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EFFECTS OF JAW CLENCHING WHILE WEARING A CUSTOMIZED BITE-ALIGNING MOUTHPIECE ON STRENGTH IN HEALTHY YOUNG MEN

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ABSTRACT

Recent studies have investigated the ergogenic effects of different types of mouthguards. There is evidence of the benefits of clenching customized mouthpieces on force and power development. The phenomenon called concurrent activation potentiation (CAP) promoted in jaw clenching seems to enhance the muscular strength and power in maximal isometric contractions and powerful actions in sport. Moreover, a bite-aligning mouthpiece may promote a more aligned and powerful clench. The objective of the present study was to investigate the effects of jaw clenching while wearing a customized bite-aligning mouthpiece (MP) on jump ability and isometric maximal strength tests in contrast to two other conditions: non-jaw clenching (NON-JAW) and jaw clenching without the mouthpiece (JAW). A within-subjects design was used to assess the jump performance and the maximal isometric force in 28 physically-active male subjects. Statistical analysis revealed significantly higher performance in JAW and NON-JAW conditions for handgrip force (HG-peakforce) as well as all variables of the back-row exercise (BRW) and countermovement vertical jump (CMVJ) ($p<0.05$). Significant differences between NON-JAW and JAW were found for HG-peakforce ($p<0.05$). These findings suggest that it is advisable to use a customized bite-aligning mouthpiece to improve strength and power performance.

KEY WORDS

Isometric force

Jump power

Mouthguard

Ergogenic effects

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INTRODUCTION

Most athletes and players in contact sports use different types of mouthguards to prevent dental injuries and to protect the maxillofacial structure from possible violent contacts during matches or competitions. With these kinds of mouthguards, athletes and players feel protected, but they are not always comfortable. In fact, different institutions recommend the use of mouthguards in sports, such as boxing, football, basketball, judo, karate, field hockey, or lacrosse (34). Moreover, they are also widely used when the comfortability is summing with the protection in sports like motorcycling, horse riding, weightlifting, or auto racing (32). There are three main types of mouthguards: standard, self-adapted, and customized. The standard type is initially ready to be used, and no fitting process is required. The standard type is widely used because of its low cost, but it is also considered the most uncomfortable among the different types. The self-adapted type consists of a "thermoplastic" liner that can be manipulated with heat to promote a fit to the maxillary teeth during an athome fitting process. This type is also inexpensive and widely available. Finally, the customized type requires dental impressions or scanning processes of the dental structure of an individual's teeth. This type is the most expensive and often requires the expertise of a dentist (12,25,37).

In recent years, several researchers have studied the ergogenic effects of wearing a jaw-repositioning mouthpiece on different functional and physiological strength and muscular power performance factors. Although the effects of jaw clenching on the isometric, dynamic, and isokinetic strength of limb muscles and posture have been reported, these findings vary between studies and parameters studied (35,41). The reason why wearing a rigid mouthpiece could produce positive effects is that jaw repositioning in the forward and/or vertical direction can be beneficial. Lateral movements of 1–3 mm promote centric occlusion and better conditions for powerful jaw clenching (9). Moreover, improvements in neuromuscular connections with jaw repositioning have been observed through improvements in muscular activation and certain proprioceptive function (6). A proper occlusion facilitates both static and dynamic muscle balance and activation conditions to a greater or lesser extent from the jaw muscles to the neck, shoulders, and lower limb musculature (23,36). Thus, ergogenic effects of jaw clenching could be caused by different factors, including the use of mandibular orthopedic repositioning appliances (MORA), the concurrent use of the Jendrassik maneuver (JM), remote voluntary contractions (RVC), or cortical motor overflow, which may contribute to the phenomenon called concurrent activation potentiation (CAP). The neuromuscular effects of jaw repositioning and contraction of the mandible muscles may translate to improved neuromuscular responses in active exercise movers. As a consequence, the activation of different limb muscles contributes to strengthen movements like rowing, running, or jumping (36,38,41). When one part of the motor cortex is active, connections to other areas of the motor cortex are also affected (15). Possible mechanisms of CAP include increases in alpha motor neuron activity, gamma loops, and muscle spindles together with descending cortical input or stimulusinvoked afferent input. These can result in inhibition of the presynaptic inhibition and postsynaptic changes in membrane potential. Thus, CAP has been suggested as a performance enhancer with regard to several acute power and strength tasks in sports (15,16,20,21). For instance, analyzing the muscle activation via electromyography in a group of healthy and active men and women, the muscles involved in a RVC are more active; this increase in activity results in a greater activity in the prime movers in isokinetic knee extension/flexion (19).

