on the other hand will be affected by extreme cold temperatures likewise, but the nose can warm the air when traveling through the nasopharynx. Nasal breathing can warm the air up to 3°C (Swift, 1982). Cold air breathing through the oral cavity can lead to bronchoconstriction responses. Anyone can be susceptible to bronchoconstriction, even the physically elite have problems with exercise induced bronchoconstriction (EIB). Parson and Mastronarde (2005) found that up to 26% of all Olympic winter sport athletes in 2000 and up to 50% of cross country skiers have EIB.

Measuring the effect of nasal and oral breathing on asthmatic or non-asthmatic individuals led to promising results for nasal breathing. The participants were asked to run on the ground with their nose or mouths covered, then later try the other protocol. The groups were five asthmatics with exercise liability, five asthmatics with no liability, and 5 healthy individuals. Flow rate was measured before, after, and 5, 10, 15, 20, and 30 minutes post exercise. If the FEV_1 was 20% or more from the basal levels then there was evidence bronchoconstriction. Mangla (2006) found a significant difference ($p<.05$) with post exercise FEV_1 rates between oral versus nasal breathing. When the participants were directed to breath only through their nose there was a markedly different post-exercise bronchoconstrictive response. Asthmatic individuals can benefit from training nasally.

In the first step of a study of the relation of nasal and oral breathing during moderate treadmill exercise to the onset of bronchoconstriction in young patients with perennial bronchial asthma, it was observed that most subjects normally breathed with their mouths open when instructed to breathe "naturally." Subsequently, when they were required to breathe nasally during the exercise, an almost complete inhibition of the post exercise bronchoconstrictive airway response was demonstrated. During exercise with oral breathing only an increased bronchoconstrictive airway response occurred, as measured by spirometry, flow-volume relationships, and body plethysmography. These findings suggest that the nasopharynx and the oropharynx play important roles in the phenomenon of exercise-induced bronchoconstriction (Shturman et al., 1978). Overall, bronchoconstriction will last 5-10 minutes after exercise and up to 30 minutes if no bronchodilator is administered (Bruno et al., 1994). Nasal breathing will not fix the issue of post exercise response with bronchoconstriction, but could reduce the impact of the response.

With these individuals dealing with respiratory problems, sleeping at night with their mouth closed 36 out of 50 participants felt comfortable with breathing primarily through the nose. Numerous asthmatics produced positive responses with 11 of 50 feeling improved sleep quality, 16 felt reduced snoring, 13 felt fresher upon waking, and 13 felt their asthma improved (Cooper, 2008). Overall, nasal acclimatizing to nasal breathing in multiple populations could provide physiological benefits.

There are numerous respiratory problems and nasal breathing alone will cure all solutions. A few studies mentioned previously elicited the closing of the airway and a sensation of loss of breath. That is a scary feeling for an individual to attempt to gasp for air, but nothing will enter the body due to a closed airway. At moments like that the reaction is to bring in the greatest amount of air possible through the oral cavity. During this respiratory problems, that is where the underlying problem exists and air should be attempted to be inspired through the nasal airway. Having individuals experience more nasal breathing at rest, exercise, and during times of distraught, nasal breathing could produce a greater benefit then oral breathing. The worst thing to occur is panic and force inspired air through the mouth only. Stay calm and take a deep, long slow breath through the nose and the issues might relieve themselves.

Nitric Oxide

Nitric oxide (NO) was first demonstrated through exhaled air. Gustafsson et al. (1991) first discovered in exhaled breath on experimental animals. Originally, NO was inhibited by multiple enzymes, but through experimentation NO synthesis occurred with L-arginine supplementation. When NO was confirmed in the presence of exhaled air, there were multiple studies conducted upon responses of exhaled NO. The occurrence of NO was first believed in the lower airways and lungs, but Alving et al. (1993) found high concentrations of exhaled NO in healthy subjects originated in the upper airways, primarily the paranasal sinuses and nasal cavity.

Physiological actions of NO include the regulation of vascular tone and blood pressure, prevention of platelet aggregation and inhibition of vascular smooth muscle proliferation.

There are differing opinions on the origin of NO. Multiple studies have expressed the contribution of endothelium and macrophages in the lungs, pulmonary vascular endothelium, but also from the small airways of the terminal and respiratory bronchioles as the source.   Others have found the upper airway like the nasal mucosa as the origination of NO. Nasal breathing produced roughly double the NO compared to oral breathing at rest and submaximal exercise (Yasuda et al., 1997). The prevalence in NO during nasal breathing yields the physiological benefit to exist during nasal breathing. Producing the same response or amounts of NO will not be possible in each individual, but would create a performance advantage. Improving nasal breathing and conditioning to decrease CO_2 exhalation and lead to greater NO production, coupled together, higher O_2 utilization could occur as a positive training effect over time. Along with other cardiorespiratory responses, NO concentrations were found to increase with physical conditioning levels (Maroun et al., 1995).   Individuals capable of obtaining higher HR during exercise on a stationary bicycle produced rapid increases in pulmonary NO excretion rate. The NO excretion rate during exercise was highly correlated with observed changes in heart rate ($p < .001$) (Bauer, 1994).

Even holding your breath for thirty seconds can produce higher NO concentration exhaled from the nasal airways compared to normal exhalation from the mouth. (Martin et al., 1997).   NO is synthesized in various types of cells, including the endothelium, macrophage, neutrophil, epithelium, autonomic nerves, etc., and is involved in many physiological functions relating to the control of vascular tone, non-specified immunity, neurotransmission, etc. (Yasuda et al., 1997).   Total NO output in the exhaled air of humans was found to increase with increases in exercise intensity in all individuals. Inhaled NO by a through the nasal cavity can produce six times fractional inhaled NO concentration than oral inhalation (Tornberg et al., 2002). The inhalation levels found in the Tornberg study were sufficient to improve oxygenation.   Would need a cannula to obtain the amounts of NO, but could provide physiological benefits. Inhaled nitric oxide appears to increase the partial pressure of arterial oxygen (PaO_2) by dilating pulmonary vessels in better-ventilated areas of the lung, moving pulmonary blood flow away from lung segments with low ventilation/perfusion (V/Q) ratios toward segments with normal or better ratios (Ballard et al., 2006). The fractional concentration of exhaled NO (FENO) in healthy children appeared to be affected by race, age and height (Kovesi et al., 2008). Greatest significance between exhaled NO concentrations were found between Asian-Canadian children and African-Canadian children ($p < .001$). The (FENO) rose slightly with age ($p=.07$) and with height ($p < .05$) in the patients with pulmonary hypertension, PVR fell significantly after inhaled NO and after prostacyclin. Inhaled NO therefore seems to be both a selective and effective pulmonary vasodilator. (Pepke-Zaba et al., 1991).

Summary

Oral breathing is necessary at higher demands of exercise eliciting a greater capacity for the individual to complete a maximal workload. During submaximal intensities nasal breathing can provide small intricate benefits that could lead to adequate exercise. The mode of breathing that will complete more efficient work upon the body is the dilemma that is desired to be answered.

Chapter 3

METHODOLOGY

Subject Characteristics

There were 23 individuals that were recruited to participate in the study. A total of 19 individuals (men N=9, women N=10) completed the entire protocol, two failed the nasal breathing test, and two individual subjects dropped out. Descriptive statistics are described in Table 1.

Table 1: Anthropometric measures of subjects

	Male	Female
N	9	10
Age (yrs)	25±7.4	24±3.0
Height (in)	70±1.7	66±3.1
Weight (lbs)	185±18.9	146.5±17.0
Body Fat %	16%±6.4	27%±6.3

Each subject completed the ACSM health risk questionnaire, and signed an informed consent document. Subjects had to be in a "low risk" category according to the ACSM health risk questionnaire. If the participants were able to answer "None of the above" on the questionnaire, check nothing in the first section (history, symptoms, other health issues), or check no more than one cardiovascular risk factor, and were a male younger than 45 years of age or a female younger than 55 years of age, they will be considered "Low Risk" according to the ACSM algorithm, and were able to participate in the investigation. The ACSM criteria for low risk includes men younger than 45 years of age and women younger than 55 years of age who are asymptomatic and meet no more than one risk factor threshold for coronary artery disease risk. Subjects were excluded from the study based on the following criteria: (a) Currently pregnant (b) Subjects with implantable devices such as Pacemaker, Automatic Implantable Cardioverter Defibrillators (AICD) (d) Orthopedic (Acute or chronic musculoskeletal injury), cardiovascular (coronary artery disease), respiratory (Chronic Obstructive Pulmonary Disease or Asthma), metabolic conditions (Diabetes), and current smoker. Current smoker is defined as someone who currently smokes or who has quit less than six months previous.

Collection of Data

Subjects were instructed to wear loose fitting clothing (i.e. shorts, t-shirt, and running shoes) and to report to the Exercise Physiology Laboratory (MPE 326) on three separate dates. The individuals were instructed to be well hydrated, consume their last meal at least 2 hours prior to testing, refrain from caffeinated beverages for 2 hours prior to testing, and to refrain from alcoholic beverages for at least 6 hours prior to the test. Participants were asked to refrain from strenuous physical exercise during the day prior to testing. Prior to exercise testing, subject's body weight, height, and body composition were measured using a Total InBody 720 Body Composition Analyzer (InBody Co., Biospace, Seoul, Korea). Prior to the test, each subject was instructed on the use of Borg’s 6-20 Rating of Perceived Exertion scale (RPE). The graded exercise test protocol (GXT) was performed on a standard treadmill (Precor C954/C956, Precor Incorporated, Los Angeles, CA) with metabolic data being collected using a Moxus metabolic System

(AEI Technologies, Pittsburg, PA, USA). The Moxus was calibrated each day of testing that occurred in the exercise physiology lab.

A V2 Hans Rudolph respiratory facemask (Hans Rudolph Inc., Shawnee, KS, USA) was used for all respiratory metabolic measurements. A heart rate monitor was applied to the participant's lower sternum under their clothing during all protocols (Polar Electro Inc., Lake Success, NY, USA). Participants completed the progressive exercise test either to the point of volitional fatigue or until a research team member decided to stop the test due to physical manifestations of severe fatigue. The criteria for a subject attaining VO_2 max will be meeting at least two of the following conditions: termination due to volitional fatigue, respiratory exchange ratio of 1.10 or greater, heart rate within 10 beats per minute of the age-estimate maximal (heart rate maximal = 220-age), or rating of perceived exertion greater than 19 on the Borg scale.

The first session was a VO_2 max with the design to measure the voluntary switching point from oral to nasal breathing. The individual was instructed to breathe only through the nose, until they were not able to do so comfortably anymore. When the individual felt they needed to "switch over" or use both breathing modes they were instructed to raise their hand. The VE at the moment their hand was raised was deemed the switching point. The protocol for the VO_2 max was 3-min of treadmill walking at 3 mph, increase to 5 mph for one minute, with further increases in speed by 1 mph each minute thereafter. On the other two sessions (one oral breathing, one nasal breathing, counterbalanced), subjects were asked to complete a submaximal treadmill protocol running at 50%, 65% and 80% of their VO_2 max for 4 minutes in each stage. Running speeds were determined using a regression equation based on the speeds and VO_2/kg values from the first session. The predicted speed was relative to the individuals results from the first test. The submaximal protocol consisted of 12 minutes of running unless the subject was not able to complete the test. After 2, 3, and 4 minutes of each stage RPE and SaO_2 were collected. SaO_2 was collected using a Pulse Oximeter (Shenzhen Creative Industry Co., Shenzhen, China) that was taped onto the finger. On sessions 2 and 3 a pre and posttest FEV_1 measure was taken using a MIR MiniSpir Light Spirometer (MIR Medical International Research, Maggiolino, Roma, Italy). The subjects were measured at rest and within 20 seconds post exercise. The FEV_1 test instructions were to take a huge deep breath in, then exhale all air out of the lungs while having the spirometer enclosed by the mouth to obtain the proper readings. The individual was instructed to help take off one part of the respiratory mask to help take the FEV_1 measure within 20 seconds of completion of the test.

Statistics

Data analysis was collected on the Moxus during all sessions measuring: RR, VE, VO_2, VCO_2, RER, HR, Veq/O_2, Veq/CO_2, VO_2/kg and SaO_2. RPE, FEV_1, and SaO_2 were taken manually as they were separate from the Moxus. The steady state values were used in analysis, the respected values at 2, 3, and 4 minutes. A 2x3 repeated measures analysis of variance (RM ANOVA) test and simple main effects analysis were conducted to compare the oral vs nasal breathing modes at the three different intensities. A paired sample t-test was completed between pre and posttest to compare the FEV_1 values. Significant results were determined using an alpha level of $p<.05$. Analysis was conducted using the Statistical Package for the Social Sciences (SPSS version 22, IBM Corporation, Armonk, NY) software.

Chapter 4

RESULTS

Findings

Below is a table with all the measures means and standard deviations displaying both breathing modes across the three different exercise intensities.

Table 2: Means and standard deviations of measures during submaximal intensities in both breathing modes

	Oral			Nasal		
Intensity	50%	65%	80%	50%	65%	80%
HR (b/min)	132±11.6	157±9.7	175±10.0	132±13.6	151±16.8	166±19.8
RR (br/min)	33.3±8.1$_a$	41.0±9.4$_b$	50.5±10.9$_c$	25.3±7.0$_a$	32.6±7.3$_b$	38.6±7.3$_c$
VE (L/min)	43.4±12.8$_a$	60.2±13.4$_b$	76.9±17.5$_c$	36.1±10.7$_a$	48.2±11.0$_b$	59.3±14.2$_c$
RER	0.85±.06$_a$	0.92±.04$_b$	0.98±.04	0.80±.08$_a$	0.88±.07$_b$	0.95±.08
VO$_2$/kg(mL/kg)	29.7±6.6$_a$	38.3±4.0$_b$	44.5±4.0$_c$	26.8±6.0$_a$	34.9±3.7$_b$	40.9±5.0$_c$
VO$_2$ (mL/min)	2250±603$_a$	2900±534$_b$	3371±627$_c$	2051±632$_a$	2657±583$_b$	3114±704$_c$
VCO$_2$ (mL/min)	1924±573$_a$	2684±524$_b$	3296±614$_c$	1677±613$_a$	2354±629$_b$	2979±814$_c$
Veq/O$_2$ (L/mL)	19.3±1.9	20.8±2.5$_b$	22.9±3.2$_c$	18.0±2.8	18.2±1.8$_b$	19.1±2.3$_c$
Veq/CO$_2$(L/mL)	22.8±2.7	22.5±3.1$_b$	23.4±3.4$_c$	22.5±3.9	20.8±2.3$_b$	20.3±814$_c$
RPE	9±1.7	12±1.8	15±2.0	10±2.5	12±2.2	15±2.3
SaO$_2$	96%±1.5%	94%±2.8%	93%±2.6%$_c$	95%±4.1%	93%±4.5%	91%±3.6%$_c$

a: Significant difference between the two breathing modes at the 50% work intensity

b: Significant difference between the two breathing modes at the 65% work intensity

c: Significant difference between the two breathing modes at the 80% work intensity

There was a significant interaction between intensity and breathing mode when respiratory rate was considered (p<.001). The results for RR were significantly greater in all exercise intensities during the oral breathing mode, compared to the nasal breathing mode (see Table 2 and Figure 1). Oral and nasal breathing produced a 34% change in RR between the 65% and 80% intensities, but the starting RR for oral breathing was33.3±8.1br/min and 25.3±7.0 br/min for nasal breathing.

