Effects of a Neuromuscular-Dentistry Designed Mouthguard on Muscular Endurance and Anaerobic Power

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RUNNING HEAD: NEUROMUSCULAR MOUTHGUARD
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ABSTRACT

Mouthguards are primarily promoted for protection against orofacial and dental injuries. Recent advances in neuromuscular dentistry have led to the development of a mouthguard touted to also enhance performance through optimal jaw alignment. The purpose of this study was to examine the effects of a neuromuscular dentistry-based mouthguard on muscular endurance, anaerobic power, and anaerobic capacity in competitive athletes. Anaerobically-trained professional and Division I college athletes (\(N=22; \text{M}_{\text{weight}} = 86.2 \pm 3.1 \text{ kg}\)) participated in this double-blind, crossover study. Subjects were randomly assigned to order of use of either the experimental (EXP) or traditional custom-fit (CON) mouthguards. Subjects completed two separate sessions in which they completed three performance tests, which included vertical jump (VJ), bench press (BP), and a 30s WAnT + eight 10s intervals, while wearing the assigned mouthguard. Significantly better performance was found for EXP compared to CON for VJ (67.6 \(\pm\) 9.4 cm vs. 65.3 \(\pm\) 8.6 cm; \(P = .003\)), 30s WAnT peak power (11.6 \(\pm\) 1.7 W·kg\(^{-1}\) vs. 11.1 \(\pm\) 1.5 W·kg\(^{-1}\); \(P = .038\)), average peak power for WAnT + intervals (10.6 \(\pm\) 1.4 W·kg\(^{-1}\) vs. 10.1 \(\pm\) 1.2 W·kg\(^{-1}\); \(P = .025\)) and average mean power for WAnT + intervals (9.0 \(\pm\) 1.1 W·kg\(^{-1}\) vs. 8.7 \(\pm\) 1.0 W·kg\(^{-1}\); \(P = .034\)). There were no significant differences for either BP or 30s WAnT mean power (\(P > .48\)). A neuromuscular dentistry-based mouthguard appears to enhance peak power output, performance, and repeated maximal efforts. However, it does not appear to enhance sustainable power output or muscular endurance. It appears that athletes in power-based sports may benefit from wearing a neuromuscular dentistry-designed mouthguard.

KEY WORDS: Wingate Anaerobic Test, vertical jump, temporomandibular joint, occlusion
INTRODUCTION

Mouthguards are common pieces of equipment used by athletes in various sports for the purpose of providing protection against orofacial 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 (1,8,12,13). Their use has also been promoted in an effort to reduce concussion frequency and severity, though the evidence for this is fairly inconclusive (1). Mouthguards function by distributing impact stresses which results in a reduction of force transmitted to the face (1, 14). Despite the protective function of a mouthguard and, in some cases, their mandated use, many athletes are reluctant to use them citing discomfort, reduced ability to breathe, and decreased performance as common reasons (20). This latter concern seems to be a major consideration for high-level athletes that are typically looking to gain any competitive advantage possible. In an effort to change this resistive attitude toward mouthguard use, research on the performance outcomes associated with mouthguard use can be particularly useful.

There are three primary categories of mouthguard: stock, boil-and-bite, and custom fitted. While limited research exists on the performance impacts of each of these types, the studies that have been done have generally concluded that mouthguards do not produce negative effects on aerobic performance capacity or measures of ventilatory capacity (3,9,11,20). At least two studies (3,20) have found that both custom fitted and stock mouthguards actually improved maximal aerobic capacity or improved economy at higher workloads. While these are useful findings, the fact remains that studies have tended to ignore performance issues associated with anaerobic exercise performance. This is an important consideration in light of the bioenergetic requirements of most sports that promote mouthguard use. Furthermore, recent advancements in...
neuromuscular dentistry may hold particular relevance for improving the functionality and ergogenic potential of the next generation of mouthguards.

Neuromuscular dentistry focuses on the alignment of the temporomandibular joint (TMJ), masticatory muscles, bones, teeth, and the neural circuitry associated with the oral cavity (15). Transcutaneous electric neural stimulation (TENS) is often used in this area of dentistry to reduce hyperactivity of musculature, to act as a local anesthetic, as a chronic pain reliever, and to treat TMJ dysfunction (TMD) (5,15). A low-voltage, low frequency TENS is administered to patients to cause the facial muscles innervated by the trigeminal nerve to contract (4,5) and allows the muscles to relax into the mandibular resting position. This provides for the identification of more ideal occlusion positions of the jaw where muscle function is “optimized” due to establishment of true resting length (5).

