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Abstract

Oxygen deprivation masks are being advertised towards athletes as a piece of fitness equipment that can simulate the effects of high altitude, as well as a respiratory muscle training device. Studies that investigated the claims as to whether ODMs increased VO2max and improved endurance were looked into. Experimental data did not find that the use of these masks increased VO2max, nor was there any supporting data to prove that it improved endurance. The function of ODMs as a training tool to increase respiratory muscle strength was also examined. There were contradicting results between the three different studies examined. One study found that ODMs did not show any improvement in respiratory muscle strength as participants in the ODM group perceived breathing efforts as higher, which can be seen as an indicator for weak muscular strength. In the second study, researchers found that participants in the ODM group had increased contraction of respiratory muscles and higher maximal voluntary ventilation than the control group which indicates stronger respiratory muscles. The final study found that the use of ODMs did not lead to any statistical significance in a 5-kilometer run, nor did it significantly increase diaphragm thickness which is associated with diaphragm strength. To conclude this paper, the claims made by oxygen deprivation masks with regard to increasing VO2max and improving endurance are incorrect. Claims that oxygen deprivation masks increase respiratory muscular strength are inconclusive, however, there is more data that indicates ODMs do not increase strength. It should be noted that the type of physical activity used for training, flow rate of oxygen, and period of training time all varied and should be considered when analyzing the findings.

Keywords

altitude, training, oxygen-deprivation, respiratory

Disciplines

Circulatory and Respiratory Physiology | Sports Medicine | Sports Sciences

Comments

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Oxygen Deprivation Masks for Training

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Introduction

An oxygen deprivation mask (ODM), commonly referred to as a training mask, is a piece of training equipment popular among athletes and regular gym-goers. The most popular brand currently being sold is the “Training Mask 2.0 Original,” priced at $40 (*TRAINING MASK 2.0 ORIGINAL*). Many celebrity athletes endorse the use of this mask, such as the Seahawk’s running back, Marshawn Lynch, who has been seen training with an oxygen deprivation mask (Friedman, 2015). Consumers are buying oxygen deprivation masks without first researching data and results companies claim these masks can produce.

Advocates of oxygen deprivation masks claim these masks can produce the same effects as training at high altitudes would. This includes physiological responses such as increased VO2max and overall improved endurance during exercise. The manufacturers and supporters of these ODMs also claim that it acts as a tool to increase respiratory muscle strength, ultimately improving performance. It is important to gain an understanding as to what this ODM can and cannot do with regard to its claims and the alleged results it can produce. Several studies analyze the effects of ODM use on multiple variables such as VO2max, endurance, and respiratory muscle strength (Porcari et al., 2016). By the end of this paper the reader will be able to understand what results ODMs are capable of producing and whether it is a piece of gym equipment that should be deemed beneficial to improve athletic performance.

High Altitude Training

For many athletes and physically active people, a common goal is to perform better which they accomplish by improving their body's metabolic, respiratory, and cardiovascular efforts. Some people believe they can enhance their endurance during physical activity by enduring what is known as “high altitude training.” High altitude training refers to training for a sport or activity at a high altitude, anywhere between 7,000 and 8,000 feet above sea level. As someone goes progressively higher in altitude, there is lower atmospheric pressure which makes it more difficult for the blood in someone's body to receive O2. Because of this, people tend to respire more in an attempt to get a sufficient amount of O2 into the body. This will fatigue them quicker, but it also leads to increased production of red blood cells to make O2 more accessible to the tissues and organs (Levine, 2016). Exercising at high altitudes eventually causes the body to adapt and adjust to help the body maintain its oxygen transportation and availability for survival at higher altitudes. However, at sea level, what is considered normal elevation for most people, this physiological adaptation is not needed because atmospheric pressure is not as low, and there is not an additional strain of impaired O2 transportation throughout the body. With that being said, the body’s physiological change that occurs at altitude would continue to occur for a short period of time in a human when they return to sea level altitude. The human body would continue to increase red blood cell production even though there are no environmental stressors, such as high altitude, that would be required for the body to regulate and maintain O2 transportation. This is the ultimate premise as to why athletes use high altitude training to perform better. Athletes train at high altitudes so that their bodies can adapt to the change in altitude by producing more red blood cells. When they return shortly to sea level to compete or perform, their body is still adapted to increase red blood cell production and, therefore, carries O2 throughout the body better. The ability to efficiently transport and circulate O2 around the body is beneficial during exercise as it supplies demanding muscles with O2. When active muscles used during exercise have a sufficient supply of O2 in the blood vessels of the muscle, the muscle is able to endure physical work longer, therefore, improving performance (Bergeson

Becco, 2017). Athletes use this physiological response that occurs at high altitudes as a form of training to increase O2 delivery to their muscles when they return to physical exercise at sea level.