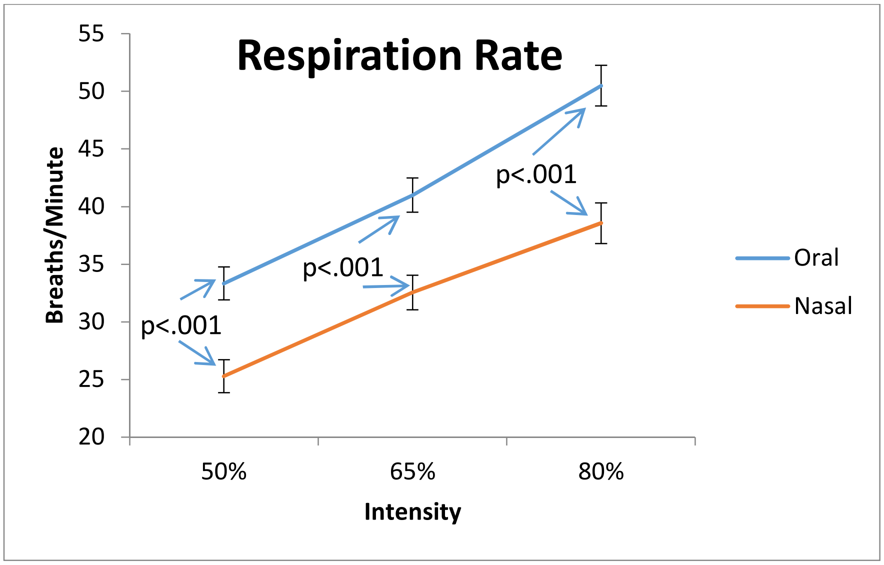


Figure 1: Respiration rates during submaximal intensities

There was a significant interaction between intensity and breathing mode in the RM ANOVA factorial analysis (p<.001). VE was significantly lower at each exercise intensity when subjects performed nasal breathing, compared to oral breathing (see Table 2 and Figure 2). The difference between breathing modes tended to increase as exercise became more intense (50% Δ = 16%, 65% Δ = 20%, 80% Δ = 23%, see Figure 2).

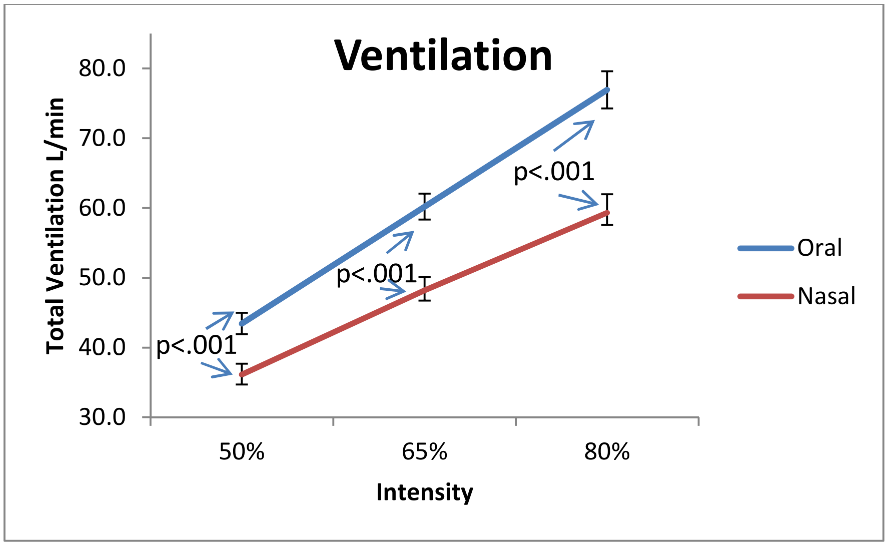


Figure 2: Ventilation rates during submaximal intensities

Interaction was significant between intensity and breathing mode when RER was measured ($p<.001$). The findings for RER were significantly greater in the two lower intensities (50% and 65%) in nasal breathing, compared to oral breathing (Table 2). The most strenuous exercise intensity had no significant difference with RER despite nasal breathing being .03 lower (oral = 0.98±.04, nasal = 0.95±.08).

There was a significant difference in all three exercise intensities between the two breathing modes in VO_2/kg, VO_2, and VCO_2. With VO_2/kg there was an 8-10% decrease in nasal breathing, when compared to oral breathing in all intensities as seen in Figure 3. VCO_2 produced a 7-9% decrease in the nasal breathing mode, compared to the oral breathing mode (Table 2). VCO_2 produced changes (50% $\Delta = 13\%$, 65% $\Delta = 10\%$, 80% $\Delta = 10\%$) as seen in Table 2. The measures VO_2/kg, VO_2, and VCO_2 all had significant interaction at intensity and breathing mode with 2x3 RM ANOVA ($p<.001$).

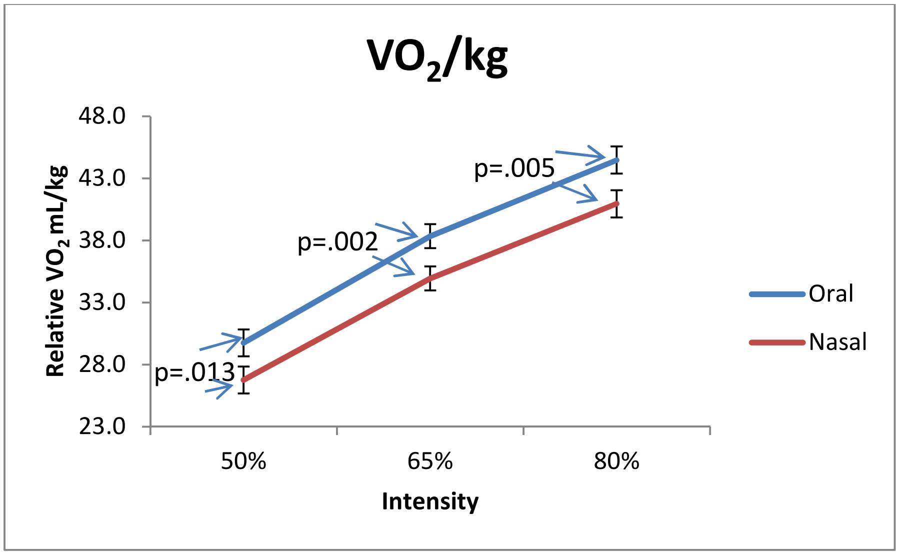


Figure 3: Relative VO_2 rates during submaximal intensities

The Veq/O_2 and Veq/CO_2 were significantly higher in the oral breathing mode during the latter two intensities, compared to the nasal breathing mode (Table 2). Oral breathing produced greater differences as the exercise intensity level increased. During the various intensities of 50%, 65%, and 80% of the individuals VO_2 max the significance between the two breathing modes in Veq/O_2 became higher as the exercise increased (50% $\Delta = 7\%$, 65% $\Delta = 13\%$, 80% $\Delta = 17\%$) seen in Figure 4 and for Veq/CO_2 was (50% $\Delta = 1\%$, 65% $\Delta = 8\%$, 80% $\Delta = 13\%$) as shown in Figure 5. The Veq/O_2 had a significant interaction with intensity and breathing mode ($p<.001$) while the Veq/CO_2 did not produce significant interaction ($p=.775$). Despite Veq/CO_2 having no interaction there was significant results with simple main effect analysis with intensity and breathing mode both producing probabilities of $p<.05$.

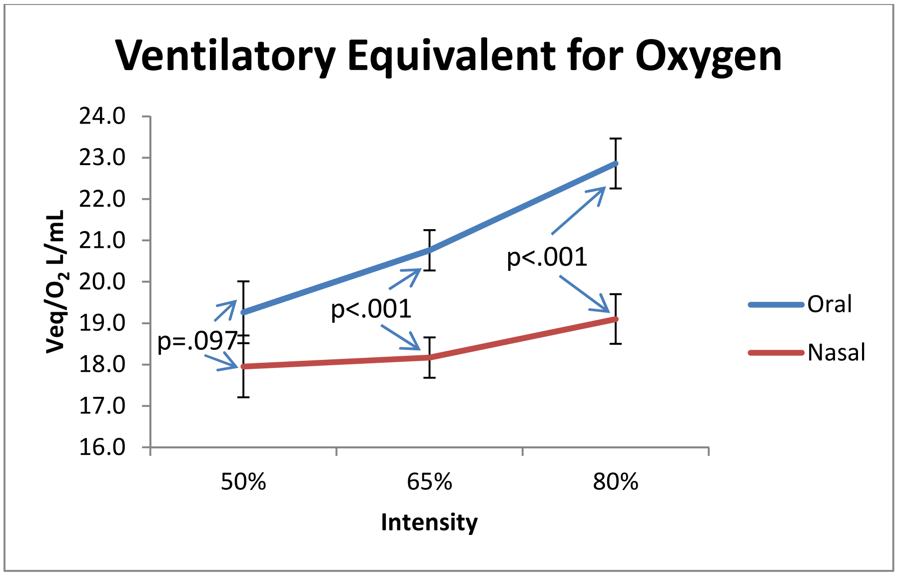


Figure 4: Ventilatory equivalent for oxygen rates during submaximal intensities

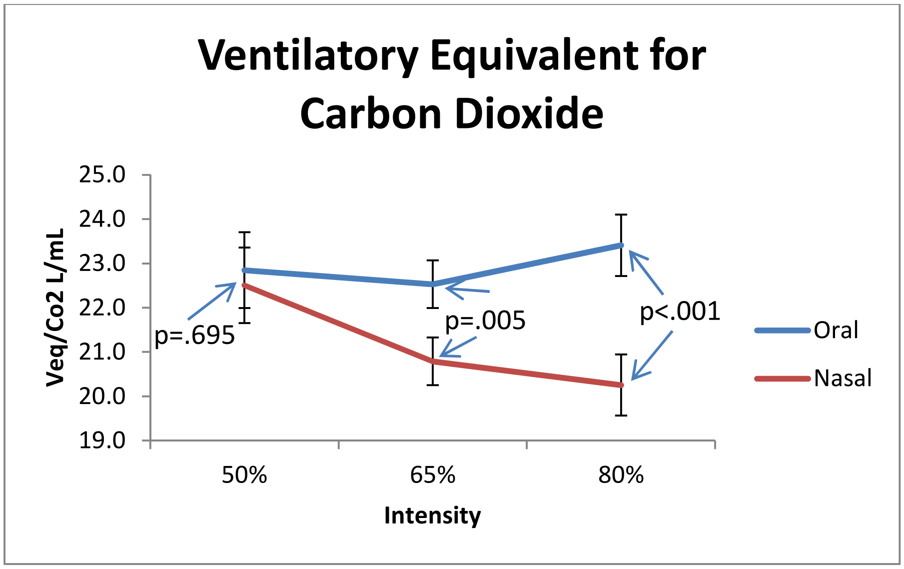


Figure 5: Ventilatory equivalent for carbon dioxide rates during submaximal intensities

There was a significant interaction between intensity and breathing mode when oxygen saturation was considered (p=0.034). Oxygen saturation resulted in lower percentages in the 80% intensity only. The nasal breathing test significantly lower in

SaO_2 values at the last exercise intensity, compared to oral breathing (p=.035) as shown in Table 2 and Figure 6. There was no statistical difference in SaO_2 during the first two stages.

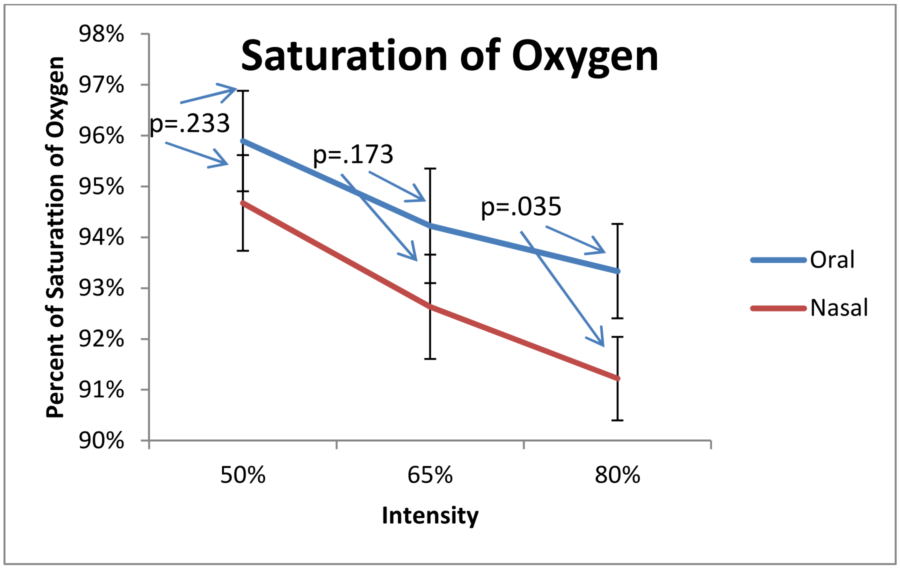


Figure 6: Saturation of oxygen rates during submaximal intensities

There was no significant difference in HR or RPE during this investigation. HR began to trend towards lower values with nasal breathing in the last intensity. The 80% exercise intensity produced a HR of 175±10.0 b/min for oral breathing and 166±19.8 b/min for nasal breathing, but was not significant (Table 2). There was greater variance or standard deviation in the nasal breathing mode. RPE produced comparable data throughout all intensities. The RPE scores were similar in both breathing modes throughout all intensities. Between the three intensities of 50%, 65%, and 80% oral breathing 9±1.7, 12±1.8, and 15±2.0, while nasal breathing was similar with 10±2.5, 12±2.2, and 15±2.3. However, there was significant interaction between intensity and breathing mode in HR and RPE during 2x3 RM ANOVA factorial analysis ($p<.001$).