Recent research examined the effect of CAP on isometric strength. Hiroshi studied the effects of different concurrent jaw clenching maneuvers before and/or during a handgrip maximal voluntary contraction (29). The author found a significant 12% increase in maximal force with the 2 conditions when jaw clenching was concurrently performed. With a group of healthy, trained, weightlifting men, Ebben et al. compared the isometric strength of knee extensors under RVC and NO-RVC conditions using jaw clenching, bilateral gripping, jaw clenching combined with contralateral gripping, the Valsalva maneuver, and the combination of jaw clenching, bilateral gripping, and the Valsalva maneuver (18). The last condition resulted in 14.6% and 14.8% improvement in average and peak torques, respectively, with respect to the no-RVC condition. The effect of wearing custom-made mouthguards on the isometric strength of the legs and back was investigated in highstandard taekwondo athletes (10). The authors found no significant improvements using the mouthguards with respect to free jaw clenching. In contrast, they found significant relationships in peak and average power during the Wingate Anaerobic Test. Ebben et al. found significantly higher peak torque and power during knee extension in the RVC condition, which included jaw clenching, hand gripping, and the Valsalva maneuver (19). They also assessed the EMG muscle activation and found significantly greater activation of prime movers in the RVC condition. The same exercise was used to assess the time-course of the ergogenic benefit of CAP during voluntary isometric contractions (24). The responders of CAP demonstrated 10.1% greater mean torque/body weight than CAP nonresponders in the first 500 ms of contraction. In assessing the ergogenic effects of MORA in isometric strength, some research also considered the vertical dimension of occlusion (VDO), as suggested by Forgione, Metha, and Westcott (21), and a promotion of a wax bite position (26) as factors that contribute to increases in strength and power. Chakfa et al. described the effects of different thick mandibular acrylic plates on deltoid and cervical isometric strength (11). The authors found a significant increase in isometric strength when elevating the vertical VDO, but it diminished when VDO was increased further.

The connections of RVC with powerful and rapid movements seem to be clear. During speedy movements and rapid changes of force generation, a sensory neuron from the muscle spindle communicates with a motor neuron in the spine, which sends the signal to the brainstem. When this information flows, the stretch reflex is activated; this is what occurs, for instance, during a countermovement vertical jump (CMVJ) (30). Muscle spindles are activated during the countermovement as the large muscle groups in the lower body are quickly lengthened during the eccentric phase. The muscle spindles communicate to the CNS, the CNS communicates contraction of the lower body muscles and promotes a forceful, explosive vertical jump (33).