A relatively new mouthguard, the Pure Power Mouthguard™ (PPM; Pure Power Athletics, Inc., Ontario, Canada), uses neuromuscular dentistry techniques in its custom-fitting design. In addition to traditional protective effects of mouthguards, PPM is purported to increase performance in sports by improving such things as strength, speed, endurance, agility, accuracy and balance. PPM developers claim that improved strength and balance will occur when muscles in the face are properly aligned and relaxed, which causes better muscle recruitment and vertebrae alignment. This claim coincides with the evidence that jaw position effects posture and stability in human subjects (4).
Strategies to improve human performance while maintaining safety are crucial in the ever increasingly competitive athletic environment. The application of neuromuscular dentistry principles in the design of athletic mouthguards is a novel technique which warrants scientific evaluation. The purpose of the current study was to compare the neuromuscular-dentistry designed PPM with a traditional custom-fitted mouthguard to examine the effects on competitive athletes’ muscular endurance, anaerobic power, and anaerobic capacity. It is hypothesized that use of the PPM will improve performance on vertical jump (VJ), bench press repetitions completed, and peak and mean power on a modified Wingate Anaerobic Test (WAnT) protocol.

METHODS

Experimental Approach

A double-blind, crossover design was used to compare the effects of the neuromuscular dentistry designed mouthguard (EXP) to a traditional custom-fitted mouthguard (CON) on anaerobic power and muscular endurance. EXP and CON were matched for material and appearance. A “no-mouthguard” condition was not used due to the fact that athletes in the sports represented in this study are often required or encouraged to wear mouthguards. Because of this, the primary consideration was to evaluate the effects of different mouthguards on key performance outcomes. All subjects underwent custom fittings for the CON and EXP. A familiarization session was paired with the fitting session. The subjects underwent two testing sessions 5-7 days apart where anaerobic power and muscular endurance were assessed using VJ, bench press with a load equal to bodyweight, and a 30s WAnT + eight 10s WAnT intervals. The order of mouthguard use was randomized between subjects. Participants refrained from training for at least 24 h prior to each testing session.
Subjects

Healthy, anaerobically-trained, male professional and collegiate athletes \( (N=22; \text{M}_{\text{weight}} = 86.2 \pm 3.1 \text{ kg}) \) ages 18-34 with 2+ years of weight training experience participated in this blind, crossover study. Each subject must have been training anaerobically 4+ days per week for at least the last 2 years. All athletes were familiar with wearing mouthguards. Sports that were represented included football \( (n=5) \), lacrosse \( (n=2) \), basketball \( (n=4) \), wrestling \( (n=8) \) and mixed martial arts \( (n=3) \). This study was limited to males in order to control for muscular power differences that exist between genders, even if controlling for training history. Risks and benefits were explained to the subjects and each of them gave written informed consent prior to participation in the study. All individuals were free from current injuries, illnesses, or metabolic conditions limiting their ability to train and complete physiological testing. A health screening was completed with each subject in accordance with American College of Sports Medicine (ACSM) exercise testing procedures. The study was approved by the Rutgers University IRB.

Procedures

Each subject completed a fitting session for the mouthguard coupled with a familiarization session to control for practice effects on the anaerobic test (2). This was followed by two separate testing sessions (T1 and T2). During T1 and T2, participants warmed-up and then completed three different performance tests: VJ, bench press with a load equal to bodyweight for maximal repetitions, and a modified Wingate Anaerobic Test (WAnT) which included the standard 30s WAnT coupled with eight 10s intervals. This latter protocol was used to simulate the interval-based nature of the work efforts that are required in sports that are highly reliant on
anaerobic energy systems. Subjects were required to refrain from training for 24 hours prior to each testing session. Additionally, each subject was tested at the same time of day for T1 and T2. Participants were instructed to continue with their normal exercise training during the study.

Following the familiarization session, which included the health screening, the fitting process to take dental molds to make the mouthguards, and a familiarization WAnT, the subjects were randomly assigned to order of use of the EXP or CON mouthguards. The mouthguards were matched for appearance and material, which was an EVA polymer. The initial fitting for the mouthguards was performed by certified PPM dentists and first involved taking a standard dental impression for the CON. The fitting for the EXP then involved the attachment of electrical stimulation (TENS) surface EMG electrodes (Myotronics, Inc., Kent, WA). A very low-voltage pulse was delivered using this device in order to facilitate muscular relaxation of the lower jaw. Muscular activation was continuously monitored to ensure a relaxed lower jaw position. Following this, new fast-setting impressions were taken to capture this “optimal” bite alignment. The total fitting process took about 80-90 minutes. Following the dental impressions, subjects underwent familiarization with the tests to be used during the actual testing. This included practice attempts on the VJ and familiarization with the bench press weight as well as completion of the 30s WAnT plus one interval using the load to be used during testing. Once the mouthguards were produced, subjects returned to the lab to complete T1 and T2, with the two trials separated by 5-7 days.

