Mouthguard use during aerobic running in men and women.

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March 30, 2015.

ABSTRACT

Background. The author conducted a study to assess the effects of a custom-fitted MaxVO2® Performance mouthguard on voluntary oxygen consumption (VO2), voluntary oxygen consumption per kilogram of body weight (VO2/kg) and other pulmonary parameters.

Methods. 6 physically fit subjects aged 29 through 53 years performed an Astrand protocol treadmill run for two 8.5-13 minute runs (5.5 to 7.5 miles per hour, dependent on gender/experience.) Baseline run was performed without the use of the mouthguard. The subject followed the initial test by mouthguard trained running for 30-60 days prior to retesting for the second run. All assessments were performed in the University of Louisville Human Performance Laboratory in Crawford Gymnasium on the Belknap Campus. I assessed gas exchange parameters by using a metabolic measurement system.

Results. The results showed improvements in VO2 and VO2/kg in the mouthguard follow-up test in 3 of 5 while 6th participant failed to complete the follow-up test. A 5th runner’s values were ruled not valid due to a prevailing viral gastronenteritis that had been inflecting the subject prior to the follow-up run. One runner has not completed follow-up in the Table 2 male group. The Table 2 group does include that invalid result of the sickened participant.

Conclusions. The study findings show that use of a custom fitted MaxVO2® Performance mouthguard resulted in improved cardiovascular/aerobic performance.
and max VO2 levels. The author will be pursuing further studies at a later point to explain the mechanisms involved in the improved endurance performance exhibited.

**Commercial and Athletic Implications.** Athletes both recreational, competitive and scholastic have an opportunity to pursue and utilize a device that not only enhances performance and protects but aids in recovery and efficiency. There is increasing research showing evidence and support of mouthguard use during exercise and athletic activity.

**Introduction.**

Athletes are often required to use mouthguards during training and competition for the purpose of providing protection against facial and dental injuries. The prevalence of these types of injuries is high, not only in contact sports, but also in non-contact activities and exercises. Mouthguards function by absorbing impact stresses which results in a reduction of force transmitted to the teeth, bone structure, cranium, and surrounding soft tissue. Recently, efforts have been made to address these concerns through redesigning mouthguards using neuromuscular dentistry techniques that promote specific jaw repositioning and other technology. Research in the ‘70’s and ‘80’s indicated mouthguards may enhance performance during endurance exercise. Francis and Brasher conducted a study to assess mouthguard use on a cycle ergometer. (1) They found that those wearing a mouthguard exhibited positive outcomes in expiratory volume and major lowered levels of ventilation. Garner and McDivitt in 2 retrospective studies showed 1) that mouthguards lowered blood lactate levels with mouthguard versus without during a 30-min run and 2) mouthguards actually produced positive changes in the airway area in width and diameter resulting in lower lactate levels hence producing less fatigue. (2-3) At least two studies have found both custom-fitted and stock mouthguards actually improve maximal aerobic capacity or improved economy at higher workloads by Bourdin and Von Arx. (10-11)

Garner and McDivitt also assessed the effects of custom-fitted mouthpieces on gas exchange parameters, including volume of oxygen consumption over time [corrected] (VO(2)), volume of oxygen consumption over time per kilogram of body weight [corrected] (VO(2) /kg) and volume of carbon dioxide production over time [corrected] (VO(2)). They found custom-fitted mouthguards resulted in improved specific gas exchange parameters again. (4)

Gebauer, et. al studied the wearing of 2 different custom-made mouthguards during male field hockey and water polo participants did not impair V(E) nor VO₂ during varying levels of exercise intensity in team sports. (5) How about effects on Tae Kwon Do athletes? Kececi and company determined the effect of mouthguard use during exercise, oxygen consumption (VO(2)) while measuring with a portable gas analysis system while an exercise tolerance test with a shuttle run test protocol was performed. The results showed that wearing mouthguards had no negative effect on maximal oxygen uptake (VO(2max)), minute ventilation (VE), tidal volume (VT) and respiratory exchange ratio (RER) while performing maximal exercise (P > 0.05). In conclusion, Tae kwon do athletes can use custom-made mouth guards without negative effects on their aerobic performance capacity. (6)
Piero and Simone, et al provided evidence supporting mouthguard use for improving performance in cycling. Their aim was to evaluate the influence of a custom-made mouthguard on maximal and submaximal physiological parameters related to performance in road cycling. Wearing the mouthguard resulted in significant increases in cycling performance. To the best of their knowledge, their study was the first to evaluate the effects of a dentistry-designed mouthguard on physical performance of road cyclists. Their results provided support for cyclists that correct jaw posture that may improve their exercise performance. (7)