Several authors studied the ergogenic effects of the RVC using mouthpieces on vertical jump performance. Ebben et al. found a 19.5% significantly better rate of force development (RFD) and a 20.15% significantly less time to force peak (TTFP) while wearing a bite-aligning mouthpiece in comparison to the open-mouth condition (18). They did not find significant differences in peak force (PF) but suggested a beneficial effect of jaw clenching in the CMVJ. With a group of recreationally athletic men, Ebben et al. (19) demonstrated a significant increase in ground reaction forces (GRF) and in the rate of force development (RDF) at 100 N$s21 while performing a back squat exercise with the RVC condition compared with the NO-RVC condition. They also found significant increases in GRF, RFD, and jump height in squat jump performance with the RVC condition. Allen et al. compared the CMVJ and the bench press 1RM performance of 2 conditions: wearing a commercial mouthpiece (MP) and without mouthpiece (noMP) in a group of recreationally trained college men (2). They did not find significant increases in countermovement jump height, RFD and PF, neither in 1RM bench press while wearing a commercial bite-aligning MP. However, all results were higher wearing the MP. When analyzing the differences in strength and power performance between different types of mouthguards in literature, we found evidence of the benefits of using customized pieces. Arent et al. (5) reported significant differences in CMVJ height and peak Wingate anaerobic power when comparing the effects of a non–dentistry-designed mouthguard and a traditional custom-fitted mouthguard. Dunn-Lewis et al. (14) compared the effects of 3 conditions (i.e., customized, self-fitted, and no mouthpiece) on different power performance tests. They reported a significantly higher power production in the plyo press power quotient (3PQ) and a higher rate of power development in the CMVJ with a customized mouthpiece in men. In contrast, Bourdin et al. (9) did not find significant differences in a group of trained men in force and power parameters in a cycle ergometer when comparing customized and self-adapted mouthguards. Also, Duarte-Pereira found no significant increases in the CMVJ or the 15 seconds rebound jump mean power when comparing the performance of 3 conditions (i.e., no mouthguard, self-adapted, and customized) (13). Recently, Golem and Arent studied the effect of over-the-counter jaw-repositioning mouth guards on several athletic performance abilities, including strength and power in college-aged male athletes. They found no significant differences on vertical jump height between conditions in absolute or relative terms, neither for absolute and relative power output. They suggested that individuality and precise jaw positioning may not be acquired without the use of advanced dental techniques. The latest evidence of the ergogenic effects of a dentistry-design bite-aligning mouthpiece suggested that more studies were needed to compare its acute effects in power and strength actions (27). However, the cost of the processes and pieces and the common uncomfortable designs drive athletes away from its use. With cheaper and more comfortable dentistry-design pieces, athletes could promote the CAP in those actions and improve their performances. This design is built without discrepancies of the mouth structure thanks to a precise scanning method and previous maneuvers for jaw repositioning. The present study is trying to address the convenience of using a customized bitealigning mouthpiece to improve the ability to develop acute higher performance on different isometric strength exercises, on explosive strength in the upper body pulling and on vertical jump. So, the use of this type of mouthpieces by athletes could promote benefits on widely used exercises in conditioning training and also contribute to better longer term adaptations. Also in reporting more evidences of the acute effects of wearing and biting customized bite-aligning mouthpieces for strength and power actions.

Therefore, the main aim of this study was to investigate the acute effects of a customized bite-aligning mouthpiece on measures of handgrip isometric strength, back-row isometric strength, and RFD of 0–150, 0–300, and 0–450 milliseconds as well as the CMVJ performance parameters in comparison with 2 conditions (i.e., clenching the jaw without a mouthpiece condition, and with an open mouth condition) in a physically active male population. It is hypothesized that the use of a customized bit-aligning mouthpiece will improve isometric strength and vertical jump with respect to the 2 other conditions tested.

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METHODS

Experimental Approach to the Problem

A randomized, repeated measures within study design were used to compare the acute effects of wearing a customized bite-aligning mouthpiece with respect to 2 other "nomouthpiece" conditions (i.e., clenching the jaw and not clenching the jaw) on jump power and muscular strength. With the jaw-clenching condition, subjects were required to clench the jaw to promote the CAP, as the subjects did wearing the mouthpieces. All mouthpieces were fitted and provided by Cleverbite Laboratory after a mouth screening and a scanning of the jaw structure by an expert dentist. A test familiarization session was paired with the mouthpiece fitting session. Mouthpieces were designed to promote a stabilization of the mandible arch in a long centric position. Different sets of head movements were performed to neutralize any postural neuromuscular disorder that might influence the mandible position with respect to cranio and the cervical muscle activation. The mouthpieces were built with minimal dentoalveolar discrepancy regarding the morphology of the mouth structure of each subject. A scanning system provided these precise models. Conditions were randomly distributed to avoid the influence of fatigue and test-learning effects. Subjects were not familiarized with mouthguards. As dependent variables, jump height (CMVJ-height) and mean power (CMVJ-meanpower) from a countermovement vertical jump were recorded. The peak force of an analogical handgrip (HG-peakforce), the peak force of an isometric BRW-peakforce, and the rate of force development at 0–150, 0–300, and 0–450 milliseconds intervals (BRW-150, BRW-300, and BRW-450, respectively) of this exercise were also assessed in this order. The comparison between the 3 conditions performed in this study (no jaw clenching, jaw clenching, and jawclenching wearing a bite-aligning mouthpiece; NON-JAW, JAW and MP, respectively) is trying to investigate the effects of CAP promotion, through a RVC, on strength and power performance with and without wearing a customized dentistry-design bite-aligning mouthpiece.