How exactly does high altitude lead to better muscle performance? Taking a look at what first occurs in the human body at high altitudes is necessary in order to understand the body's mechanism of trying to bring oxygen transportation and saturation levels back to homeostasis. As someone travels up to higher altitudes, the concentration of oxygen remains the same no matter what the altitude is, however, the barometric pressure changes, causing the partial pressures of oxygen to decrease. When the partial pressure of oxygen has decreased in the environment, there is less pressure enforcing the movement of oxygen within the body (Grocott et al., 2007). High altitude causes a decrease in the partial pressure of oxygen which leads to insufficient levels of oxygen in the blood (blood serves as oxygen's mode of transportation to tissues and organs in the body). Now that it is understood why high altitude causes decreased oxygen throughout the body, an explanation as to how the body attempts to regulate oxygen levels can be provided.

There is one pathway that is mainly responsible for the body's response to hypoxia (low availability of oxygen in the body) at high altitudes which is the hypoxia-inducible factor (HIF) pathway. HIF, in short, regulates transcription during the body's response to hypoxia. It consists of a β subunit (HIF-β) and three α subunits (HIF-1α, HIF-2α, and HIF-3α). The mechanism in which HIF activity is regulated during fluctuations in oxygen availability is through hydroxylation (addition of a hydroxyl group) of the α subunit (Raju, 2019). Under normal conditions where oxygen is readily available to the body and barometric pressure is tolerable for the human body, there are three enzymes: prolyl hydroxylase domain protein 1 (PHD1), prolyl hydroxylase domain protein 2 (PHD2), and prolyl hydroxylase domain protein 3 (PHD3), that hydroxylate the α subunit of HIF. The addition of a hydroxyl group to the three different α subunits then allows for the Hippel-Lindau (VHL) protein to bind, which ultimately leads to degradation of the hydroxylated alpha subunit. Therefore, VHL inhibits the function and expression of HIF thereby inhibiting expression of HIF genes that are induced by hypoxia. At normal altitudes and under normal circumstances, the use of the HIF pathway is not needed. VHL inhibits the genes involved in the pathway that would normally attempt to help the body survive during hypoxic events (Bigham & Lee, 2014). Under hypoxic conditions, the α subunit is not hydroxylated, preventing the binding of VHL to the α subunit, causing stability between the α and β subunits. Now that the α subunit is not degraded by VHL, it is also able to bind to hypoxia response elements (HRE). The stability between the α and β subunits allows for the activation of many genes that will help the body adapt to the hypoxic events, one of which will specifically address the HIF-2α gene.

A product of the HIF-2α gene is erythropoietin (EPO), a hormone that is critical in the production of red blood cells. This hormone is released by the kidney and liver when the body detects hypoxia in the tissues (SCHOLZ et al., 1990). Now that the HIF pathway is not inhibited due to hypoxia, it is able to turn on the expression of the HIF-2α gene which regulates synthesis of EPO. Activation of the HIF-2α gene thereby mediates erythropoiesis in the kidney and liver, resulting in more red blood cells (Haase, 2012). Red blood cells act as a carrier for oxygen throughout the body. By increasing red blood cell production, more oxygen is able to transport throughout the body and reach tissues and muscles that demand oxygen during exercise (Grocott et al., 2007).

A summary of the sequence of events that occurs in the body in response to hypoxia is as follows: decreased oxygen levels restrict the inhibiting VHL protein from binding to the α subunit in HIF. Expression of HIF genes, such as the HIF-2α gene, now occurs. Activation of the HIF-2α gene leads to erythropoiesis in the kidney and liver, leading to an increased quantity of red blood cells in the body. People that are at high altitudes for a substantial amount of time will start to express these HIF genes and, therefore, increase their red blood cell production. Ultimately, more oxygen will reach their muscles, enabling them to work better and longer.

Masks as a Simulation for High Altitude

Oxygen deprivation masks are sold on the market with the pitch that they simulate the effects of high altitude training by decreasing the influx of oxygen into the body. As discussed in the "High Altitude Training" section, training at such high altitudes can improve performance through altered cardiovascular efforts which allow active muscles to work for longer periods of time. This mechanism is caused by altitude-induced hypoxia due to decreased atmospheric pressure. In addition to the inconvenience of having to travel to a region with high altitude, many other inconveniences that result from being so far above sea level. Acute Mountain Sickness is commonly associated with high altitude and can cause headaches, nausea, vomiting, insomnia, and suppression of appetite; in severe cases, it can progress into life-threatening illnesses such as high-altitude cerebral edema or high-altitude pulmonary edema (Muza, 2007). What makes ODM so appealing to its consumers is the idea that they can achieve the effects of high altitude training without having to travel to high altitude regions or endure the sicknesses associated with altitude. (Sellers et al., 2016). While the cons of high altitude training can be avoided with ODMs, it is necessary to investigate whether ODMs can produce the same physiological effects and advantages that high altitude training would create, such as increased VO2max (Biggs et al., 2017) and enhanced endurance during exercise (Wilber et al., 2007).