Further, Queiroz AF, et, al evaluated the influence of different types of mouthgards on physical performance of female soccer players. They analyzed an agility test (shuttle run) and aerobic capacity and VO2 (Cooper test). Data showed that a custom fitted mouthguard presented better results in the VO2 and aerobic capacity tests. There were no reports of pain, discomfort, or nausea in wearing the mouthguard in this aerobic sport. Among the three types utilized, the customized mouthguard presented better results in the athletes' physical performance evaluation, even taking into account physical tests performed without the use of mouthguards. (8)

Rapisura and Coburn investigated the effects of mouthguard use on physiological variables in women using a self-adapted mouthguard made for women and a universal self-adapted mouthguard. They found VO2 increased for each mouthguard condition across power levels. Their specific study was designed to analyze if the mouthguards inhibited performance. In the end, the mouthguard did not negatively affect HR, RPE, VE, VO2, or RER at any given power level during exercise, including the guard made specifically for women. Therefore, in conclusion the authors state, “Athletes are encouraged to use mouthguards without fear of negative aerobic performance effects.” (9)

**Participants and Methods.**

We recruited 6 participants (3 men and 3 women) aged 29 through 53 years (38.5 years) for this study. Participants’ average height and body mass were 170.2 centimeters and 72.4 kilograms, respectively. The men and women were physically active and had participated in mini-marathon, half marathon and marathon-based events and a current schedule of endurance and aerobic training. All participants had no prior experience nor use of a mouthguard.

All participants provided oral and written consent before participating in the study and provided medical history forms to the University of Louisville Exercise Physiology lab; they were asked whether they understood all of the study’s running methods and procedures; and we informed them of their right to drop out of the study at any time. Each participant was asked to complete a MaxO2® Performance Mouthguard user survey after the second test with the use of the mouthguard.

**Dental impressions.** After the baseline testing, a dentist, maxillofacial physician, and other support staff customized the mouthguard to mold to each of the participant’s upper and lower teeth as well as the upper gum/maxilla area. The mouthguard composition consists of material provided and purchased by MaxO2® Mouthguards from DuPont™ for Elvax® 210W 62 durometer mold. The Elvax® composition is 28% vinyl acetate comonomer and contains a “W” amide additive. The Elvax® resins
as noted by DuPont™ can be used for molded, compounding, sealants and wax blends. Corrosion only occurs at high temperatures above 446° degrees F and has been approved by the FDA for use in contact with foods.

**Treadmill runs.** Participants performed an initial run without mouthguard ranging from 8-13.5 minute treadmill runs. The second run with use of mouthguard ranged from 8.5-10 minutes. First run is performed without the use of a mouthguard and the second post-treatment run is performed 30-60 days after mouthguard use. The Astrand Protocol is the gold standard used for VO2 max testing. The test requires subjects to run as long as possible on a treadmill whose slope increments at timed intervals. The Woodway treadmill, Desmo model was utilized for testing. The testing staff sets up the treadmill with a speed of (5.5-7.5 mph) based on level of experience and expertise. The timer is started and the athlete commences the test. The testing staff, after 2 minutes into the test, adjusts the treadmill incline up by 1%, and then every 2-minutes thereafter increases the incline by 1%. The test is stopped after the athlete is unable to continue and RPE (ratings of perceived exertion) has been maxed out. All participants maxed out at an average RPE of 17.8 and maximal heart rate of 182.2 beats per minute on the baseline treadmill testing without mouthguard. On the treated treadmill testing using mouthguard, RPE maxed out at 17.8 and a maximal heart rate of 180.8 beats per minute.

Parvo TrueOne 2400 Metabolic Measurement System (Parvo Medics, Sandy, Utah) was used to measure voluntary oxygen consumption (VO2) and voluntary oxygen consumption per kilogram of body mass (VO2/kg). VO2 is defined as the amount of oxygen in liters that the body uses per minute during aerobic exercise. VO2/kg is the amount of oxygen in milliliters that a person consumes per minute relative to body mass. In addition to VO2 & VO2/kg, the metabolic cart measured participants’ respiratory rate (RR) (number of breaths per minute), tidal volume (Vt) (amount of air inspired and expired per breath), Ve (total volume of inspired and expired air per minute) and HR.

The second trial with mouthguard use was performed 30-60 days after the first test. All parameters were the same as the first testing. Parvo TrueOne 2400 Metabolic Measurement System (Parvo Medics, Sandy, Utah) was used to measure voluntary oxygen consumption (VO2) and voluntary oxygen consumption per kilogram of body mass (VO2/kg). VO2 is defined as the amount of oxygen in liters that the body uses per minute during aerobic exercise. VO2/kg is the amount of oxygen in milliliters that a person consumes per minute relative to body mass. In addition to VO2 and VO2/kg, I also measured participants’ respiratory rate (RR) (number of breaths per minute), tidal volume (Vt) (amount of air inspired and expired per breath), Ve (total volume of inspired and expired air per minute) and HR by using the metabolic cart.