Subjects

Twenty-eight healthy and physically active male subjects (age: 23.60 6 3.48 years, age range: 20–26 years, height: 1.79 6 7.4 m, weight: 77.01 6 8.11 kg, BMI: 23.92 6 1.53) were voluntarily recruited for this study. All participants were involved in at least 3 training sessions per week and were injury free for the last 3 months. The sports practiced by the subjects included soccer, basketball, and volleyball in regional competitions. A subject voluntarily withdrew from participation because of academic incompatibilities. Other subject suffered a mild ankle injury and was excluded from the study. The third nonresponder suffered low back pain during the first test and was excluded from the measurements. Subjects were not familiarized in wearing mouthguards in their daily practice. A health screening was completed with each subject in accordance with the American College of

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Sports Medicine exercise testing procedures. All subjects were also evaluated by an expert dentist before the mouthpiece fitting process to guarantee an adequate dental health to participate in the study. The study was approved by Ramon Llull University Institutional Review Board and the subjects were informed of the benefits and risks of the investigation before signing an institutionally approved informed consent document to participate in the study.

Procedures

Data collection was completed from 11:00 AM to 1:00 PM in groups of 3 subjects, avoiding interferences and noisy conditions in the laboratory. Sessions were developed at the second and third week of May just before the end of regular seasons in team sports. The subjects stopped train at least 48 hours before the testing session. Each subject participated in 3 sessions. The first session was used to provide all the information about the risks and benefits of the study, to obtain the informed consent, to assess anthropometric measurements, and to scan the mouth structure. In the second session, subjects were familiarized with the test protocols during a learning session, including isometric force tests and the CMVJ test. This included 3 trials of each test with or without jaw clenching and with or without the mouthpiece. Researchers kept the mouthpieces until the next session to ensure that all subjects were in the same conditions of use. In the third session, after a 15-minute warm-up including 10-minute jogging, 5 minutes of callisthenic exercises, and 5 minutes of warm-up tests trials (including 2 repetitions of each test), we performed the measurements where the conditions were randomly distributed. The subjects performed 2 trials of each test and condition: no jaw clenching (NON-JAW), jaw clenching (JAW), and jaw clenching with mouthpiece (MP) with a minimum rest time of 3 minutes. The best trial was considered for the analyses. The subjects were asked to wear the mouthpiece where the condition required it. In JAW and MP testing conditions, subjects were encouraged to clench their jaws as powerful as possible. The order of the tests was the following: (a) jump, (b) handgrip and (c) BRW in the same condition. This order was kept in the 2 other conditions. Second and third sessions were separated by 48 hours.

Bite-aligning mouthpiece

For this study, the subjects wore the mouthpiece CleverBite (Cleverbite SL, Terrassa, Spain), which is a Class III mouthguard (3). The mouthpieces were manufactured by taking a digital recording obtained by scanning both the maxillary and mandibular dental arches. This record was complemented by a digital recording of the interocclusal relation associated with the resting neutral position of the mandible.

Prior the scanning, subjects performed different maneuvers to neutralize any postural neuromuscular disorders that might influence the mandible position with respect to cranio and the cervical muscle activation. Subjects wore a 2-cm long and 0.5-cm thick cylindrical piece of cotton in both sides of the mouth (i.e., at the level from first molar to the distal slope of the canine cusped) and were asked to walk barefoot for 2 minutes. After walking, subjects performed neck rotations, flexo-extensions, and lateral flexions for 1 minute each. Theses maneuvers helped stabilize the mandible arch in a long centric position. The device fabrication was performed on a digital model made of Pearlstone VisiJet Plastic Material (Urethane Acrylate and Phenylbis [2, 4, 6-trimethylbenzoyl] phosphine oxide) obtained by the technique of scanning the dentoalveolar maxillary and mandibular environment using the 3Shape Trios System (3Shape Inc., Copenhagen, Denmark). Digital models exhibited minimal dentoalveolar discrepancy regarding the morphology of the scanned subject. On the maxillary model in each subject, a sheet of 2-mm-thick Ethylen-Vinylacetat-copolyme`re (EVA) was used (VA. Ca. 28%, Anorg Pigments [PA/PE], antibacterial additive; Kopp GmbH Erich ERKODENT, Siemensstr. 3 Pfalzgrafenweiler D-72285), which after vacuum thermoformed and properly cooled to reduce its thickness by 30%, resulted in a homogenously thick layer of 1.4 mm EVA. Overlying the first layer of EVA, a 4 mm thick layer of Polyethylenterephthalat-1 (PETG; Kopp GmbH Erich ERKODENT, Siemensstr. 3 Pfalzgrafenweiler D-72285) was used (Figure 1).