For each testing day, subjects reported to the Rutgers University Human Performance Laboratory. Subjects were asked to arrive for testing normally hydrated, have eaten a high
carbohydrate meal 2 hours prior, and to refrain from ingesting substances that could affect normal physiological functioning (i.e., tea, coffee, alcohol, nicotine). At each trial, the subjects completed a 10 min systemic warm-up before being tested on the VJ followed by the bench press with a load equal to bodyweight for maximal repetitions. VJ was assessed using the “Just Jump Mat” (Probotsics, Huntsville, AL). Subjects completed 3 trials with 45-60 sec rest between trials. The highest of the 3 jumps was recorded. After completing the VJ, the individuals rested for 3 min and then completed a standard upper body muscular endurance test (bench press with bodyweight for reps). After 2 warm-up sets of 8-10 repetitions with 50% of the weight to be used, subjects were given a 4-5 min rest before attempting the test. The score consisted of the total number of repetitions completed in good form before momentary muscular failure. The athletes rested for 5 min rest before beginning the WAnT protocol.

Subjects performed the 30s WAnT plus eight 10s intervals on a Monark 894E Anaerobic Test Ergometer (Monark Exercise AB, Sweden). The load was set according to each subject’s weight (19) and was equivalent to 0.10 kp/kg body weight. Following the 30s WAnT, subjects rested for 5 min and then completed eight 10s intervals using the same load with a 2 minute rest between each interval.

**Performance Measures**

Peak power during the WAnT was defined as the highest mechanical power output elicited during each 30s test. Mean power was calculated based on the average mechanical power produced during the test. Average peak power and average mean power were calculated across
the WAnT plus intervals. Maximal VJ height was used to establish power and the number of repetitions completed for the bench press constituted the scores for muscular endurance.

**Statistical Analyses**

A repeated measures MANOVA was used to assess the effects of the EXP and CON mouthguards on VJ, bench press repetitions, peak power for the 30s WAnT, mean power for the 30s WAnT, average peak power for the WAnT + intervals, and average mean power for the 30s WAnT + intervals. Significant multivariate effects were followed by univariate follow-up tests. For each univariate analysis, the Huynh-Feldt epsilon was calculated to test the assumption of sphericity. If this statistic was greater than .75, the sphericity assumption was considered to have been met and the unadjusted statistic was used. If epsilon was less than .75, sphericity was considered to have been violated and the Huynh-Feldt adjusted statistic was used to test significance.

Because of the impact that even small effects may have on overall performance of athletes at this level and in accord with recent recommendations for statistical follow-up (16), effect sizes (ES) were calculated to compare magnitude of changes in the EXP and CON conditions using Hedges’ $g$ formula for ES computation. This ES computation was used for all variables. Group data are expressed as mean ± SD and statistical significance was set at the $P<.05$ level.
RESULTS

There was a significant multivariate effect for Condition \((P = .008)\). Follow-ups indicated significantly better performance for EXP compared to CON for VJ \((67.6 \pm 9.4 \text{ cm vs. } 65.3 \pm 8.6 \text{ cm}; P = .003; \text{ES} = 0.27)\), peak power for the 30s WAnT \((11.6 \pm 1.7 \text{ W} \cdot \text{kg}^{-1} \text{ vs. } 11.1 \pm 1.5 \text{ W} \cdot \text{kg}^{-1}; P = .038; \text{ES} = 0.33)\), average peak power for WAnT + intervals \((10.6 \pm 1.4 \text{ W} \cdot \text{kg}^{-1} \text{ vs. } 10.1 \pm 1.2 \text{ W} \cdot \text{kg}^{-1}; P = .025; \text{ES} = 0.42)\) and average mean power for WAnT + intervals \((9.0 \pm 1.1 \text{ W} \cdot \text{kg}^{-1} \text{ vs. } 8.7 \pm 1.0 \text{ W} \cdot \text{kg}^{-1}; P = .034; \text{ES} = 0.3)\) (See Figures 1-4). There were no significant differences between EXP and CON for either bench press repetitions \((16.1 \pm 5.4 \text{ reps vs. } 15.8 \pm 5.5 \text{ reps}; P = .48; \text{ES} = 0.05)\) or mean power for the 30s WAnT \((8.5 \pm 1.2 \text{ W} \cdot \text{kg}^{-1} \text{ vs. } 8.4 \pm 1.0 \text{ W} \cdot \text{kg}^{-1}; P = .54; \text{ES} = 0.1)\).