The mean and standard deviation for the voluntary switching point of all the subjects was 52.5±14.2 L/min. Switching point for the genders was 66.2±13.7 L/min for males and 44.9±10.5 L/min for females.

Forced expiratory volume was statistically significant between the pre and posttest of the oral breathing condition ($p=.003$) as seen in Table 3 and Figure 7. The pretest values were 3.84±.94 L for the oral breathing test and 3.98±.92 L for the nasal breathing test which resulted in a significant result between the two breathing modes ($p=.032$).

Table 3: Forced expiratory volume comparisons

FEV_1	Pre	Post
Oral (L)	$3.84\pm.94_{ab}$	$4.04\pm.93_{a}$
Nasal (L)	$3.98\pm.92_{b}$	3.97±.90

a: significant difference between oral pre and post tests

b: significant difference between pretests in the two breathing modes

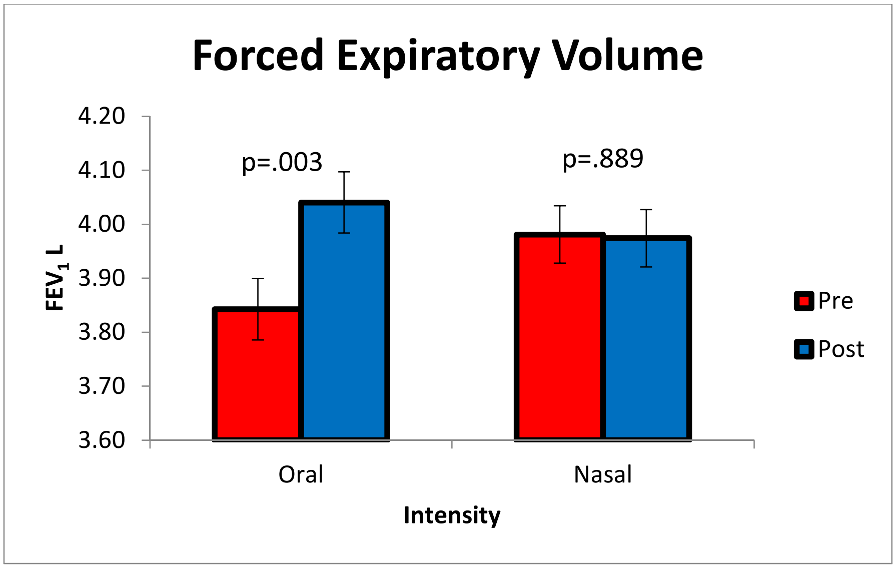


Figure 7: Forced expiratory volume comparisons

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Discussion

The study was carried out in attempt to provide evidence regarding the most efficient breathing mode during various submaximal intensities of exercise. Oral breathing and nasal breathing both have physiological benefits and shortcomings, but the aim of this investigation was to conclude which mode of breathing is energetically more efficient. Oral breathing is able to produce a larger volume of air due to the size of the passage way, whereas nasal breathing can humidify, purify, and filtrate the air allowing the gas to be selectively chosen to be is inspired. Due to the unique properties and advantages of both breathing modes; the overall respiratory measures, ventilation, and oxygen consumption were greater throughout the investigation in oral breathing.

The greatest difference between breathing through the nose and mouth is the amount of air that can be transported into the lungs for respiration. The total VE between the two breathing modes were significantly different between all three intensities ($p<.001$). Nasal breathing produced lower VE which corresponds with previous reports by Michailow et al. (1976), and Morton et al. (1995). The nose cannot transport the same volume of air as the mouth at any given exercise intensity. However it is unknown whether this limitation in VE be made up through other respiratory or metabolic measures to make nasal breathing worthy. VE increased in both conditions as the exercise intensity increased. The separation between oral VE compared to nasal VE was even more apparent during higher levels of exercise with a 23% decrease. Two participants dropped out of the study during the nasal breathing trial, and anecdotally the limited ventilation may have led to a feeling of panic feeling and termination of the test.

Due to the nasal cavity being larger in anatomical structure, it creates greater dead space than oral breathing (Tanaka et al, 1988). The greater volume of dead space creates a decrease in ventilation during nasal breathing. The structure and length of the nasal cavity could have a small influence on the significant ventilation changes seen between the two breathing modes. Besides the longer passageway, the nose has greater resistance to air than the mouth. The nasal cavity is filled with fine coarse hairs and vibrissae that filter and trap pollutants and toxicants. The unnecessary particles are immediately expired and sent back out the nasal cavity. The extra resistance from the filtering process would lead to a decrease in ventilation through the nasal cavity.

Comparing the switching point in the males was 60.2 L/min and in females was 44.9 L/min. The voluntary switching point was in the range stated in previous research (Ninimaa et al., 1980; Saibene et al., 1978) with the designated range of 35-45 L/min. Males generally have larger facial structures due to their larger frame, and it is likely that the nostrils and nasal cavity are also greater in volume than in females. This could allow for males to have greater VE rates and inspiratory strength through the nasal cavity (Hall et al., 2006) and result in a higher switching point than females. Further investigation is necessary to confirm this observation.

Another common physiological phenomenon that was observed in the present study was that RR was significantly lower in nasal breathing than oral breathing. The mouth can easily obtain and exchange large volumes of air with short, quick breaths. The nasal cavity cannot reach the same volumes of air and does not have the capabilities to rapidly inspire and expire at the rate that the mouth is able to. RR was significantly lower in all intensities which relates to our previously unpublished study (2014), Hall et al., 2006, Bennet et al., 2003, and Chinevere et al., 1999,. The last stage produced roughly 55 br/min in oral breathing compared to 38 br/min in nasal breathing. As more CO_2 is being expired, the sensation to breathe is increased. If you are unable to increase the rate at which are able to complete respiration, then the oxygen consumption will not meet the body's needs.

The Veq/O_2 and Veq/CO_2 both produced significant differences at the 65% and 80% intensities. During 50% of the individuals VO_2 max, an exercise stage comparable to a brisk walk or light jog, the Veq/O_2 and Veq/CO_2 were similar between the breathing modes. At the higher intensities, there was a significant response that nasal breathing was a more efficient breathing mode due to greater amounts of the O_2 and CO_2 being produced per volume of air. Due to the lower volumes of air being created at the higher intensities in nasal breathing the oxygen consumption and carbon dioxide expiration was sufficient to complete the work rate. When aerobically training above 50% of an individual's max VO_2, by this definition nasal breathing is a greater source of metabolic efficiency. The work rates were attainable for 19 of the 21 individuals in the study presenting the belief that per volume of air being transferred, nasal breathing utilizes the molecules more efficiently than oral breathing.

During the 50% work intensity, there appears to be a trend of the oxygen consumption to reach steady state during oral breathing as shown in Figure 8. There is a noticeable difference between nasal breathing and oral breathing as the nasal breathing mode produced lower values at all of the time values. At roughly the two minute mark the VO_2/kg value began to plateau for oral breathing but it is unclear whether the nasal breathing trial produced steady state values. The length of time to reach steady state during exercise under the condition of nasal breathing is an area that necessitates further investigation.

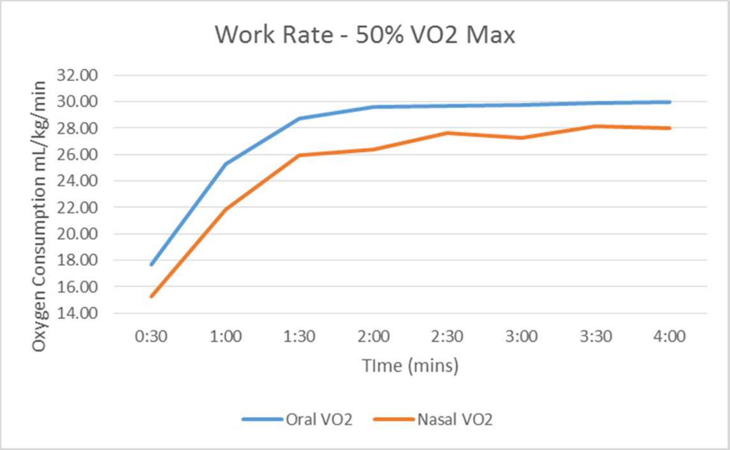
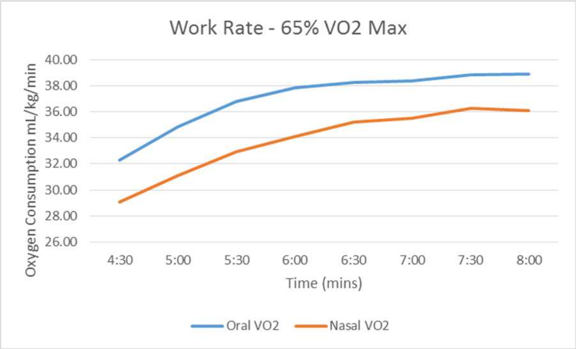


Figure 8: Oxygen consumption at 50% of VO_2 max

Figure 9: Oxygen consumption at 65% of VO_2 max (Left)



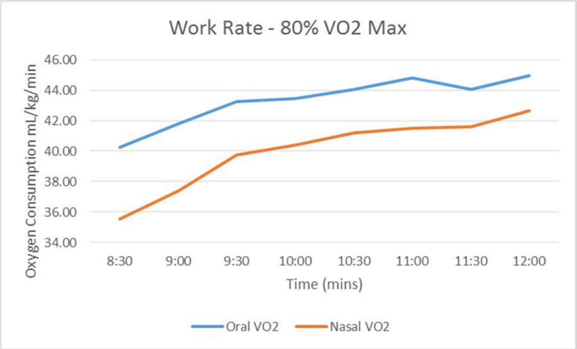


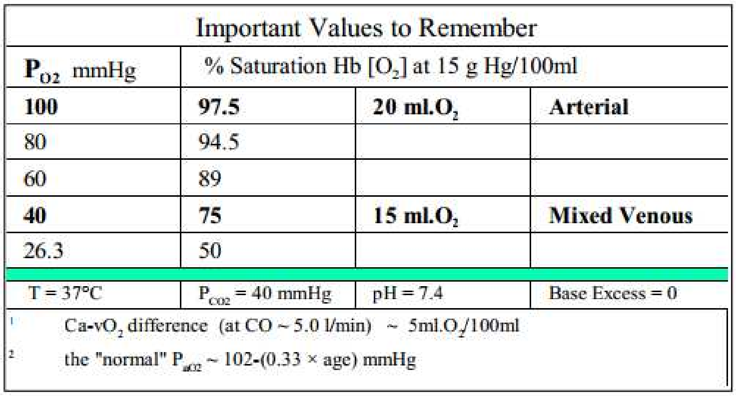
Figure 10: Oxygen consumption at 80% of VO_2 Max (Right)

At the 65% VO2 max work intensity both breathing modes were continuously increasing and no distinct plateau or steady state can be clearly identified in either mode (see figure 9). Nasal breathing displays a greater incline of VO_2/kg values as steady state was not reached. As the study's protocol moved towards 80% VO_2 max the oxygen consumption values continued a steady incline, but never reached a constant rate (see figure 10). The lack of steady state found at 80% intensity suggests that 4 minutes is not an appropriate length of time for a stage requiring this level of exertion. During all intensities the nasal breathing mode was lower and visually shows that nasal breathing underperformed in terms of oxygen consumption. There were lower oxygen consumption values in nasal breathing ranging from 5-14% throughout all the time points in the study. It is likely that oxygen consumption values are consistently lower during the nasal breathing trials because of insufficient time to reach steady state.

Using the Fick equation ($VO_2/kg = Q \times a\text{-}vO_2$ diff) to explain oxygen consumption is standard in physiology. Cardiac output is the product of heart rate and stroke volume. Stroke volume should have a similar value throughout both breathing modes. As the resistance increases in nasal breathing, the blood pressure might increase minimally causing a small adjustment to stroke volume. With lower HR in nasal breathing there may be minor compensation to increase stroke volume. SV was not measured in this investigation but these possibilities seem reasonably small and should not influence the gross effect on cardiac output. The heart rates between the two breathing modes were not statistically significant at the lowest intensities. As the exercise demand increased the HR showed a 4% and 5% decrease in nasal breathing in the 65% and 80% relative intensities. These findings are congruent to Morton et al. (1995) and Chinevere et al. (1999), that nasal breathing will produce lower HR than other breathing conditions involving the mouth. During the nasal breathing protocol, lower heart rates transpired which infers the body was not able to reach the same physical working capacity. That would lead to a theoretically lower cardiac output; however, not significant enough to substantially account for the 10% change in VO_2.

The latter part of the Fick equation leads involves a-vO2 difference which measures the delivery of the oxygen to the muscles. The larger the difference between arterial and venous oxygenated blood will potentially result in greater aerobic performance. The oxygen saturation in the present study was found to be significantly different between oral and nasal breathing at the 80% intensity. With a 2% change between oxygen saturation in the last intensity the venous oxygenated blood could be 1-2 mmHg (based off conversion table) lower than with the oral breathing mode. Oxygen saturation provided no statistically significant difference during the first two intensities. The last stage was significant at p=.035 and was 2.2% greater in oral breathing. Resting SaO2 is between 95-98% and normally does not have much variance. To find statistically significant data at the highest intensity of this study provides evidence to the postulation by Morton et al. (1995) that slower respiration rates will results in less O2 transported through the body.