Figure 1 about here

Performance measures

Handgrip Force

Handgrip Force. In a standing position with the dominant arm completely extended and separated 458 from the trunk in abduction, subjects took the handgrip dynamometer Model T.K.K. 5001 (Takei Scientific Instruments Co. Ltd, Niigata, Japan) and were asked to generate their maximum hand press force with their dominant hand. Subjects were not allowed to flex the trunk or make other movements during the HG generation. The peak force was manually recorded. Intraclass correlation coefficient (ICC) for handgrip measures was r = 0.92.

Back-Row Isometric Force

In a sitting position with extended knees, shoulders at 908 of flexion, and extended elbows, subjects were asked to pull as much as possible on an ergonomic handle connected to a strain gauge. A Mark-10 R01 Series (Mark-10 Corp., Copiague, NY, USA) strain gauge was connected to a Biopac MP100 through a transducer amplifier DA100C (Biopac Systems, Inc., CA, USA) that recorded variations in force during the exercise. The software Acqnowledge 3.0.9. (Biopac Systems, Inc.) plotted and recorded the force on a time scale. The sample rate was established at 200 Hz. The peak force was detected and the rate of force development was calculated according to previous methods described by Agaard et al. (1). The RFD was calculated over time intervals of 0–150, 0–300, and 0–450 milliseconds following suggestions from different authors on maximum muscular force actions (4,28). The ICC for back-row isometric force measurements ranged from r = 0.88 to r = 0.92.

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Measures of Vertical Countermovement Jump

In a standing position with his feet shoulder width apart, subjects kept their hands on their hips throughout the measurement and jumped vertically as much as possible doing a previous countermovement. Jumps were assessed using a contact mat connected to a Chronopic of Chronojump (Bosco System, Barcelona, Spain), and the data were sent to the Chronojump 1.4.9 software. The Chronojump Bosco System is a useful system created for the assessment and data management of speed actions in sport based on a precise chronograph (chronopic) that detects electric potential changes. The system consists of free software that uses open hardware (7). Flight time jumps were measured by the system, and the software immediately calculated the jump height and average power according the procedures followed by Bosco et al. (8). Subjects were asked to perform an elastic countermovement during the contact phase and landing with a complete leg extension and a plantar flexion of the ankle.

The output data of flight time, initial velocity, average power, and jump height were recorded by the Chronojump System. The ICC for CMVJ measurements ranged from r = 0.93 to r = 0.95. Each jump was also recorded using a highspeed video camera (i.e., Casio Ex-F1) at 1000 frames per second. All video files were analyzed to determine the knee angle of flexion. Only the jumps with a maximum deviation of 65% with respect to a 908 angle of flexion were considered for the analyses.

Statistical Analyses

Standard statistical analysis methods were used to calculate means and standard deviations. We assumed that distributions were normal and that variances were homogenous because the data met all of the criteria to use linear statistics. A repeated measures analysis of variance was used to test the differences between the 3 conditions (JAW, NON-JAW, and MP) in HG-peakforce, BRW-peakforce (BRW-150, BRW-300, and BRW-450), and countermovement vertical jump (CMVJheight and CMVJ-meanpower). When a significant F score was found, Bonferroni post hoc tests were used to test the pairwise differences between the performances in the 3 conditions. Statistical analyses were performed using the statistical software package SPSS (Version 22.0 for Windows, SPSS, Inc., Chicago, IL, USA). Significance was accepted at p # 0.05 for all tests

RESULTS

Hand Grips

A significant effect was found for condition in HG-peakforce (F(2,54) = 32.71, p # 0.05; h2 p = 0.548). Pairwise comparison indicated significantly better performances for MP with respect to JAW and NONJAW, and JAW with respect to NON-JAW (Figure 2).

Back-Row Isometric Force

There was a significant effect for condition in all variables analyzed in BRW: BRWpeakforce (F(2,54) = 13.74, p # 0.05; h2 p = 0.337), BRW150 (F(2,54) = 12.14, p # 0.05; h2 p =

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0.312), BRW-300 (F(2,54) = 9.06, p # 0.05; h2 p = 0.251), and BRW-450 (F(1.73,46.83) = 11.99, p # 0.05; h2 p = 0.308) (e = 0.98). All variables respected the assumption of sphericity according to Mauchly's test except the last variable where degrees of freedom were corrected using the Hynh-Feldt estimation. Pairwise comparisons indicated significantly better performances for MP with respect to NON-JAW and JAW (Table 1).