DISCUSSION

Results of the current study indicate that, in comparison to a traditional custom-fitted mouthguard, a neuromuscular dentistry-designed mouthguard resulted in greater VJ, peak power on a 30s WAnT, and greater average peak power and average mean power across ten WAnT intervals. There was no apparent effect on measures of muscular endurance or anaerobic endurance, expressed as repetitions completed on a bench press with body weight test and a 30s WAnT, respectively. Overall, these findings may hold practical relevance for athletes involved in sports that require power-based movements and explosive ability (e.g., football, baseball, MMA, field-events, etc.). It is possible that these improved effects on power and anaerobic capacity may translate beyond immediate use in the competitive arena and also hold promise for improving
overall capacity during training. While mouthguards have traditionally been reserved for use during competition in order to prevent facial and dental trauma, a mouthguard that improves performance in outcome measures such as those assessed in the current study has the potential to be used during training in order to facilitate use of an overall greater workload. This may be particularly useful during interval-based training given the improvements in average peak power and average mean power seen over the WAnT intervals.

The use of a mouthguard to reposition the jaw in an attempt to improve performance is not a new concept. Early work in this area focused on a mandibular orthopedic repositioning appliance (MORA). While some positive effects on isometric strength about the head and neck were reported with the MORA (10), the findings were mostly mixed and the studies were plagued with methodological problems and lack of applicability to sport-specific tasks (10). Since this time, however, neuromuscular dentistry techniques have become more advanced and are reflected in the fairly intensive fitting process that is required for the PPM. Based on the current study, it appears that neuromuscular dentistry has the potential to impact athletic performance in areas related to maximal power and repeatable power outputs. This may hold significance for the athlete that is required to wear a mouthguard while still looking for a competitive advantage and improvement in performance.

While this study represents one of the first to apply neuromuscular dentistry techniques to sport performance, previous research in this area of dentistry has also found positive effects for other variables that may have application to sport. Bracco et al. (4) found that optimal jaw alignment achieved using neuromuscular dentistry techniques resulted in improved posture and
stability. Similarly, Sforza et al. (18) found reduced postural sway and more symmetric muscular activation. Given these findings as well as claims associated with the PPM, future studies should consider evaluating the influence of jaw alignment using neuromuscular dentistry-designed mouthguards on range of motion, agility, speed, accuracy, and balance in athletes. Based on the theories driving the application of neuromuscular dentistry, it is conceivable that a more “optimal” position of the mandibular joint is not only plausible but that it has the potential to improve neural conduction and proprioception (4). Given the implications for neuromuscular facilitation and peak power production, the use of this next generation of neuromuscular dentistry techniques appears to hold at least some promise for the strength and power athlete.

Based on the design of the current study, it is not possible to directly conclude that the PPM improved performance in comparison to a “no-mouthguard” condition. However, this was not the purpose of this study. The working assumption driving this design was that athletes are often required or encouraged to wear mouthguards, particularly for the sports represented in this study. In this case, the important consideration was to evaluate the effects of different mouthguards on key performance outcomes. In previous studies that have compared custom-fitted mouthguards to a no-mouthguard condition, it has been concluded that custom-fitted mouthguards do not project any negative effects on aerobic performance or ventilatory capacity, nor do they interfere with maximal exercise performance (3,11,20). The results have been mixed for non-custom-fitted mouthguards, with Francis & Basher (9) noting improvements in economy at higher intensities while Delaney and Montgomery (6) found no differences at submaximal intensities, but a decrease in $V_E$ and $VO_2$ at maximal intensities. Based on these previous results, as well as a general agreement among researchers that the custom-fitted mouthguard provides
more protection and is more accepted by athletes (7,17), we opted to compare the PPM to a custom-fitted mouthguard in order to provide the most stringent comparison.

These previous studies may provide insight into why significant effects were not found with the PPM for bench press and for average power during the 30s WAnT. These tests may have led to open-mouth breathing which would negate the positioning effects of the PPM. The inability to bite down into the PPM during prolonged anaerobic activities renders it similar to standard custom-fitted mouthguards, which do not affect performance outcomes. It appears that there is an optimal bite conundrum for muscular endurance activities which limits the ergogenic effects of the PPM. Specific training and practice on PPM use may be needed to ensure athletes benefit from the occlusional positioning.

PRACTICAL APPLICATION

The present study indicated that the novel mouthguard, PPM, significantly improved performance in a vertical jump, peak power of a 30s WAnT, average peak power and average mean power across nine WAnT intervals. Each of these tests requires quick bursts of anaerobic energy at very high intensity levels, much like activities encountered in many sport activities. These findings can be applied to athletes and non-athletes engaged in activities that require power-based movements and explosive strength (e.g., MMA, football, baseball, etc.). Additionally, these finding may potentially translate to long-term training effects as the PPM may improve peak power gains and workload during training, especially interval-based training. Using neuromuscular dentistry techniques to design a mouthguard that ensures optimal jaw alignment proved effective in improving anaerobic peak performance which is a common goal.
among athletes engaged in anaerobically-based sports. Use of the PPM is another strategy that may help improve performance in individuals who engage in certain sports.

REFERENCES


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