Table 4: Conversion table of oxygen saturation to arterial and mixed venous oxygenation content in blood



Important Values to Remember

P_{O2} mmHg	% Saturation Hb [O_2] at 15 g Hg/100ml		
100	**97.5**	**20 ml.O_2**	**Arterial**
80	94.5		
60	89		
40	**75**	**15 ml.O_2**	**Mixed Venous**
26.3	50		
T = 37°C	P_{CO2} = 40 mmHg	pH = 7.4	Base Excess = 0

[1] Ca-vO_2 difference (at CO ~ 5.0 l/min) ~ 5ml.O_2/100ml

[2] the "normal" P_{aO2} ~ 102-(0.33 × age) mmHg

A standard used in the exercise science field is the ACSM metabolic equation to measure oxygen cost during aerobic exercise. All speeds above 3.5 mph were deemed as running speeds. The ACSM metabolic equation for running is VO2/kg = (0.2 x running speed) + (0.9 x running speed x grade) + 3.5. Running speed is measured in m/min and grade was 0 during the entire protocol, eliminating that part of the equation. Each individual's oxygen cost was calculated and compared to the actual VO2/kg in all intensities during oral breathing and nasal breathing tests. In 13 of the 57 conditions nasal breathing underperformed the estimated measure while oral breathing exceeded the value. That leads to the possibility that anaerobic pathways made up for the deficit in oxygen delivery and utilization. For the stage to be completed with less oxygen consumption there must be other physiological contributions for the demands to be met. Due to the short stages, it is likely that greater anaerobic contributions compensated for the reduction in oxygen. Unfortunately, lactate measures were not obtained in the present study, and this is a measurement that would be warranted in future investigations on nasal breathing.

The pre-test for FEV_1 was significantly greater in oral breathing ($p<.05$). Resting values should have been consistent considering the test conditions being counterbalanced and kept from the subjects until their first submaximal test. Our results do not agree with previous investigations. There was an opposite response when compared to asthmatic study when breathing through the nose or keeping the mouth taped shut. The following studies: Mangla et al., 1981, Benninger et al., 1992, and Cooper et al., 2008 all found FEV_1 values to be higher in nasal breathing conditions compared to oral breathing. Relaxing the thoracic muscles and diaphragm should allow the contraction and forced expiratory volume to be larger after undergoing exercise in the nasal breathing condition (Mangla et al, 1981), but those results did not occur in this study. The short relative time of exercise might have been a warm up to the thoracic muscles therefore not creating any fatigue in the area. No response in FEV_1 after the nasal breathing condition could be a result from individuals gasping for air as soon as tape was removed from their mouth. The goal was to test the FEV_1 within 20 seconds of exercise. There were limitations to not completing this sooner due to the multiple facets of the mask. Individuals would gasp for air with their mouth shortly after the tape being pulled off of their mouth, possibly creating lower scores on the FEV_1 test that occurred shortly after.

Nasal breathing was more efficient strictly based on the variable Veq/O_2. However when other variables are considered, oral breathing produced greater respiratory and metabolic effects. Nasal breathing produced oxygen uptake values that were approximately 10% lower compared to oral breathing and there are a number of possible explanations. We propose that the greatest contributing factor is the inability to reach a steady state oxygen level, but also consider that increased anaerobic energy production, the restriction of airflow with nasal breathing, and increased oxygen extraction at the tissue level could also play roles.

Appendix A

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

Department of Kinesiology and Nutrition Sciences

INFORMED CONSENT FORM

TITLE OF THE STUDY: Oral vs. Nasal Breathing in Submaximal Aerobic Exercise
INVESTIGATOR/S: Dr. James Navalta
CONTACT INFORMATION: If you have any questions or concerns about the study, please contact Dr. Navalta at (702) 895-2344.
For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact the **UNLV Office of Research Integrity – Human Subjects Research at (702) 895-2794.**

Purpose

We wish to observe the respiratory responses during submaximal aerobic exercise comparing mouth to nose breathing.

Participants

You are being asked to participate in the study because you are between the ages of 18-44 years, and are a healthy, active non-smoking individual.

Procedure

If you volunteer to participate in this part of the study, you will be asked to report to the Exercise Physiology Laboratory on three occasions at a mutually agreed upon time. You will be screened for heart and lung disease using the American College of Sports Medicine's Health-Risk Questionnaire. Your height, weight, and percent body fat will be measured. Your aerobic fitness ($VO_{2\ max}$) will be determined by breathing in a mask that covers your mouth and nose – you should be able to breathe normally when wearing this mask. This test involves walking and then running/jogging on a treadmill at progressively increasing speeds to exhaustion, or until a research team member stops the test due to physical manifestations of fatigue. Heart rate will be measured using a heart rate monitor. On the other times (one test nose breathing, one test mouth breathing), you will be asked to complete two submaximal treadmill runs for a total of 12 minutes.

Risks

This study involves some risk to you. One exercise test requires you to work at maximal abilities and is therefore demanding, vigorous, and stressful. The American College of Sports Medicine has stated that the risk of death during or immediately after a maximal exertion test is less than or equal to 0.01%, while the risk of an acute myocardial infarction is less than or equal to 0.04%. Data from these surveys included a wide variety of healthy AND diseased individuals. Since you are an apparently healthy adult between the ages of 18 - 44 years and are considered "low-risk" according to the American College of Sports Medicine guidelines, no medical supervision is necessary during the exercise test. There are discomforts to the test. Muscle soreness, nausea, breathlessness, dizziness, and lightheadedness may occur. There is the possibility of falling or tripping on the treadmill. Muscle soreness may ensue 24-48 hours later. The tests will be stopped any time you are not adapting well to the activity or when any major discomfort arises. You will be instructed to grab onto the handrails and straddle the treadmill when you wish to end the exercise test. In addition, a research team member will "spot" you from behind during the test.

Benefits of Participation

There is no financial cost to you for participating in this study. You will be able to receive information regarding your cardiovascular fitness.

Cost /Compensation

There will not be any financial cost to you to participate in this study. The study will take approximately three hours of your time during the laboratory visits; however there is no compensation for your time.

Participation

Your participation in this study is completely voluntary. You may refuse to participate in this study or in any part of this study and you may withdraw at any time without prejudice to your relations with the University. You are encouraged to ask questions about this study prior to the beginning or at any time during the study. You will be given a copy of this form.

Confidentiality

All information gathered in this study will be kept completely confidential. Only those persons who are directly related to this study (i.e.: researchers, data analysts) will have access to your data. No reference will be made in written or oral materials, which could link you to this study. All records will be stored at UNLV for a period of 3 years. After 3 years, any documentation with identifiable information (e.g., name) will be destroyed. Unidentifiable data will be stored in locked storage indefinitely.

Freedom to Consent

I have read the above information carefully and I am aware of the tests/procedures to be performed. Knowing these risks and having the opportunity to ask questions, I agree (consent) to participate in this study. With this freedom to consent, I have a right to withdraw from this study at any time without prejudice. I am at least 18 years old and a copy of the informed consent has been given to me.

________________________ ________

Signature of the Participant Date

________________________ ________

Signature of Witness Date

Participant Note: Please do not sign this document if the Approval Stamp is missing or is expired.

Appendix B

AHA/ACSM Health Risk Questionnaire

Assess your health status by marking all *true* statements

History

You have had:
____ a heart attack
____ heart surgery
____ cardiac catheterization
____ coronary angioplasty (PTCA)
____ pacemaker/implantable cardiac
____ defibrillator/rhythm disturbance
____ heart valve disease
____ heart failure
____ heart transplantation
____ congenital heart disease

Symptoms

____ You experience chest discomfort with exertion
____ You experience unreasonable breathlessness
____ You experience dizziness, fainting, or blackouts
____ You take heart medications

Other health issues

____ You have diabetes
____ You have asthma or other lung disease
____ You have burning or cramping sensation in your lower legs when walking short distances
____ You have musculoskeletal problems that limit your physical activity
____ You take prescription medication(s)
____ You are pregnant

Cardiovascular risk factors

____ You smoke, or quit smoking within the previous 6 months
____ Your blood pressure is >140/90 mm Hg
____ You take blood pressure medication
____ Your blood cholesterol level is >200 mg/dL
____ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister)
____ You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week)
____ You are > 20 pounds overweight

____ None of the above

Appendix C

Table 3: 2x3 RM ANOVA Results - Values are presented as probabilities

	Mauchly's Test of Sphericity		**Test of Within Subject Effects**			
	Intensity	**Intensity * Breathing Mode**	**Intensity**	**Breathing Mode**	**Intensity * Breathing Mode**	**F**
HR	**0.001**	**0.03**[a]	**0.003**[c]	**0.336**	**0.001**[e]	**160.1**
RR	**0.115**	**0.039**[a]	**0.113**	**0.001**[d]	**0.001**[e]	**87.3**
VE	**0.001**	**0.002**[a]	**0.036**[c]	**0.001**[d]	**0.001**[3]	**152.9**
RER	**0.048**	**0.001**[a]	**0.012**[c]	**0.188**	**0.001**[3]	**82.1**
VO2/kg	**0.013**	**0.066**[b]	**0.001**[c]	**0.022**[d]	**0.001**[3]	**232**
VO2	**0.005**	**0.083**[b]	**0.001**[c]	**0.019**[d]	**0.001**[3]	**236.8**
VCO2	**0.002**	**0.091**[b]	**0.001**[c]	**0.025**[d]	**0.001**[e]	**318.3**
Veq/O2	**0.302**	**0.005**[a]	**0.001**[c]	**0.009**[d]	**0.001**[e]	**32.5**
Veq/CO2	**0.618**	**0.01**[a]	**0.001**[c]	**0.046**[d]	**0.775**	**0.178**
RPE	**0.063**	**0.002**[a]	**0.002**[c]	**0.586**	**0.001**[e]	**91.7**
SaO2	**0.004**	**0.226**[b]	**0.001**[c]	**0.13**	**0.034**[e]	**3.7**

a: Sphericity was violated, reject the null hypothesis, and use Huyn-Feldt in Within Subject Effect Analysis

b: Sphericity assumed, retain the null hypothesis, and use Sphericity Assumed in Within Subject Effect Analysis

c: Main effect analysis for Intensity is significant

d: Main effect analysis for Breathing mode is significant

e: Interaction is significant for the 2x3 factorial ANOVA

Appendix D

2x3 RM ANOVA - HR

Descriptive Statistics

	Mean	Std. Deviation	N
HR	131.8070	11.56587	19
HR2	157.0877	9.70480	19
HR3	174.5965	9.92850	19
N_HR	131.8596	13.62791	19
N_HR2	151.1140	16.79654	19
N_HR3	166.2896	19.76571	19

Mauchly's Test of Sphericity[a]

Measure: HR

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	.223	25.546	2	.000	.563	.574	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.663	6.991	2	.030	.748	.800	.500

Tests of Within-Subjects Effects

Measure: HR

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intensity	Huynh-Feldt	3929.870	1.148	3422.089	10.600	.003
Error(intensity)	Huynh-Feldt	6673.650	20.671	322.852		
breathing_mode	Huynh-Feldt	16.469	1.000	16.469	.898	.356
Error(breathing_mode)	Huynh-Feldt	329.945	18.000	18.330		
intensity * breathing_mode	Huynh-Feldt	25594.114	1.601	15989.284	160.138	.000
Error(intensity*breathing_mode)	Huynh-Feldt	2876.861	28.813	99.847		

Paired Samples t-test - HR

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	HR	131.8070	19	11.56587	2.65339
	N_HR	131.8596	19	13.62791	3.12646
Pair 2	HR2	157.0877	19	9.70480	2.22643
	N_HR2	151.1140	19	16.79654	3.85339
Pair 3	HR3	174.5965	19	9.92850	2.27775
	N_HR3	166.2896	19	19.76571	4.53456

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	HR - N_HR	-.05263	7.82230	1.79456	-.029	18	.977
Pair 2	HR2 - N_HR2	5.97368	15.13706	3.47268	1.720	18	.103
Pair 3	HR3 - N_HR3	8.30684	20.64094	4.73536	1.754	18	.096

One way ANOVA – oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: HR

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.240	24.228	2	.000	.568	.581	.500

Tests of Within-Subjects Effects

Measure: HR

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	17585.197	1.162	15132.388	198.506	.000
Error(intensity)	Huynh-Feldt	1594.581	20.918	76.231		

Pairwise Comparisons

Measure: HR

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-25.281	2.138	.000	-30.923	-19.638
	3	-42.789	2.868	.000	-50.359	-35.220
2	3	-17.509	1.091	.000	-20.388	-14.630

One way ANOVA – nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: HR

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.370	16.889	2	.000	.614	.635	.500

Tests of Within-Subjects Effects

Measure: HR

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	11314.218	1.271	8902.336	43.197	.000
Error(intensity)	Huynh-Feldt	4714.625	22.877	206.089		

Pairwise Comparisons

Measure: N_HR

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-19.254	3.719	.000	-29.070	-9.439
	3	-34.430	4.820	.000	-47.152	-21.708
2	3	-15.176	2.071	.000	-20.641	-9.710

2x3 RM ANOVA - VE

Descriptive Statistics

	Mean	Std. Deviation	N
VE	43.4454	12.80177	19
VE2	60.2054	13.36375	19
VE3	76.9247	17.46169	19
N_VE	36.1130	10.72503	19
N_VE2	48.2148	11.04484	19
N_VE3	59.3154	14.17530	19

Mauchly's Test of Sphericity[a]

Measure: VE

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.347	18.003	2	.000	.605	.625	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.480	12.470	2	.002	.658	.689	.500

Tests of Within-Subjects Effects

Measure: VE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	422.733	1.250	338.220	4.605	.036
Error(intensity)	Huynh-Feldt	1652.509	22.498	73.452		
breathing_mode	Huynh-Feldt	531.151	1.000	531.151	28.449	.000
Error(breathing_mode)	Huynh-Feldt	336.064	18.000	18.670		
intensity * breathing_mode	Huynh-Feldt	19131.194	1.379	13875.490	152.950	.000
Error(intensity*breathing_mode)	Huynh-Feldt	2251.469	24.818	90.719		

Paired samples t-test - VE

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	VE	43.4454	19	12.80177	2.93693
	N_VE	36.1130	19	10.72503	2.46049
Pair 2	VE2	60.2054	19	13.36375	3.06586
	N_VE2	48.2148	19	11.04484	2.53386
Pair 3	VE3	76.9247	19	17.46169	4.00599
	N_VE3	59.3154	19	14.17530	3.25204

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	VE - N_VE	7.33246	6.76051	1.55097	4.728	18	.000
Pair 2	VE2 - N_VE2	11.99061	8.18763	1.87837	6.384	18	.000
Pair 3	VE3 - N_VE3	17.60930	11.59145	2.65926	6.622	18	.000

One way ANOVA – oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: VE

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.327	19.024	2	.000	.598	.616	.500