Vertical Countermovement Jump

There were significant effects for conditions in CMVJmeanpower (F(2,54) = 8.04, p # 0.05; h2 p = 0.23) and CMVJ-height (F(2,54) = 10.76, p # 0.05; h2 p = 0.285). Pairwise comparisons indicated significantly better performances for MP with respect to NON-JAW and JAW (Figure 3).

Figure 2 about here

Figure 3 about here

Table 1 about here

DISCUSSION

The main finding of the present study was that a customized bite-aligning mouthpiece provokes a significant ergogenic effect on measures of maximal upper body isometric strength and lower body muscular power. The mouthpiece used in this study was designed using a new method for mouth structure scanning that optimizes the building process and provides a precise and comfortable design. An expert dentist ensured a neutral and improved jaw positioning according to suggestions that reported the necessity to create an individual and precise jaw-repositioning mouthguard to promote ergogenic acute effects on muscular power performance (27).

Benefits were observed in both handgrip and BRW when comparing the 3 conditions used in this study (i.e., no jaw clenching, jaw clenching, and jaw clenching with mouthpiece). According to Hiroshi, statistically significant improvements were found when the subjects performed the handgrip test while clenching their jaw (JAW and MP, in this study) with respect to NON-JAW (29). In this respect, the H-reflexes' facilitation of the forearm muscles during a voluntary jaw clenching could explain the differences found in the handgrip test (40). In addition, the arguments of the ergogenic effects of the CAP seemed to be the most appropriate to describe the main reasons for these differences in a maximal handgrip voluntary contraction (15,17). Moreover, significant greater peak forces were observed for MP with respect to the 2 other no-mouthpiece conditions (see Figure 2). The better comfortability of clenching the jaw and the optimized occlusion wearing the customized mouthpiece expressed by the subjects could be an interpretation of these differences (13). In contrast, Kec¸eci et al. (31) found no significant differences when comparing the handgrip isometric strength with and without mouthguards in taekwondo elite fighters. This is probably because mouthguards do not improve the quality of occlusion and

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simply protect the teeth from dental accidents. Although the coincidence in the use of custom-made mouthguards, there are a number of issues that could affect the performance in the different tests, including the sample differences between studies and the missing data about the timing of the different assessment procedures, especially for the presence of the Wingate test. In the present study, subjects demonstrated a significant increase in isometric back-row strength using the mouthpiece with respect to free jaw clenching and no jawclenching conditions. This finding differs from the previously mentioned handgrip results. Although significant differences were found between NON-JAW and JAW in the handgrip test, in the back-row test, no significant differences between these 2 conditions were observed. The different agonist muscles involved in this test and the difficulties to keep the mandible muscles relaxed could be possible explanations for the differences between both isometric tests. The isometric back row is a global exercise that involves a lot of muscles, including some muscles near the jaw in a quasiperpendicular line of force with respect to the handgrip direction test. This difference activates postural muscles, such as the trapezius, the lateral neck muscles, and masticatory muscles, which hinder the realization of the back-row isometric force on NON-JAW and JAW. Conversely, this does not occur in the handgrip and may explain the difference of the results between both tests. The change of the muscle-working angle makes participate much more postural muscles as the trapezius and other cervical muscles, which are activated at the same time as mandible muscles; this effect made it more difficult to relax them with or without jaw clenching (22,35,36). Some research corroborates the hypothesis of different muscle-specific responses to the benefits of the RVC (15). Moreover, benefits of the relaxation of jaw muscles when deltoid muscles participate in the exercise have been suggested (39). In the BRW, deltoid muscles fix the position and guarantee the stability of the strength during the contraction phase. Nevertheless, the benefits of wearing a mouthpiece seemed to be clear when observing the performance of BRW-peakforce and BRW150, BRW-300, and BRW-450. Reported differences between no mouthpiece conditions and the mouthpiece condition could be explained by the ergogenic benefit of the use of MORA. A centric occlusion and a wax bite position could enhance the isometric strength produced by the muscles involved in the back-row test (21,26). A correct VDO also supports the idea that wearing a dentistry-designed bitealigning mouthpiece with an optimal thickness design, like the one used in the present study, could contribute to enhance isometric strength in some muscles, also those involved in the test, respect the possible benefits obtained clenching the jaw without mouthpiece (11). In fact, in the back-row test, no significant differences were found between NON-JAW and JAW. The RVC of the jaw muscles during the isometric efforts with the NON-JAW condition, observed in most of the subjects, could be substitutive of the effects of jaw clenching and could also promote a CAP (15). Thus, in agreement with similar findings of previous research that describe the benefits of wearing MORA (15,18,20,26), a dentistry-designed bite-aligning mouthpiece seems to promote the optimal conditions for a powerful jaw clenching that contributes to isometric strength (9). Jaw clenching with the protective role of the mouthpiece for teeth integrity may be another explanation of a possible more powerful muscular activation in jaw muscles and may constitute a significant enhancer of the remote activation of prime movers. But a limitation for this study is that no data of biting force generation was collected. In addition, the significant differences between the 3 RFD time periods tested are in accordance with the time course of CAP differences, mainly, in the torque differences in the first 1,000 milliseconds of contraction (24). In the present study, the RDF was calculated in the first 450 milliseconds, and the bigger differences were observed in the first 150 milliseconds.