The first claim manufacturers state ODMs can do is increase maximal oxygen consumption (VO2max) (Porcari et al., 2016). VO2max is the maximum amount of oxygen the body can take in; it is considered the best indicator of cardiorespiratory fitness (Buttar et al., 2019). One study examined the impact of an ODM on VO2max in moderately-athletic male and female college students during a 6-week high-intensity training. Participants exercised on ergometers for 30 minutes twice a week and VO2max results were calculated from respiratory gas exchange and heart rate measurements. VO2max data was taken pre-training and after the 6-week training for both the mask and control (no mask) groups. The results of the study found that both the experimental and control group had increases, 16.5% and 13.5% respectively, in VO2max results, however, there was no statistical difference between the groups. There was no difference between male and female results either (Porcari et al., 2016). This data suggests that the use of ODMs does not appear to have a significant effect on VO2max in comparison to if an ODM was not used during training. Another study examined the effects of an ODM on VO2max in male Reserve Officers Training Corps (ROTC) cadets over a 7-week period. VO2max was measured in experimental (ODM use) and control (no masks) groups before and after a training period in which participants ran 1.5 miles three times a week. Results of the study showed that there was no significant statistical difference between pre-training and post-training VO2max for both experimental and control groups (Warren et al., 2017). Because participants in this study were training cadets that must meet certain physical standards, findings from this study indicate that there is no significant improvement in VO2max of very athletic individuals after a 7-week training using ODM. There is also not a significant difference in VO2max between ODM users and individuals who did not use ODM. Overall, given the results from studies that examined the effects of ODMs on VOXmax, there is strong data suggesting that ODM use during training does not improve VO2max, therefore, ODMs do not produce equivalent VO2max results as high altitude training would.

Proponents of ODM use also claim that these masks improve endurance during exercise (Porcari et al., 2016). The basis for which improved endurance is noted is through decreased muscle fatigue (Gacesa et al., 2013). In one study that examined the effects of ODMs on work velocity in male weight lifters, peak velocity was obtained from running strides in participants over a 6-week period. Peak velocity was measured before and after training for the ODM group and control group. Results from the study showed that on average, peak velocity decreased in the ODM group in comparison to the control group (Jagim et al., 2018). Decrease in velocity is indicative of muscle fatigue (SANCHEZ-MEDINA & JOSE GONZALEZ-BADILLO, 2011), therefore, training with the use of ODM is shown to cause a faster onset of muscle fatigue in comparison to the control group. Another study examined the effects of ODM use on exercise performance through time-to-exhaustion cycling tests in male and female participants. Time-to-exhaustion was measured both before and after a 6-week training period for both ODM and control groups. Results from the study showed that time-to-exhaustion was reduced more in the ODM group than in the control. With faster onset of exhaustion as a result of ODM use, it is suggested that it causes reduced exercise performance (Boyle et al., 2022). Upon analysis of both of the studies that examine the effect of ODMs use during training, ODMs were found to cause faster onset of muscle exhaustion and therefore decreased endurance in participants (Bogdanis, 2012).

As mentioned previously, high altitude training is capable of increasing both VO2max and endurance in individuals. With consideration of the results from the studies that looked into the effects of ODMs on VO2max, there is no statistically significant data that backs up the claim that ODMs increase VO2max. Additionally, there is no data that suggested that weeks of training with ODM use improved endurance. In conclusion, VO2max and endurance do not increase with the use of ODMs during training.

Respiratory Muscle Training

While ODMs are used among athletes with the goal of achieving similar results to that of high altitude training, ODMs are also used for respiratory muscle training (RMT) (Segizbaeva & Aleksandrova, 2018). RMT, also referred to as inspiratory muscle training, is intended to decrease respiratory fatigue through improved respiratory muscle strength and endurance (Hartz et al., 2018). It should also be noted that while inspiratory muscle training is commonly used among athletes to improve performance, there are also medical purposes for this training such as for pulmonary rehabilitation in individuals with weak inspiratory muscle strength, such as chronic obstructive pulmonary disease (COPD) patients (Figueiredo et al., 2020). The mechanism by which RMT improves muscle strength and endurance is through increased strength and endurance of the diaphragm and additional accessory muscles of respiration. By strengthening the muscles of the respiratory system, the amount of oxygen that is inhaled through external respiration increases and therefore better supplies the tissues (Álvarez-Herms et al., 2019).