Tests of Within-Subjects Effects

Measure: VE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	5117.537	1.613	3173.487	87.623	.000
Error(intensity)	Huynh-Feldt	1051.278	29.027	36.218		

Pairwise Comparisons

Measure: VE

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-16.760	1.980	.000	-21.985	-11.535
	3	-33.479	2.740	.000	-40.712	-26.247
2	3	-16.719	1.202	.000	-19.892	-13.547

One way ANOVA – nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_VE

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	.671	6.775	2	.034	.753	.806	.500

Tests of Between-Subjects Effects

Measure: N_VE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	130678.086	1	130678.086	344.298	.000
Error	6831.893	18	379.550		

Pairwise Comparisons: N_Ve

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]
1	2	-12.102	1.518	.000
	3	-23.202	2.198	.000
2	3	-11.101	1.444	.000

2x3 RM ANOVA – RR

Mauchly's Test of Sphericity[a]

Measure: RR

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.776	4.307	2	.116	.817	.888	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.683	6.471	2	.039	.760	.815	.500

Tests of Within-Subjects Effects

Measure: RR

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	108.075	1.775	60.883	2.390	.113
Error(intensity)	Huynh-Feldt	813.908	31.952	25.473		
breathing_mode	Huynh-Feldt	421.351	1.000	421.351	30.918	.000
Error(breathing_mode)	Huynh-Feldt	245.302	18.000	13.628		
intensity * breathing_mode	Huynh-Feldt	6517.855	1.630	3998.859	87.307	.000
Error(intensity*breathing_mode)	Huynh-Feldt	1343.782	29.339	45.802		

Paired Samples t-test – RR

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	RR	33.3333	19	8.06532	1.85031
	N_RR	25.2809	19	7.01657	1.60971
Pair 2	RR2	41.0000	19	9.43136	2.16370
	N_RR2	32.5528	19	7.31146	1.67736
Pair 3	RR3	50.4912	19	10.94113	2.51007
	N_RR3	38.5614	19	7.32158	1.67969

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	RR - N_RR	8.05246	6.19670	1.42162	5.664	18	.000
Pair 2	RR2 - N_RR2	8.44719	6.51076	1.49367	5.655	18	.000
Pair 3	RR3 - N_RR3	11.92982	7.65747	1.75674	6.791	18	.000

One way ANOVA - oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: RR

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.714	5.732	2	.057	.777	.837	.500

Tests of Within-Subjects Effects

Measure: RR

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	2807.279	2	1403.639	55.999	.000
Error(intensity)	Sphericity Assumed	902.351	36	25.065		

Pairwise Comparisons

Measure: RR

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.
1	2	-7.667	1.701	.001
	3	-17.158	1.927	.000
2	3	-9.491	1.144	.000

One way ANOVA - nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_RR

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.864	2.492	2	.288	.880	.968	.500

Tests of Within-Subjects Effects

Measure: N_RR

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	1680.592	2	840.296	44.095	.000
Error(intensity)	Sphericity Assumed	686.026	36	19.056		

Pairwise Comparisons

Measure: N_RR

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]
1	2	-7.272	1.322	.000
	3	-13.281	1.654	.000
2	3	-6.009	1.239	.000

2x3 RM ANOVA - RER

Descriptive Statistics

	Mean	Std. Deviation	N
RER	.8470	.06138	19
RER2	.9246	.04308	19
RER3	.9786	.04098	19
N_RER	.8037	.08383	19
N_RER2	.8776	.06617	19
N_RER3	.9475	.07529	19

Mauchly's Test of Sphericity[a]

Measure: RER

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.699	6.091	2	.048	.769	.826	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.287	21.225	2	.000	.584	.600	.500

Tests of Within-Subjects Effects

Measure: RER

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	.015	1.653	.009	5.594	.012
Error(intensity)	Huynh-Feldt	.049	29.745	.002		
breathing_mode	Huynh-Feldt	.002	1.000	.002	1.874	.188
Error(breathing_mode)	Huynh-Feldt	.023	18.000	.001		
intensity * breathing_mode	Huynh-Feldt	.392	1.199	.327	82.129	.000
Error(intensity*breathing_mode)	Huynh-Feldt	.086	21.582	.004		

Paired Samples t-test - RER

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	RER	.8470	19	.06138	.01408
	N_RER	.8037	19	.08383	.01923
Pair 2	RER2	.9246	19	.04308	.00988
	N_RER2	.8776	19	.06617	.01518
Pair 3	RER3	.9786	19	.04098	.00940
	N_RER3	.9475	19	.07529	.01727

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	RER - N_RER	.04333	.05588	.01282	3.380	18	.003
Pair 2	RER2 - N_RER2	.04693	.05271	.01209	3.881	18	.001
Pair 3	RER3 - N_RER3	.03105	.06663	.01529	2.031	18	.057

One way ANOVA – oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: RER

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.406	15.311	2	.000	.627	.652	.500

Tests of Within-Subjects Effects

Measure: RER

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	.166	1.305	.127	75.943	.000
Error(intensity)	Huynh-Feldt	.039	23.481	.002		

Pairwise Comparisons

Measure: RER

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.078	.010	.000	-.105	-.050
	3	-.132	.014	.000	-.169	-.095
2	3	-.054	.007	.000	-.071	-.037

One way ANOVA – nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_RER

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.861	2.538	2	.281	.878	.966	.500

Tests of Within-Subjects Effects

Measure: N_ RER

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	.197	2	.098	73.321	.000
Error(intensity)	Sphericity Assumed	.048	36	.001		

Pairwise Comparisons

Measure: N_RER

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.074	.011	.000	-.102	-.046
	3	-.144	.014	.000	-.181	-.107
2	3	-.070	.011	.000	-.099	-.041

2x3 RM ANOVA - RPE

Descriptive Statistics

	Mean	Std. Deviation	N
RPE	9.1754	1.72623	19
RPE2	12.0702	1.79361	19
RPE3	15.2018	1.96307	19
N_RPE	9.5261	2.45548	19
N_RPE2	12.3247	2.20148	19
N_RPE3	15.4475	2.30260	19

Mauchly's Test of Sphericity[a]

Measure: RPE

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.722	5.544	2	.063	.782	.844	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.485	12.294	2	.002	.660	.692	.500

Tests of Within-Subjects Effects

Measure: RPE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intensity	Huynh-Feldt	202.641	1.687	120.117	37.286	.000
Error(intensity)	Huynh-Feldt	97.826	30.367	3.222		
breathing_mode	Huynh-Feldt	.370	1.000	.370	.308	.586
Error(breathing_mode)	Huynh-Feldt	21.613	18.000	1.201		
intensity * breathing_mode	Huynh-Feldt	477.898	1.384	345.281	91.648	.000
Error(intensity*breathing_mode)	Huynh-Feldt	93.861	24.913	3.767		

Paired Samples t-test - RPE

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	RPE	9.1754	19	1.72623	.39602
	N_RPE	9.5261	19	2.45548	.56333
Pair 2	RPE2	12.0702	19	1.79361	.41148
	N_RPE2	12.3247	19	2.20148	.50505
Pair 3	RPE3	15.2018	19	1.96307	.45036
	N_RPE3	15.4475	19	2.30260	.52825

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	RPE - N_RPE	-.35070	2.73215	.62680	-.560	18	.583
Pair 2	RPE2 - N_RPE2	-.25456	1.62539	.37289	-.683	18	.504
Pair 3	RPE3 - N_RPE3	-.24579	1.58100	.36271	-.678	18	.507

One way ANOVA – oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: RPE

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	.691	6.285	2	.043	.764	.820	.500

Tests of Within-Subjects Effects

Measure: RPE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intensity	Huynh-Feldt	345.184	1.641	210.370	123.034	.000
Error(intensity)	Huynh-Feldt	50.501	29.535	1.710		

Pairwise Comparisons

Measure: RPE

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.^{b}	95% Confidence Interval for Difference^b	
					Lower Bound	Upper Bound
1	2	-2.895	.365	.000	-3.858	-1.931
	3	-6.026	.474	.000	-7.278	-4.775
2	3	-3.132	.291	.000	-3.901	-2.363

One way ANOVA – nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_RPE

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon^b		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.414	14.996	2	.001	.630	.656	.500

Tests of Within-Subjects Effects

Measure: N_RPE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	333.432	1.312	254.181	75.954	.000
Error(intensity)	Huynh-Feldt	79.019	23.612	3.347		

Pairwise Comparisons

Measure: N_RPE

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-2.799	.437	.000	-3.951	-1.646
	3	-5.921	.633	.000	-7.591	-4.252
2	3	-3.123	.319	.000	-3.966	-2.280

2x3 RM ANOVA – SaO_2

Descriptive Statistics

	Mean	Std. Deviation	N
SaO2	95.8947	1.57939	19
SaO22	94.2281	2.80443	19
SaO23	93.3333	2.56520	19
N_SaO2	94.6756	4.10307	19
N_SaO22	92.6314	4.47778	19
N_SaO23	91.2191	3.59078	19

Mauchly's Test of Sphericity[a]

Measure: SaO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.520	11.105	2	.004	.676	.711	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.840	2.972	2	.226	.862	.945	.500

Tests of Within-Subjects Effects

Measure: SaO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	193.491	2	96.745	10.268	.000
Error(intensity)	Sphericity Assumed	339.204	36	9.422		
breathing_mode	Sphericity Assumed	9.551	1	9.551	2.523	.130
Error(breathing_mode)	Sphericity Assumed	68.143	18	3.786		
intensity * breathing_mode	Sphericity Assumed	52.903	2	26.451	3.730	.034
Error(intensity*breathing_mode)	Sphericity Assumed	255.274	36	7.091		

Paired Samples t-test – SaO_2

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SaO2	95.8947	19	1.57939	.36234
	N_SaO2	94.6756	19	4.10307	.94131
Pair 2	SaO22	94.2281	19	2.80443	.64338
	N_SaO22	92.6314	19	4.47778	1.02727
Pair 3	SaO23	93.3333	19	2.56520	.58850
	N_SaO23	91.2191	19	3.59078	.82378

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	SaO2 - N_SaO2	1.21912	4.30700	.98809	1.234	18	.233
Pair 2	SaO22 - N_SaO22	1.59667	4.90925	1.12626	1.418	18	.173
Pair 3	SaO23 - N_SaO23	2.11421	4.04127	.92713	2.280	18	.035

One way ANOVA – oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: SaO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	.958	.738	2	.692	.959	1.000	.500

Tests of Within-Subjects Effects

Measure: SaO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	64.214	2	32.107	14.831	.000
Error(intensity)	Sphericity Assumed	77.934	36	2.165		

Pairwise Comparisons

Measure: SaO2

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	1.667	.475	.008	.414	2.920
	3	2.561	.519	.000	1.191	3.932
2	3	.895	.434	.162	-.251	2.040

One way ANOVA – nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_SaO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.949	.897	2	.639	.951	1.000	.500

Tests of Within-Subjects Effects

Measure: N_SaO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intensity	Sphericity Assumed	114.764	2	57.382	12.775	.000
Error(intensity)	Sphericity Assumed	161.706	36	4.492		

Pairwise Comparisons

Measure: $N\_ SaO_2$

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	2.044	.746	.040	.075	4.013
	3	3.456	.611	.000	1.845	5.068
2	3	1.412	.699	.176	-.433	3.258

2x3 RM ANOVA – VO_2/kg

Descriptive Statistics

	Mean	Std. Deviation	N
VO2_KG	29.7439	6.58121	19
VO2_KG2	38.3351	3.97255	19
VO2_KG3	44.4667	4.00077	19
N_VO2_KG	26.7586	5.98361	19
N_VO2_KG2	34.9309	3.74222	19
N_VO2_KG3	40.9439	4.92262	19

Mauchly's Test of Sphericity[a]

Measure: VO2/kg

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.602	8.627	2	.013	.715	.760	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.726	5.444	2	.066	.785	.847	.500

Tests of Within-Subjects Effects

Measure: VO2/kg

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	292.256	2	146.128	9.810	.000
Error(intensity)	Sphericity Assumed	536.249	36	14.896		
breathing_mode	Sphericity Assumed	30.507	1	30.507	6.299	.022
Error(breathing_mode)	Sphericity Assumed	87.183	18	4.844		
intensity * breathing_mode	Sphericity Assumed	3993.131	2	1996.566	231.947	.000
Error(intensity*breathing_mode)	Sphericity Assumed	309.883	36	8.608		

Paired Samples t-test – VO_2/kg

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	VO2_KG	29.7439	19	6.58121	1.50983
	N_VO2_KG	26.7586	19	5.98361	1.37273
Pair 2	VO2_KG2	38.3351	19	3.97255	.91137
	N_VO2_KG2	34.9309	19	3.74222	.85853
Pair 3	VO2_KG3	44.4667	19	4.00077	.91784
	N_VO2_KG3	40.9439	19	4.92262	1.12933

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	VO2_KG - N_VO2_KG	2.98526	4.74674	1.08898	2.741	18	.013
Pair 2	VO2_KG2 - N_VO2_KG2	3.40421	4.19339	.96203	3.539	18	.002
Pair 3	VO2_KG3 - N_VO2_KG3	3.52281	4.75610	1.09112	3.229	18	.005

One way ANOVA - oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: VO2/kg

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.316	19.608	2	.000	.594	.611	.500

Tests of Within-Subjects Effects

Measure: VO2/kg

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	2078.388	1.223	1699.623	187.701	.000
Error(intensity)	Huynh-Feldt	199.311	22.011	9.055		

Pairwise Comparisons

Measure: VO2/kg

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.^{b}	95% Confidence Interval for Difference^{b}	
					Lower Bound	Upper Bound
1	2	-8.591	.851	.000	-10.838	-6.344
	3	-14.723	.954	.000	-17.241	-12.204
2	3	-6.132	.336	.000	-7.018	-5.246

One way ANOVA – nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_VO2/kg

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon^{b}		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.699	6.096	2	.047	.768	.826	.500

Tests of Within-Subjects Effects

Measure: N_VO2/kg

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	1926.371	1.652	1165.949	105.447	.000
Error(intensity)	Huynh-Feldt	328.834	29.739	11.057		

Pairwise Comparisons

Measure: N_VO2/kg

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-8.172	.978	.000	-10.752	-5.592
	3	-14.185	1.192	.000	-17.332	-11.039
2	3	-6.013	.712	.000	-7.893	-4.133