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It has been shown that jaw clenching is an enhancer of force production during a vertical jump (5,14,16,17) in accordance with the results found in the present study. Some of the aforementioned studies experimented with jaw clenching using a mouthguard. In fact, Arent et al. (5) used a custom-made mouthguard and Dunn-Lewis et al. (14) used an accurate procedure of a boil-and-bite mouthguard. In contrast, other studies found no significant acute effects of wearing mouthguards on jumping performance (2,10). The use of commercial bite-aligning mouthpieces (2), or the different jump protocols and instrumentation used (10) possibly had an influence on those findings. This argument is reinforced by results reported on significant differences in jump performance parameters when comparing the ergogenic effects of wearing customized versus standard mouthguards (5,14). Furthermore, the instructions for jaw clenching provided in the present study differ from the recently cited investigations. Although no specific instructions for jaw clenching were established for subjects in all jump measurements (2,5,10,14), in the present study, the subjects were asked to clench their jaw powerfully in JAW and MP. This could modify the effect of a possible RVC and the consequent CAP although other studies provided instructions to clench the jaw and found no significant differences between different conditions with and without different types of mouthguards (27). Another difference of this study with some of these works and a limitation of this particular study was the use of a mat to measure the jumping performance. This made it impossible to obtain the forces exerted during the pushing phase and the RFD at different time intervals. Nevertheless, results show an advantage of wearing the mouthpiece in all variables of CMVJ.

Although conflicting results have been reported in previous research, the present study reflects a positive effect of wearing a customized bite-aligning mouthpiece on isometric strength and CMVJ. There are benefits to having an accurate mouth-scanning process for mouthpiece fitting that provides a precise mouth adjustment and comfortability. This design seems to offer good conditions for powerful jaw clenching and also benefits from the CAP. In the present study, no mouthguard comparisons were performed, and this is a limitation. In future research, other sports performance parameters should be tested in different sports and also with women. Ebben et al. (16) suggested considering the jawclenching forces to clarify the influence of different magnitude of these RVC on the forces exerted by different prime movers in the most important exercise in sport and conditioning. This provides a good direction for next steps for this research.

PRACTICAL APPLICATIONS

The use of customized bite-aligning mouthpieces for sports requiring strength and power actions not only improves occlusion but also promotes an ergogenic effect in the analyzed variables. A customized and dentistry-designed device appears to be more comfortable and reduces wear on teeth, especially in athletes with a malocclusion because jaw clenching is unconsciously performed in power and strength actions.

Jaw clenching while wearing customized devices is suggested to improve the joint alignment and proprioception induced by customized jaw repositioning and the daily effects of strength training, not only in testing sessions and competition (36). Thus, if athletes are able to produce higher forces while wearing a customized mouthpiece, these improvements in strength and power could transfer to other actions and muscles in sport.

This study contributes to changing the idea that customized mouthpieces only protect the teeth. The findings support the idea that wearing dentistry-designed bite-aligning mouthpieces can also improve sport performance as suggested in previous studies (5). Only custom-made mouthguards fitted by an expert dentist using a precise scanner seems to be effective to promote ergogenic effects on strength and power actions because the specific improvement of temporomandibular alignment. We provide additional evidence that there are no negative performance effects on using a mouthguard, especially on sports with high risk of dental injury (9,13,27). Thus, this study wants to encourage practitioners for recommending the use of dentistry-designed mouthpieces to their athletes. Its use in training sessions and also in competition could promote improvements in strength and power actions.