<u>Masks for Respiratory Muscle Training</u>

A postulation regarding ODMs is that they help to increase respiratory muscle strength through respiratory muscle training (Barbieri et al., 2020). In a study that examined the outcome of ODM use on respiratory muscle training, female and male participants of both the ODM group and control group were asked to complete phases of cycling. SpO2 and self-perceived breath efforts of healthy males and females were measured at each phase of cycling. Results showed that perceived breath efforts were higher in the ODM group than in the no mask group for both female and male participants (Jung et al., 2019). Increased perceived breath efforts indicate troubling breathing which can be associated with weak respiratory muscle function (Pavletic & Hnatiuk, 2012). Given the data of this study, it can be determined that ODMs do not lead to increased respiratory muscle function. However, another study examined the effects of ODMs on the function of respiratory muscles and found opposing results. This study examined the vital capacity, forced vital capacity, forced expiratory volume in one second, peak expiratory flow rate, and maximal voluntary ventilation of participants twice a week over a 12-week intense training period. These values all rely on functioning respiratory muscles to carry out their action. Values were obtained for both ODM and control groups, before and after the training period. Results of the study found that the use of ODMs over a 12-week period significantly increased the function of respiratory muscles. Furthermore, increased contraction of muscles and higher maximal voluntary ventilation in ODM participants further suggest improved respiration muscle function (Segizbaeva & Aleksandrova, 2018). There is a parallel relationship between contraction of respiratory muscles and strength of respiratory muscles (Akınoğlu et al., 2019). In alignment with the data from this study, it is suggested that ODMs do increase the outcome and performance of respiratory muscle function. In review of a final study, the effects of ODM use and inspiratory muscle training on running performances were examined in three different groups: only ODM use, only inspiratory muscle training, and a control (no mask or respiratory muscle training). These groups underwent a 6-week training period that included HIIT training and 5-kilometer run; data was collected both before and after the training periods. Results of the data showed that participants of all of the groups showed improvement in their running performance, however, the group that only received inspiratory muscle training had the largest improvement. Furthermore, diaphragm thickness was the most improved in the inspiratory muscle training group (Faghy et al). Increase in diaphragm thickness is associated with increased muscle strength of the diaphragm (Goligher et al., 2015). This implies that use of ODM on muscle strength was not as significant on performance in comparison to just simple inspiratory muscle training that resulted in the most improvement.

Overall, with consideration of the results from all three studies, it is difficult to make a definitive and conclusive statement regarding the effect of ODMs on respiratory muscle strength and function. Based on the data presented, however, it suggests that ODMs create very little improvement on respiratory muscle strength in comparison to inspiratory muscle training alone.

Conclusion

Oxygen deprivation masks are being advertised towards athletes as a piece of fitness equipment that can simulate the effects of high altitude, as well as a respiratory muscle training device. Studies that investigated the claims as to whether ODMs increased VO2max and improved endurance were looked into. Experimental data did not find that the use of these masks increased VO2max, nor was there any supporting data to prove that it improved endurance. The function of ODMs as a training tool to increase respiratory muscle strength was also examined.

There were contradicting results between the three different studies examined. One study found that ODMs did not show any improvement in respiratory muscle strength as participants in the ODM group perceived breathing efforts as higher, which can be seen as an indicator for weak muscular strength. In the second study, researchers found that participants in the ODM group had increased contraction of respiratory muscles and higher maximal voluntary ventilation than the control group which indicates stronger respiratory muscles. The final study found that the use of ODMs did not lead to any statistical significance in a 5-kilometer run, nor did it significantly increase diaphragm thickness which is associated with diaphragm strength. To conclude this paper, the claims made by oxygen deprivation masks with regard to increasing VO2max and improving endurance are incorrect. Claims that oxygen deprivation masks increase respiratory muscular strength are inconclusive, however, there is more data that indicates ODMs do not increase strength. It should be noted that the type of physical activity used for training, flow rate of oxygen, and period of training time all varied and should be considered when analyzing the findings.

Future studies on oxygen deprivation masks should examine effects of hypoxia from ODMs, hypobaric chambers, and high altitude (Warren et al., 2017) to be able to get a closer and more accurate cross-analysis of the effects on VO2max, endurance, and respiratory muscle strength. Other considerations for future studies include obtaining data throughout different time periods of the training period to gain a better understanding of when the effects of hypoxia from either high altitude or ODMs take place.

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