2x3 RM ANOVA – VO_2

Descriptive Statistics

	Mean	Std. Deviation	N
VO2	2250.0877	603.70203	19
VO22	2900.3860	533.62925	19
VO23	3371.2807	627.06232	19
N_VO2	2050.8333	632.23309	19
N_VO22	2657.3247	583.51173	19
N_VO23	3114.3507	704.07958	19

Mauchly's Test of Sphericity[a]

Measure: VO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.538	10.542	2	.005	.684	.721	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.746	4.990	2	.083	.797	.862	.500

Tests of Within-Subjects Effects

Measure: VO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	1842598.703	2	921299.351	11.797	.000
Error(intensity)	Sphericity Assumed	2811531.732	36	78098.104		
breathing_mode	Sphericity Assumed	143834.688	1	143834.688	6.687	.019
Error(breathing_mode)	Sphericity Assumed	387154.252	18	21508.570		
intensity * breathing_mode	Sphericity Assumed	22421912.349	2	11210956.174	236.837	.000
Error(intensity*breathing_mode)	Sphericity Assumed	1704099.758	36	47336.104		

Paired Samples t-test – VO_2

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	VO2	2250.0877	19	603.70203	138.49875
	N_VO2	2050.8333	19	632.23309	145.04422
Pair 2	VO22	2900.3860	19	533.62925	122.42295
	N_VO22	2657.3247	19	583.51173	133.86677
Pair 3	VO23	3371.2807	19	627.06232	143.85796
	N_VO23	3114.3507	19	704.07958	161.52693

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	VO2 - N_VO2	199.25439	291.41230	66.85457	2.980	18	.008
Pair 2	VO22 - N_VO22	243.06123	270.93844	62.15754	3.910	18	.001
Pair 3	VO23 - N_VO23	256.93000	337.18871	77.35640	3.321	18	.004

One way ANOVA - oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: VO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.357	17.522	2	.000	.609	.629	.500

Tests of Within-Subjects Effects

Measure: VO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	12044121.312	1.259	9568518.160	161.223	.000
Error(intensity)	Huynh-Feldt	1344682.316	22.657	59349.457		

Pairwise Comparisons

Measure: VO_2

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-650.298	64.433	.000	-820.347	-480.249
	3	-1121.193	80.909	.000	-1334.722	-907.664
2	3	-470.895	33.130	.000	-558.330	-383.459

One way ANOVA - nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_VO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.669	6.845	2	.033	.751	.804	.500

Tests of Within-Subjects Effects

Measure: N_VO$_2$

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	10815900.403	1.609	6723230.948	101.616	.000
Error(intensity)	Huynh-Feldt	1915907.173	28.957	66163.323		

Pairwise Comparisons

Measure: N_VO2

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-606.491	70.044	.000	-791.347	-421.636
	3	-1063.517	93.152	.000	-1309.359	-817.676
2	3	-457.026	56.770	.000	-606.850	-307.202

2x3 RM ANOVA – VCO$_2$

Descriptive Statistics

	Mean	Std. Deviation	N
VCO2	1923.6842	573.81397	19
VCO22	2684.2281	524.46488	19
VCO23	3295.8947	613.66187	19
N_VCO2	1676.5439	612.61287	19
N_VCO22	2353.6577	628.91814	19
N_VCO23	2979.0788	814.35770	19

Mauchly's Test of Sphericity[a]

Measure: VCO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.477	12.591	2	.002	.657	.688	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.755	4.785	2	.091	.803	.870	.500

Tests of Within-Subjects Effects

Measure: VCO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	2495536.455	2	1247768.228	13.132	.000
Error(intensity)	Sphericity Assumed	3420531.104	36	95014.753		
breathing_mode	Sphericity Assumed	172485.194	1	172485.194	5.944	.025
Error(breathing_mode)	Sphericity Assumed	522330.010	18	29018.334		
intensity * breathing_mode	Sphericity Assumed	33950334.140	2	16975167.070	318.333	.000
Error(intensity*breathing_mode)	Sphericity Assumed	1919707.714	36	53325.214		

Paired Samples t-test – VCO_2

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	VCO2	1923.6842	19	573.81397	131.64195
	N_VCO2	1676.5439	19	612.61287	140.54303
Pair 2	VCO22	2684.2281	19	524.46488	120.32049
	N_VCO22	2353.6577	19	628.91814	144.28372
Pair 3	VCO23	3295.8947	19	613.66187	140.78369
	N_VCO23	2979.0788	19	814.35770	186.82647

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	VCO2 - N_VCO2	247.14035	275.96391	63.31046	3.904	18	.001
Pair 2	VCO22 - N_VCO22	330.57035	303.56977	69.64368	4.747	18	.000
Pair 3	VCO23 - N_VCO23	316.81597	433.81912	99.52493	3.183	18	.005

One way ANOVA - oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: VCO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.514	11.325	2	.003	.673	.708	.500

Tests of Within-Subjects Effects

Measure: VCO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	17958323.747	1.415	12691358.380	257.077	.000
Error(intensity)	Huynh-Feldt	1257402.994	25.470	49367.859		

Pairwise Comparisons

Measure: VCO_2

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-760.544	58.868	.000	-915.905	-605.183
	3	-1372.211	77.428	.000	-1576.555	-1167.866
2	3	-611.667	39.614	.000	-716.213	-507.120

One way ANOVA - nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_VCO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.569	9.585	2	.008	.699	.740	.500

Tests of Within-Subjects Effects

Measure: N_VCO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	16126135.176	1.479	10903245.223	118.400	.000
Error(intensity)	Huynh-Feldt	2451616.297	26.622	92088.517		

Pairwise Comparisons

Measure: $N\_ VCO_2$

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-677.114	71.580	.000	-866.025	-488.203
	3	-1302.535	108.911	.000	-1589.966	-1015.103
2	3	-625.421	67.232	.000	-802.855	-447.987

2x3 RM ANOVA – Veq/O_2

Descriptive Statistics

	Mean	Std. Deviation	N
VEQO2	19.2614	1.87489	19
VEQO22	20.7614	2.51654	19
VEQO23	22.8596	3.16125	19
N_VEQO2	17.9554	2.80141	19
N_VEQO22	18.1674	1.77765	19
N_VEQO23	19.1018	2.29165	19

Mauchly's Test of Sphericity[a]

Measure: Veq/O_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.869	2.394	2	.302	.884	.973	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.531	10.758	2	.005	.681	.717	.500

Tests of Within-Subjects Effects

Measure: Veq/O_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	65.817	1.946	33.821	9.772	.000
Error(intensity)	Huynh-Feldt	121.232	35.029	3.461		
breathing_mode	Huynh-Feldt	19.317	1.000	19.317	8.514	.009
Error(breathing_mode)	Huynh-Feldt	40.837	18.000	2.269		
intensity * breathing_mode	Huynh-Feldt	238.840	1.435	166.485	32.522	.000
Error(intensity*breathing_mode)	Huynh-Feldt	132.189	25.823	5.119		

Paired Samples t-test – Veq/O_2

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	VEQO2	19.2614	19	1.87489	.43013
	N_VEQO2	17.9554	19	2.80141	.64269
Pair 2	VEQO22	20.7614	19	2.51654	.57733
	N_VEQO22	18.1674	19	1.77765	.40782
Pair 3	VEQO23	22.8596	19	3.16125	.72524
	N_VEQO23	19.1018	19	2.29165	.52574

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	VEQO2 - N_VEQO2	1.30596	3.25195	.74605	1.751	18	.097
Pair 2	VEQO22 - N_VEQO22	2.59404	2.11468	.48514	5.347	18	.000
Pair 3	VEQO23 - N_VEQO23	3.75789	2.62981	.60332	6.229	18	.000

One way ANOVA - oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: Veq/O_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.291	20.987	2	.000	.585	.601	.500

Tests of Within-Subjects Effects

Measure: Veq/O_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Huynh-Feldt	124.133	1.202	103.244	28.985	.000
Error(intensity)	Huynh-Feldt	77.088	21.642	3.562		

Pairwise Comparisons

Measure: Veq/O_2

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-1.500	.457	.012	-2.705	-.295
	3	-3.598	.630	.000	-5.262	-1.934
2	3	-2.098	.265	.000	-2.797	-1.400

One way ANOVA - nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_ Veq/O_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.892	1.948	2	.378	.902	.997	.500

Tests of Within-Subjects Effects

Measure: N_ Veq/O_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
intensity	Sphericity Assumed	14.136	2	7.068	3.289	.049
Error(intensity)	Sphericity Assumed	77.371	36	2.149		

Pairwise Comparisons

Measure: N_ Veq/O_2

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.212	.498	1.000	-1.526	1.103
	3	-1.146	.526	.129	-2.535	.243
2	3	-.934	.392	.085	-1.969	.100

2x3 RM ANOVA – Veq/CO_2

Descriptive Statistics

	Mean	Std. Deviation	N
VEQCO2	22.8474	2.66327	19
VEQCO22	22.5281	3.06520	19
VEQCO23	23.4053	3.39323	19
N_VEQCO2	22.5068	3.90704	19
N_VEQCO22	20.7895	2.27626	19
N_VEQCO23	20.2546	2.55796	19

Mauchly's Test of Sphericity[a]

Measure: Veq/CO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
intensity	.945	.963	2	.618	.948	1.000	.500
breathing_mode	1.000	.000	0	.	1.000	1.000	1.000
intensity * breathing_mode	.584	9.142	2	.010	.706	.749	.500

Tests of Within-Subjects Effects

Measure: Veq/CO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intensity	Huynh-Feldt	135.366	2.000	67.683	15.830	.000
Error(intensity)	Huynh-Feldt	153.922	36.000	4.276		
breathing_mode	Huynh-Feldt	9.727	1.000	9.727	4.572	.046
Error(breathing_mode)	Huynh-Feldt	38.300	18.000	2.128		
	Lower-bound	38.300	18.000	2.128		
intensity * breathing_mode	Huynh-Feldt	1.628	1.497	1.087	.178	.775
Error(intensity*breathing_mode)	Huynh-Feldt	164.682	26.952	6.110		

Paired Samples t-test - Veq/CO_2

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	VEQCO2	22.8474	19	2.66327	.61100
	N_VEQCO2	22.5068	19	3.90704	.89634
Pair 2	VEQCO22	22.5281	19	3.06520	.70321
	N_VEQCO22	20.7895	19	2.27626	.52221
Pair 3	VEQCO23	23.4053	19	3.39323	.77846
	N_VEQCO23	20.2546	19	2.55796	.58684

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	VEQCO2 - N_VEQCO2	.34053	3.72020	.85347	.399	18	.695
Pair 2	VEQCO22 - N_VEQCO22	1.73860	2.34142	.53716	3.237	18	.005
Pair 3	VEQCO23 - N_VEQCO23	3.15070	3.01627	.69198	4.553	18	.000

One way ANOVA – oral breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: Veq/CO_2

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	.437	14.070	2	.001	.640	.667	.500

Tests of Within-Subjects Effects

Measure: Veq/CO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intensity	Huynh-Feldt	7.490	1.335	5.613	2.308	.136
Error(intensity)	Huynh-Feldt	58.416	24.021	2.432		

Pairwise Comparisons

Measure: Veq/CO_2

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.319	.372	1.000	-.663	1.301
	3	-.558	.543	.952	-1.990	.874
2	3	-.877	.282	.018	-1.622	-.133

One way ANOVA - nasal breathing between different intensities

Mauchly's Test of Sphericity[a]

Measure: N_Veq/CO_2

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	.653	7.247	2	.027	.742	.793	.500

Tests of Within-Subjects Effects

Measure: N_Veq/CO_2

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intensity	Huynh-Feldt	52.619	1.587	33.156	7.991	.003
Error(intensity)	Huynh-Feldt	118.529	28.566	4.149		

Pairwise Comparisons

Measure: N_VEQCO2

					95% Confidence Interval for Difference[b]	
(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
1	2	1.717	.594	.029	.151	3.284
	3	2.252	.721	.018	.348	4.156
2	3	.535	.409	.621	-.543	1.613

Paired Samples t-test - FEV

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	FEV1	3.8426	19	.93716	.21500
	FEV12	4.0405	19	.93121	.21364
Pair 2	N_FEV1	3.9811	19	.92176	.21147
	N_FEV2	3.9742	19	.89874	.20619

Paired Samples Test

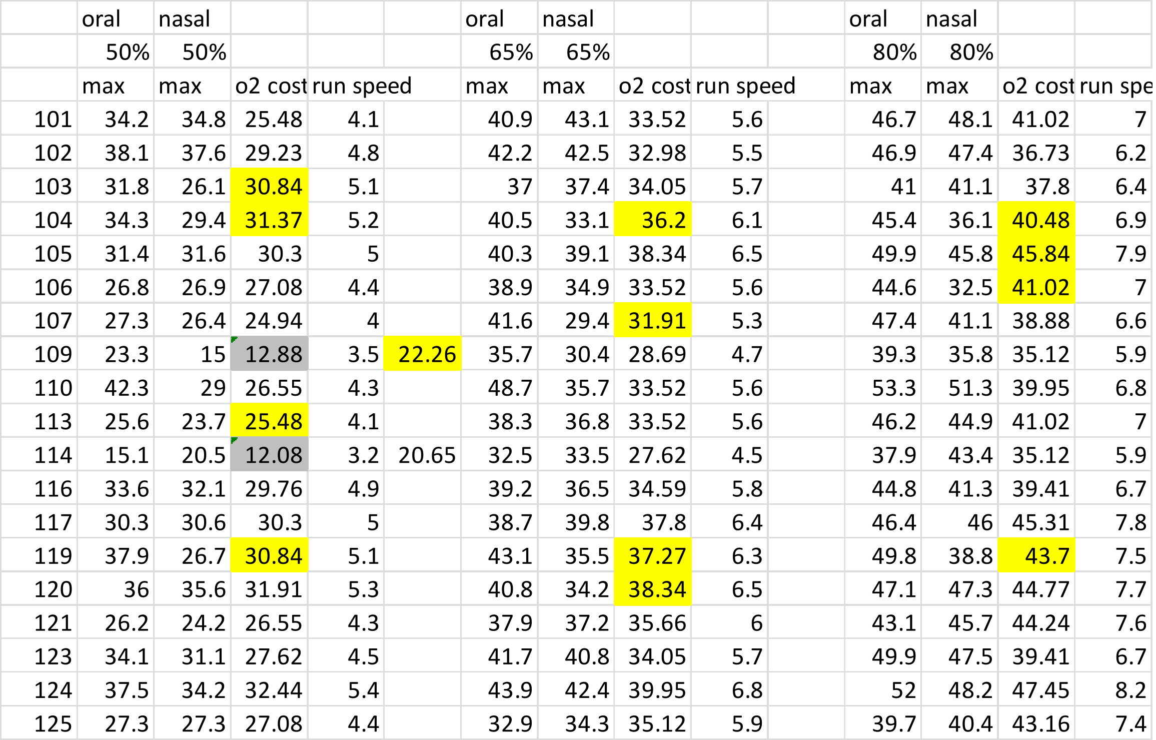
		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	FEV1 - FEV12	-.19789	.24809	.05692	-3.477	18	.003
Pair 2	N_FEV1 - N_FEV2	.00684	.23173	.05316	.129	18	.899