These parameters were measured every thirty (30) seconds and averaged run time of 8.5 to 12 minutes. On all test days, the metabolic cart was calibrated according to the manufacturer’s specifications for 16.02% oxygen, 3.98% carbon dioxide with a nitrogen balance. For the mouthguard run (table 1/table 2), we asked participants to bite down on the custom-fitted mouthpiece and breathe through their mouths while their noses were clamped with a metal clamp attached to the face mask. For the initial no-mouthguard condition (table 1/2), we asked participants to breathe through their open mouths while their noses were clamped.
Results.

Data from one male of the 3 male participants was incomplete while a female subject failed to complete test #2. Data for another male subject’s mouthguard data was included but was ruled invalid. His mouthguard test #2 was performed while recovering from a viral gastroenteritis that afflicted him after the Chicago marathon. The 2\textsuperscript{nd} mouthguard test thus compromised pulmonary function testing results for him skewing data to show no major improvements for the male population in contrast to significant changes seen in the females. That male’s data severely hampered the endpoint results for mouthguard use in men. As shown in Tables 1, VO\textsubscript{2} and VO\textsubscript{2}/kg were statistically significantly higher in the female participants with mouthguard use versus their initial no-mouthguard test. Maximum oxygen uptake (VO\textsubscript{2} max) is the standard measure of aerobic capacity and is directly related to the physical working capacity of an individual. VO\textsubscript{2} max of an individual is affected by uptake of oxygen in the lungs, extraction of oxygen from the arterial circulation by working muscles and by cardiac output.

Ve, RR or V\textsubscript{t} between Table 1 showed significantly different changes for no-mouthguard versus mouthguard use in women. In Table 2, due to the inclusion of the sick male subject only RR showed positive changes. It is my conclusion that if the sick male was in healthy, normal condition as his no-mouthguard results, the mouthguard use results for men would have been in alignment with the female mouthguard. Positive significant changes would have been noted for both men and women in the mouthguard use testing. Finally, I found differences in HR for the women while the men including the sickened runner show a different result (Tables 1 and 2).

<table>
<thead>
<tr>
<th>TABLE 1: Data for Female Participants</th>
<th>(3) without Mouthguard</th>
<th>(2) with Mouthguard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max VO\textsubscript{2}</td>
<td>2.56</td>
<td>2.74</td>
</tr>
<tr>
<td>VO\textsubscript{2}/kg# (mL/kg/Minute)</td>
<td>37.3</td>
<td>41.7</td>
</tr>
<tr>
<td>Ventilation (L/Minute) Ve</td>
<td>62.15</td>
<td>69.97</td>
</tr>
<tr>
<td>Respiratory Rate (RR) (Breaths/Minute)</td>
<td>47.7</td>
<td>47.5</td>
</tr>
<tr>
<td>Tidal Volume (L) Vt</td>
<td>1.62</td>
<td>1.84</td>
</tr>
<tr>
<td>Heart Rate (Beats/Minute)</td>
<td>178.3</td>
<td>173.5</td>
</tr>
</tbody>
</table>

VO\textsubscript{2}: Voluntary oxygen consumption. 
# VO\textsubscript{2}/kg: Voluntary oxygen consumption per kilogram of body weight. 
** mL: Milliliters.


<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data for Male Participants:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Max VO2</td>
</tr>
<tr>
<td>VO2/kg# (mL/kg/Minute)</td>
</tr>
<tr>
<td>Ventilation (L/Minute) Ve</td>
</tr>
<tr>
<td>Respiratory Rate (RR) (Breaths/Minute)</td>
</tr>
<tr>
<td>Tidal Volume (L) Vt</td>
</tr>
<tr>
<td>Heart Rate (Beats/Minute)</td>
</tr>
</tbody>
</table>

VO2: Voluntary oxygen consumption.
# VO2 /kg: Voluntary oxygen consumption per kilogram of body weight.
** mL: Milliliters.

* Data was included from a subject that would be considered invalid due to his recovery from a viral gastroenteritis that inflicted him after the Chicago marathon and into the 2nd mouthguard test. Also, 3rd male data not included as still complete.

Discussion.
Athletes and others have worn mouthpieces during sports as protective devices against dental injuries and concussions. The American Dental Association’s Council on Access, Prevention and Interprofessional Relations and Council on Scientific Affairs concluded that mouthguards provide a protective effect against hard-tissue or soft-tissue damage in the mouth. (12) However, increased use of mouthpieces for performance enhancement is expanding in exercise and sports. Athletes want to see favorable changes and better recovery, stamina and pace in aerobic events.