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FIGURES AND TABLES

Figure 1.

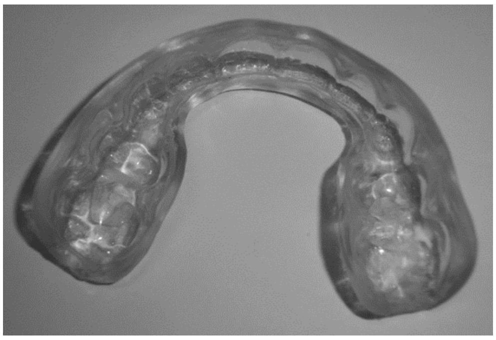

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Figure 2.

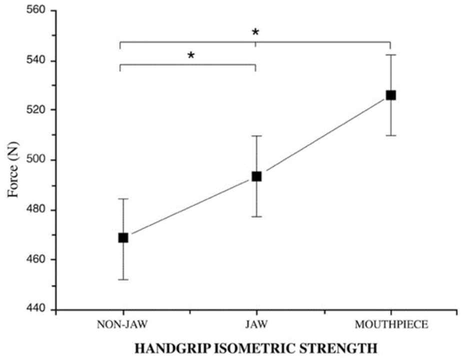

Figure 3.

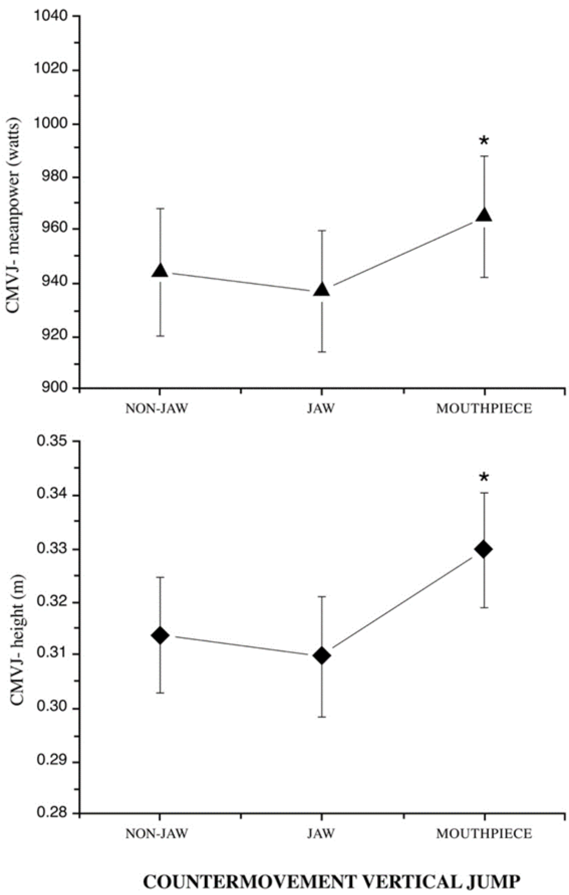

Table 1. Comparisons of back-row rate of force development and peak force between the three conditions.

	BRW-150 ($N \cdot s^{-1}$)	BRW-300 ($N \cdot s^{-1}$)	BRW-450 ($N \cdot s^{-1}$)	BRW-peakforce (N)

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NON-JAW	4.02 (0.28)	2.89 (0.18)	2.18 (0.11)	1216.48 (44.290)
JAW	3.75 (0.27)	2.74 (0.15)	2.12 (0.09)	1219.13 (47.085)
MP	5.25 (0.37)*	3.37 (0.17)*	2.54 (0.11)*	1322.39 (45.861)*

BRW-150= Back-row Rate of force development (0-150 ms); BRW-300= Back-row Rate of force development (0-350 ms); BRW-450= Back-row Rate of force development (0-450 ms); BRW-peakforce= Back-row peak force; MP= Mouthpiece. *Indicates a significant pairwise difference ($p \leq 0.05$) between the three conditions.

FIGURE LEGENDS

Figure 1. Dentistry-designed mouthpiece used in the study.

Figure 2. Comparisons of Hand Grip Isometric Strength between the three conditions. *Indicates a significant difference ($p<0.05$) between the three conditions.

Figure 2. Comparisons of Countermovement vertical jump between three conditions. *Indicates a significant difference ($p<0.05$) between the three conditions.