Appendix E

Metabolic Equation for Oxygen Cost w/ running speed

Running - VO2/kg = (0.2 x running speed) + (0.9 x running speed x grade) + 3.5

Walking - VO2/kg = (0.1 x walking speed) + (1.8 x running speed x grade) + 3.5



	oral	nasal				oral	nasal				oral	nasal		
	50%	50%				65%	65%				80%	80%		
	max	max	o2 cost	run speed		max	max	o2 cost	run speed		max	max	o2 cost	run spe
101	34.2	34.8	25.48	4.1		40.9	43.1	33.52	5.6		46.7	48.1	41.02	7
102	38.1	37.6	29.23	4.8		42.2	42.5	32.98	5.5		46.9	47.4	36.73	6.2
103	31.8	26.1	30.84	5.1		37	37.4	34.05	5.7		41	41.1	37.8	6.4
104	34.3	29.4	31.37	5.2		40.5	33.1	36.2	6.1		45.4	36.1	40.48	6.9
105	31.4	31.6	30.3	5		40.3	39.1	38.34	6.5		49.9	45.8	45.84	7.9
106	26.8	26.9	27.08	4.4		38.9	34.9	33.52	5.6		44.6	32.5	41.02	7
107	27.3	26.4	24.94	4		41.6	29.4	31.91	5.3		47.4	41.1	38.88	6.6
109	23.3	15	12.88	3.5	22.26	35.7	30.4	28.69	4.7		39.3	35.8	35.12	5.9
110	42.3	29	26.55	4.3		48.7	35.7	33.52	5.6		53.3	51.3	39.95	6.8
113	25.6	23.7	25.48	4.1		38.3	36.8	33.52	5.6		46.2	44.9	41.02	7
114	15.1	20.5	12.08	3.2	20.65	32.5	33.5	27.62	4.5		37.9	43.4	35.12	5.9
116	33.6	32.1	29.76	4.9		39.2	36.5	34.59	5.8		44.8	41.3	39.41	6.7
117	30.3	30.6	30.3	5		38.7	39.8	37.8	6.4		46.4	46	45.31	7.8
119	37.9	26.7	30.84	5.1		43.1	35.5	37.27	6.3		49.8	38.8	43.7	7.5
120	36	35.6	31.91	5.3		40.8	34.2	38.34	6.5		47.1	47.3	44.77	7.7
121	26.2	24.2	26.55	4.3		37.9	37.2	35.66	6		43.1	45.7	44.24	7.6
123	34.1	31.1	27.62	4.5		41.7	40.8	34.05	5.7		49.9	47.5	39.41	6.7
124	37.5	34.2	32.44	5.4		43.9	42.4	39.95	6.8		52	48.2	47.45	8.2
125	27.3	27.3	27.08	4.4		32.9	34.3	35.12	5.9		39.7	40.4	43.16	7.4

Gold highlights – Oxygen Cost was met in oral breathing mode but was insufficient in nasal breathing

Gray highlights – treadmill speed determined the use of walking equation

Appendix F

Oral Breathing Individual Data

	RR	VE	VO2	VCO2	RER	HR	VEQO2	VEQCO2	VO2_KG	RPE	SaO2	FEV1
1	45	49.53	2399.33	1836	0.76	148	20.63	27	33.23	9	96	3.53
2	30	52.88	2860.67	2311.33	0.81	133.33	18.47	22.83	36.27	9	96	3.49
3	42.33	38.83	1784	1487.67	0.83	141.33	21.77	26.1	30.5	7.67	96.33	2.79
4	49.67	67.44	2955.67	2648	0.89	136.67	22.8	25.43	33.77	12.33	95	3.8
5	36	50.76	2621.67	2202	0.84	118	19.4	23.07	30.73	7	98	5.37
6	35.67	41.6	1950	1555.67	0.8	130	21.3	26.8	25.6	10	98.33	4.17
7	28	30.05	1624	1325	0.82	110.67	18.47	22.63	25.2	9.33	95.67	2.06
8	26.33	25.57	1397	1081	0.78	121.67	18.3	23.67	22.47	9	97.33	2.81
9	23	35.15	2349.33	1886.67	0.8	134.67	14.97	18.67	41.4	11.33	92.33	3.25
10	34	35.62	1652.33	1456.33	0.88	127.67	21.57	24.47	23.8	7	97.67	4.39
11	26	18.11	964.67	697.67	0.72	130.67	18.77	25.97	12.73	10.33	97	2.82
12	47	64.86	3393.67	2869	0.84	133.67	19.1	22.6	32.27	11.33	94	4.45
13	26.67	41.15	2209.67	2111.33	0.95	109.33	18.6	19.47	29.37	8.33	93.33	5.09
14	29.33	37.06	2079	1777.67	0.86	136.33	17.8	20.83	36.7	8	95.33	3.7
15	34	49.2	2436.67	2083.33	0.86	158	20.17	23.63	33.8	12.33	95.67	4.6
16	20.33	40.56	2278	2036.33	0.89	132.67	17.8	19.97	25	9.33	97.33	5.61
17	35.67	58.27	2849	2675.67	0.94	138.33	20.43	21.77	32.9	7.33	95.67	4.2
18	32.33	52.53	2827	2626.67	0.93	132	18.57	19.93	34.8	7	96.33	3.47
19	32	36.3	2120	1882.67	0.89	131.33	17.07	19.27	24.6	8.67	94.67	3.41
	RR2	VE2	VO22	VCO22	RER2	HR2	VEQO22	VEQCO22	VO2_KG2	RPE2	SaO22	
1	54.67	63	2812.67	2427.67	0.86	164.33	22.43	25.97	38.97	13	94	
2	35	64	3228	2877.67	0.89	142.33	19.8	22.23	40.9	12	94.33	
3	51.67	46.13	2027.67	1779.33	0.88	158.33	22.7	25.9	34.63	9	96	
4	56.67	91.72	3483.67	3354.67	0.96	160.33	26.33	27.33	39.8	13.67	90.33	
5	34	64.79	3360.33	2977.67	0.88	140.33	19.27	21.77	39.4	13	96.33	
6	35.33	57.59	2731.67	2322.67	0.85	160.33	21.07	24.8	35.83	12	98.33	
7	37	47.91	2489.33	2301.33	0.92	152	19.2	20.8	38.63	11	92	
8	44.67	46.54	2154.67	2095.33	0.97	166.33	21.57	22.13	34.67	14	95.33	
9	27.67	44.8	2747.67	2582.33	0.94	151.33	16.33	17.37	48.47	13.67	87.67	
10	35.67	49.63	2533.67	2368.33	0.93	156	19.53	20.93	36.5	7.33	95.33	
11	58	64.33	2412.33	2147.33	0.89	167	26.67	29.97	31.8	13	94.33	
12	53.67	82.88	4077	3644.67	0.89	157	20.33	22.77	38.77	12.33	89	
13	30.33	54.77	2832	2795	0.99	134	19.33	19.57	37.63	12	96.67	
14	37	44.89	2360	2186.67	0.93	161.67	19.03	20.53	41.6	12	93.33	
15	38.67	58.18	2872	2561.67	0.89	168.67	20.23	22.7	39.83	14.33	95	
16	32	62.34	3214	3059.67	0.95	160.33	19.37	20.37	35.23	12.67	97	
17	42.33	79.45	3535.33	3499.67	0.99	170	22.47	22.7	40.83	13.33	93.33	
18	35.33	67.96	3485	3367.33	0.97	159.67	19.5	20.2	42.93	9.67	97	
19	39.33	53.01	2750.33	2651.33	0.96	154.67	19.3	20	31.93	11.33	95	
	RR3	VE3	VO23	VCO23	RER3	HR3	VEQO23	VEQCO23	VO2_KG3	RPE3	SaO23	FEV12
1	57.33	83.08	3340.33	3148.67	0.94	176.33	24.87	26.37	46.27	16	93	3.59
2	42.67	75	3622.67	3380.67	0.93	154.67	20.73	22.2	45.9	13	92.33	3.75
3	53.67	54.04	2320	2058.33	0.89	172.33	23.27	26.23	39.67	11.67	95	2.83
4	74	114.6	3878.33	3802.67	0.98	175	29.53	30.13	44.3	17.67	93	4.45
5	48	86.14	4074	3893	0.95	158.67	21.17	22.1	47.77	18	97	5.65
6	44.67	71.92	3326.67	3170	0.95	178.67	21.6	22.67	43.63	13.67	98.33	4.08
7	52	61.25	2882	2768.67	0.97	177.67	21.3	22.17	44.73	13.67	90	2.81
8	54	64.23	2431.33	2550	1.05	187.33	26.4	25.17	39.13	18.67	94.33	2.94
9	33.67	50.11	2929.33	2943	1	158.33	17.13	17	51.67	16.5	89	3.44
10	41.67	65.31	3092	3137.33	1.02	177.67	21.13	20.8	44.53	13	93.67	4.25
11	67.33	84.38	2812.67	2720.67	0.97	179.67	29.97	31	37.03	15.67	92	3.12
12	62.33	102.05	4609.33	4360	0.95	176.67	22.13	23.43	43.8	15	90.67	4.76
13	37	67.55	3367.67	3402.67	1.01	157.33	20.07	19.83	44.7	13.67	96.33	5.24
14	50.67	59.65	2639	2659	1.01	183.67	22.63	22.47	46.53	17	89	3.45
15	53.33	77.85	3372.67	3192.33	0.95	184	23.1	24.37	46.73	17	95.67	5.1
16	32.33	79.46	3768.33	3652	0.97	179.67	21.1	21.77	41.33	15.67	92.33	5.84
17	60	105.26	4185	4250.33	1.02	185.33	25.17	24.77	48.3	15	93.33	4.27
18	44.67	90.64	4114	4108	1	177	22	22.07	50.67	13	94.67	3.68
19	50	69.07	3289	3424.67	1.04	177.33	21.03	20.17	38.17	15	93.67	3.52

Nasal Breathing Individual Data

	N_RR	N_VE	N_VO2	N_VCO2	N_RER	N_HR	N_VEQO2	N_VEQCO	N_VO2_K	N_RPE	N_SaO2	N_FEV1
1	29	42.66	2336.67	1741.33	0.74	149	18.27	24.53	32.37	8.33	93.33	3.39
2	22.67	48.05	2890.33	2205	0.76	139.67	16.6	21.8	36.63	9.67	96.67	3.43
3	37.33	31.85	1464.33	1210.33	0.83	146.33	21.77	26.3	25	8.67	94	3.02
4	43.67	47.79	2489	2082	0.83	141	19.17	22.93	28.43	7.33	95.67	4.27
5	20.67	39.56	2562	1884.33	0.74	110.67	15.43	21.03	30.03	8.33	95.33	5.48
6	19.33	29.16	1932.67	1420.33	0.73	134.67	15.1	20.53	25.33	8.33	98	3.95
7	16.67	24.74	1582	1113.33	0.7	116	15.67	22.3	24.57	12	92	2.79
8	28.33	18.39	722	550	0.75	126	26.5	35.17	11.6	8.33	97	2.98
9	29	30.67	1638	1301	0.8	121	18.73	23.6	28.87	10	97.33	3.28
10	20	28.5	1458.67	1168.33	0.8	123	19.5	24.4	21.03	6.67	95	4.33
11	17.67	23.08	1256.67	856	0.68	133	18.33	26.97	17.4	11	96.33	3.23
12	31	55.83	3139.67	2852	0.91	146.33	17.73	19.57	29.83	13.67	94	4.44
13	20	40.27	2293.67	2177	0.95	113	17.57	18.5	30.43	7	98.33	5.27
14	23	17.47	1340.5	885	0.66	144	13.05	19.8	23.65	16	90.5	3.59
15	22.33	40.57	2447.67	2083.67	0.85	156	16.63	19.47	33.7	11	80	5.22
16	18.33	37	2085.67	1803.33	0.86	112.67	17.7	20.53	22.87	7.67	98	5.87
17	27	41.34	2431.33	2100.67	0.86	138.33	16.9	19.67	28.07	11.33	95.33	4.23
18	25	48.05	2662.67	2467.33	0.93	129.33	18.07	19.47	32.97	8.33	96.33	3.46
19	29.33	41.16	2232.33	1953.33	0.87	125.33	18.43	21.07	25.63	7.33	95.67	3.41
	N_RR2	N_VE2	N_VO22	N_VCO22	N_RER2	N_HR2	N_VEQO2	N_VEQCO	N_VO2_K	N_RPE2	N_SaO22	
1	33.33	52.79	2790	2283	0.82	164	18.93	23.13	38.67	12.33	91.33	
2	27.33	54.08	3194.33	2743.67	0.86	144.33	16.9	19.73	40.47	12.33	93	
3	39.33	42.82	2037.33	1743.67	0.85	163.33	21.07	24.6	34.83	8.67	92.33	
4	50.67	58.88	2877.67	2608.33	0.91	162	20.43	22.6	32.87	10.67	94.33	
5	31.67	57.55	3292	2826.67	0.86	135	17.5	20.33	38.6	14.67	96	
6	32	38.49	2532.67	1970.33	0.78	102.33	15.23	19.57	33.2	11.67	95.33	
7	18	27.62	1788.67	1382	0.77	121.33	15.43	20.03	27.77	12	91	
8	34.33	31.91	1691.33	1390	0.82	150.33	18.9	23.13	27.23	13.67	96	
9	35.33	37.88	1986.67	1720.33	0.87	156.67	19.07	22	35.07	13.33	95	
10	29	45.59	2389	2082.33	0.87	150	19.1	21.9	34.43	7	95	
11	45	49.92	2315.33	1908	0.82	164	21.57	26.2	32.1	13	83.33	
12	38	63.18	3600.67	3205	0.89	153	17.57	19.73	34.23	14	89	
13	25.33	50.13	2916.67	2804	0.96	140.33	17.17	17.87	38.77	9.67	97.67	
14	25.5	31.08	2010.5	1636.5	0.82	160.5	15.45	19	35.45	16.5	94.5	
15	29	41.31	2374	2205.67	0.93	170.67	17.43	18.73	32.73	14	79.5	
16	28.67	60.78	3145	3167	1.01	157.33	19.37	19.23	34.5	12.33	94.67	
17	34.33	60.62	3401.33	3258	0.96	165.67	17.8	18.6	39.27	14	94.33	
18	30.33	58.5	3234.67	3098.67	0.96	155.33	18.1	18.87	40.07	11.67	94.67	
19	31.33	52.97	2911.33	2686.33	0.92	155	18.17	19.73	33.43	12.67	93	
	N_RR3	N_VE3	N_VO23	N_VCO23	N_RER3	N_HR3	N_VEQO2	N_VEQCO	N_VO2_K	N_RPE3	N_SaO23	N_FEV2
1	51	75.73	3323.67	3033.33	0.91	177	22.77	24.93	46.07	17.33	91.67	3.42
2	32	63.4	3653	3390.33	0.93	158.33	17.33	18.67	46.27	14.67	90.67	3.69
3	34.67	43.77	2322.67	2078.67	0.89	177.33	18.83	21.07	39.67	11.33	89.33	2.96
4	54	71.07	3099.33	3084.33	1	178.67	22.9	23.07	35.4	13.67	95.33	3.98
5	38	70.03	3784.33	3383.33	0.89	154.67	18.5	20.7	44.37	19	95	5.32
6	35.67	35.24	2322.67	1875.67	0.8	97.33	15.17	18.8	30.5	12.33	97.33	4.14
7	33.67	39.89	2098.33	1659	0.79	150	19.6	24.77	32.6	13	88	2.91
8	50.33	50.09	2161.33	2238.33	1.03	155.67	23.13	22.37	34.77	18.33	90.67	3.07
9	39	49.87	2388.67	2287.33	0.96	160.33	20.73	21.63	42.17	15.33	91.67	2.91
10	34.33	55.93	3062.33	2933.33	0.96	169.67	18.27	19.1	44.13	12.33	94.67	4.29
11	48	61.22	2802.33	2546	0.91	174.67	21.83	24.07	38.87	16	90	3.01
12	41	77.97	4234.33	4314.33	1.02	182.67	18.4	18.07	40.23	17	90.67	4.76
13	29.33	54.11	3310.67	3336	1.01	160.67	16.33	16.23	44	14	92	5.57
14	32	35.18	2144	1865.5	0.87	165.5	16.4	18.9	37.8	18	91.5	3.65
15	36.33	57.7	3267	3097	0.95	179.33	17.63	18.67	45.03	16	80	4.71
16	32.33	79.29	3950.67	4076.33	1.03	178	20.07	19.47	43.3	16.5	92	5.7
17	42	74.44	4022.67	4157	1.04	182.33	18.5	17.9	46.43	18	88.67	4.25
18	37	68.48	3755.67	3715.67	0.99	175.33	18.23	18.43	46.53	13.67	92	3.54
19	32	63.6	3469	3531	1.02	182	18.3	18	39.8	17	92	3.63