Researchers previously in the area of airway dynamics have reported differences between nasal and mouth breathing during various intensities of exercise. In fact, they have found better gas exchange with mouth breathing than with nasal breathing as discussed by Garner and McDivitt (4). Garner and McDivitt measured a significant increase in VO2 /kg when participants wore the mouthguard with mouth breathing and our results correlated with this data. However, Francis and Brasher, also noted that participants reported a feeling of restricted airflow with mouthguard use. (1) As with Garner and McDivitt’s results of not reporting feeling a restriction, our test subjects concurred there were no issues, restrictions and no discomfort. The key factors can be and will be the mouthguard used in each study, how it is molded, the composition, custom-fit versus stock or self-fitted mouthguards as well if the mouthguard affects mandibular condyle movement or if the mouthguard opens airway passages in the nasal and pharyngeal area of the upper jaw. Many studies in the past focused on participants wearing a custom-fitted mandibular mouthpiece that did not obstruct breathing (4) to ones that were not of custom fit and obstructed airflow. (1). For instance, Garner and McDivitt, wore a custom-fitted mandibular mouthguard that
functioned by creating an opening between the maxillary and mandibular teeth. This mouthguard accordingly shifts the mandible down and into a more forward position, which they report resulted in increased airway openings. (2-4)

In our study, the MaxO2® Performance mouthguard does not affect a change in the mandible nor does it move the lower jaw forward. The primary focus is on the upper maxilla/jaw area, as well as the maxillary, frontal and ethmoidal sinus cavities. With the mouthguard, these sinus cavities are opened resulting in enhanced air flow through these sinus cavities into the nasopharynx (Figure 1).

The mouthguard thus opens these upper airways while promoting increased air through the nasopharynx area down into the trachea. This in turn affects the nasal, maxillary and bronchial tree as the subject is able to breathe via the mouth as well via the sinus areas. The mouthguard rarely causes irritation in the anterior region of the maxilla upper jaw. The mouthguard limits risk of bony growth in the upper maxilla jaw due to lessened friction, better fit and enhanced composite materials. The guard in turn protects the teeth as well as causes no occlusion nor restriction to breathing.

On the other hand, current custom-fitted mouthguards that move the ‘jaw forward’ can result in many of the following symptoms and discomforts: drooling, soreness, pain, occlusion & gag reflex.

**Conclusion.**

**The results of this study show improved airway performance in participants who wore a custom designed mouthguard by MaxO2.** The improvements in gas exchange and Ve observed with mouthguard use may explain the physiological outcomes of improved lactate levels during endurance running, as reported previously by Garner and McDivitt (2-4).

In addition, the improvement in oxygen consumption and production during the running protocol demonstrated higher VO2 and VO2 /kg levels in mouthguard wearing participants in table 1 but not so much due to the flawed data on the sick subject for the male subjects in Table 2. Mouthguard use also may affect initial oxygen deficit (defined as the amount of oxygen needed for exercise and actual oxygen consumption resulting in less fatigue at the conclusion of activity. There is one theory as purported by Garner and McDivitt (4) of how the mouthguard may affect lactate levels is by decreasing the time for oxygen to reach the muscle being exercised. Thereby, this results in decreased fatigue during cardiovascular and aerobic running. The mouthguard delays lactate production, with increased airway openings, thereby improves oxygen kinetics such as lowered oxygen deficit and/or improves breathing working rates. (3) The current research study correlates with previous studies showing
Efficacious changes in aerobic performance with the use of a custom-fitted mouthguard during aerobic activity.

In conclusion, the MaxVO2® Performance Mouthguard raises VO2 max thus leads to increased aerobic fitness. Many experts believe that VO2 max is a key physiological determinant of an athlete’s running performance, and that it is an important objective of a training program to improve it. Hence, the MaxVO2® mouthguard use would be another strategic tool to aid in a runner’s performance, pace/speed, lower lactate production that can lead to fatigue and enhance aerobic power output. VO2 max is the beginning and the end of your aerobic capacity, but it has the potential to elevate an individual to being the best athlete they can be.

Conflicts of Interest/Disclosure
Mr. Bhatt has no financial disclosures nor conflict of interest.

Acknowledgements
The author would like to thank Max Behr, DMD., Peter Resnik, CFA, CPA & Jim Hazard, DMD. for making the molds/fitting of the mouthguard and MaxO2® Performance Mouthguards by Vox Max, LLC. (Louisville, Kentucky) for supplying the custom-fitted mouthguards to each participant with the express written rights of DuPont™ for the use of Elvax® 210W. The author would like to thank Alex Burch, Graduate Research Asst. for performing the treadmill testing and Mike Jett, MS., Director of Fitness Evaluation Program for the use of the Exercise Physiology Lab in Crawford Gymnasium at the University of Louisville.
REFERENCES