Reference

Ballard, Roberta A., et al. "Inhaled Nitric Oxide in Preterm Infants Undergoing Mechanical Ventilation." *N Engl J Med* 355.4 (2006): 343-53. Web.

Baraniuk, James N., and Samantha J. Merck. "Nasal Reflexes: Implications for Exercise, Breathing, and Sex." *Current allergy and asthma reports* 8.2 (2008): 147-53. Web.

Bauer, John Anthony, et al. "Endogenous Nitric Oxide in Expired Air: Effects of Acute Exercise in Humans." *Life Sciences* 55.24 (1994): 1903-9. Web.

Bennett, William D., Kirby L. Zeman, and Annie M. Jarabek. "Nasal Contribution to Breathing and Fine Particle Deposition in Children Versus Adults." *Journal of Toxicology and Environmental Health, Part A* 71.3 (2007): 227-37. Web.

Bennett, W. D., K. L. Zeman, and A. M. Jarabek. "Nasal Contribution to Breathing with Exercise: Effect of Race and Gender." *Journal of applied physiology (Bethesda, Md.: 1985)* 95.2 (2003): 497-503. Web.

Benninger, M. S., et al. "Nasal Patency, Aerobic Capacity, and Athletic Performance." *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery* 107.1 (1992): 101-4. Web.

Boas, A. P. D. V., et al. "Walk Test and School Performance in Mouth-Breathing Children." *Brazilian Journal of Otorhinolaryngology* 79.2 (2013): 212-8. *SCOPUS.*Web. 10 October 2014.

Boggs, G. W., J. R. Ward, and S. Stavrianeas. "The External Nasal Dilator: Style Over Function?" *Journal of strength and conditioning research / National Strength & Conditioning Association* 22.1 (2008): 269-75. Web.

Camner, Per, and Birger Bakke. "Nose Or Mouth Breathing?" *Environmental research* 21.2 (1980): 394-8. Web.

Chinevere, T. D., E. W. Faria, and I. E. Faria. "Nasal Splinting Effects on Breathing Patterns and Cardiorespiratory Responses." *Journal of sports sciences* 17.6 (1999): 443-7. Web.

Churchill, Steven E., et al. "Morphological Variation and Airflow Dynamics in the Human Nose." *American Journal of Human Biology* 16.6 (2004): 625-38. Web.

Clarke, RW, AS Jones, and H. Richardson. "Peak Nasal Inspiratory flow–the Plateau Effect." *The Journal of Laryngology & Otology* 109.05 (1995): 399-402. Web.

Forsyth, RD, P. Cole, and RJ Shephard. "Exercise and Nasal Patency." *J Appl Physiol* 55.3 (1983): 860-5. Web.

Fregosi, R. F., and R. W. Lansing. "Neural Drive to Nasal Dilator Muscles: Influence of Exercise Intensity and Oronasal Flow Partitioning." *Journal of applied physiology (Bethesda, Md.: 1985)* 79.4 (1995): 1330-7. Web.

Gehring, J. M., et al. "Nasal Resistance and Flow Resistive Work of Nasal Breathing during Exercise: Effects of a Nasal Dilator Strip." *Journal of applied physiology (Bethesda, Md.: 1985)* 89.3 (2000): 1114-22. Web.

Griffin, John W., et al. "Physiologic Effects of an External Nasal Dilator." *The Laryngoscope* 107.9 (1997): 1235-8. Web.

Gustafsson, L. El, et al. "Endogenous Nitric Oxide is Present in the Exhaled Air of Rabbits, Guinea Pigs and Humans." *Biochemical and biophysical research communications* 181.2 (1991): 852-7. Web.

Hall, Roberta L. "Energetics of Nose and Mouth Breathing, Body Size, Body Composition, and Nose Volume in Young Adult Males and Females." *American Journal of Human Biology* 17.3 (2005): 321-30. Web.

James, David S., et al. "Oronasal Distribution of Ventilation at Different Ages." *Archives of Environmental Health: An International Journal* 52.2 (1997): 118-23. Web.

Jones, Nick. "The Nose and Paranasal Sinuses Physiology and Anatomy." *Advanced Drug Delivery Reviews* 51.1–3 (2001): 5-19. Web.

Kovesi, Thomas, Ryan Kulka, and Robert Dales. "Exhaled Nitric Oxide Concentration is Affected by Age, Height, and Race in Healthy 9-to 12-Year-Old Children."*CHEST Journal* 133.1 (2008): 169-75. Web.

Liu, W. Y., and Macfarlane, D.J. "Inspiratory Oral and Nasal Ventilation during Treadmill Running: Little Benefit of External Nasal Dilators." *Med. Sci. Sports Exerc.*33.S315 (2001)Print.

Macfarlane, Duncan J., and Stanley KK Fong. "Effects of an External Nasal Dilator on Athletic Performance of Male Adolescents." *Canadian journal of applied physiology* 29.5 (2004): 579-89. Web.

Mangla, PK, and MPS Menon. "Effect of Nasal and Oral Breathing on exercise-induced Asthma." *Clinical & Experimental Allergy* 11.5 (1981): 433-9. Web.

Maroun, M. J., et al. "Effects of Physical Conditioning on Endogenous Nitric Oxide Output during Exercise." *Journal of applied physiology (Bethesda, Md.: 1985)* 79.4 (1995): 1219-25. Web.

Martin, Una, et al. "Increased Levels of Exhaled Nitric Oxide during Nasal and Oral Breathing in Subjects with Seasonal Rhinitis." *Journal of allergy and clinical immunology* 97.3 (1996): 768-72. Web.

Meir, R., et al. "The Acute Effect of Mouth Only Breathing on Time to Completion, Heart Rate, Rate of Perceived Exertion, Blood Lactate, and Ventilatory Measures during a High-Intensity Shuttle Run Sequence." *Journal of Strength and Conditioning Research* 28.4 (2014): 950-7. *SCOPUS.* Web. 10 October 2014.

Milanesi, Jovana de Moura, et al. "Childhood Mouth-Breathing Consequences at Adult Age: Ventilatory Function and Quality of Life." *Fisioterapia em Movimento* 27.2 (2014): 211-8. Web.

Morton, A. R., et al. "Comparison of Maximal Oxygen Consumption with Oral and Nasal Breathing." *Australian Journal of Science and Medicine in Sport* 27.3 (1995): 51-5. *SCOPUS.* Web. 10 October 2014.

Niinimaa, Veli. "Oronasal Airway Choice during Running." *Respiration physiology* 53.1 (1983): 129-33. Web.

Niinimaa, VPSRJ, P. Cole, and RJ Shephard. "Oronasal Distribution of Respiratory Airflow." *Respiration physiology* 43.1 (1981): 69-75. Web.

Niinimaa, V., et al. "The Switching Point from Nasal to Oronasal Breathing." *Respiration physiology* 42.1 (1980): 61-71. Web.

O'Kroy, JA. "Oxygen Uptake and Ventilatory Effects of an External Nasal Dilator during Ergometry." *Medicine & Science in Sports & Exercise* 32.8 (2000): 1491-5. Web.

Overend, T., et al. "External Nasal Dilator Strips do Not Affect Treadmill Performance in Subjects Wearing Mouthguards." *Journal of athletic training* 35.1 (2000): 60-4. Web.

Parsons, Jonathan P., and John G. Mastronarde. "Exercise-Induced Bronchoconstriction in Athletes." *CHEST Journal* 128.6 (2005): 3966-74. Web.

Pepke-Zaba, Joanna, et al. "Inhaled Nitric Oxide as a Cause of Selective Pulmonary Vasodilatation in Pulmonary Hypertension." *The Lancet* 338.8776 (1991): 1173-4. Web.

Pickering, Daniel N., and Caroline S. Beardsmore. "Nasal Flow Limitation in Children." *Pediatric pulmonology* 27.1 (1999): 32-6. Web.

Pires, Melissa Guerato, et al. "Evaluation of Inspiratory Pressure in Children with Enlarged Tonsils and Adenoids." *Revista Brasileira de Otorrinolaringologia* 71.5 (2005): 598-602. Web.

Richerson, Hal B., and Paul M. Seebohm. "Nasal Airway Response to Exercise." *Journal of Allergy* 41.5 (1968): 269-84. Web.

Saibene, Franco, et al. "Oronasal Breathing during Exercise." *Pflügers Archiv* 378.1 (1978): 65-9. Web.

Shturman-Ellstein, R., et al. "The Beneficial Effect of Nasal Breathing on Exercise-Induced Bronchoconstriction." *The American Review of Respiratory Disease* 118.1 (1978): 65-73. Web.

Swift, AC, IT Campbell, and TessaM Mckown. "Oronasal Obstruction, Lung Volumes, and Arterial Oxygenation." *The Lancet* 331.8577 (1988): 73-5. Web.

Swift, DAVID L. "Physical Principles of Airflow and Transport Phenomena Influencing Air Modification." *The Nose: Upper Airway Physiology and the Atmospheric Environment, eds Proctor DF, Andersen IB.(Elsevier Biomedical, Amsterdam)* (1982): 337-49. Web.

Tanaka, Y. U. K. I. O., T. S. U. G. U. O. Morikawa, and Y. O. S. H. I. Y. U. K. I. Honda. "An assessment of nasal functions in control of breathing." Journal of Applied Physiology 65.4 (1988): 1520-1524.

Tong, T. K., F. H. Fu, and B. C. Chow. "Effect of Nostril Dilatation on Prolonged all-Out Intermittent Exercise Performance." *Journal of Sports Medicine & Physical Fitness* 41.2 (2001): 189-95. Web.

---. "Nostril Dilatation Increases Capacity to Sustain Moderate Exercise Under Nasal Breathing Condition." *Journal of Sports Medicine & Physical Fitness* 41.4 (2001): 470-8. Web.

Tornberg, D. C., et al. "Nasal and Oral Contribution to Inhaled and Exhaled Nitric Oxide: A Study in Tracheotomized Patients." *The European respiratory journal* 19.5 (2002): 859-64. Web.

Warren, Donald W., et al. "The Relationship between Nasal Airway Size and Nasal-Oral Breathing." *American Journal of Orthodontics and Dentofacial Orthopedics* 93.4 (1988): 289-93. Web.

Wheatley, JR, TC Amis, and LA Engel. "Oronasal Partitioning of Ventilation during Exercise in Humans." *J Appl Physiol* 71 (1991): 546-51. Web.

Yasuda, Y., et al. "Comparison of Exhaled Nitric Oxide and Cardiorespiratory Indices between Nasal and Oral Breathing during Submaximal Exercise in Humans." *The Japanese journal of physiology* 47.5 (1997): 465-70. Web.

Zhu, Jian Hua, et al. "Evaluation and Comparison of Nasal Airway Flow Patterns among Three Subjects from Caucasian, Chinese and Indian Ethnic Groups using Computational Fluid Dynamics Simulation." *Respiratory physiology & neurobiology* 175.1 (2011): 62-9. Web.

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