Effects of Wearing Bite-Aligning Mouthguards

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The purpose of the present entry was to determine the acute effects of wearing bite-aligning mouthguards on muscle strength, power, agility and quickness in athletes. A search of the current literature was performed using the electronic databases (until 1 May 2021) Web of Science, Scopus and Medline. The inclusion criteria were: (1) descriptive design studies; (2) with randomized clinical trials; (3) examining the within-subject acute effects of wearing mouthguards on functional and neuromuscular performance parameters; (4) in physical active, recreational or highstandard athletes. Twenty-seven studies met the inclusion criteria. Sixteen reported positive effects in some of the variables assessed, two reported negative effects and the rest found no significant differences. Overall, the main findings described in the literature are inconclusive concerning the neuromuscular advantages of using mouthguards in muscle strength, power, agility and quickness. These discrepancies might be related to several factors such as differences in testing protocols, poor control of the jaw magnitude and improper mouthguard designs. Despite these differences, after conducting the present systematic review, the authors speculate that jaw clenching while wearing custom-made, bite-aligning oral devices might promote beneficial effects in lower limb power actions, especially in jump ability and knee extension movements. Thus, athletes might consider the use of mouthguards, not only for their protective role but also for the potential ergogenic effects in specific actions, mainly those for which lower limb muscular power are required.

Keywords: mouthguards ; jaw clenching ; vertical dimension ; ergogenic effects ; neuromuscular performance ; sport

1. Introduction

Originally, sports mouthguards were designed to minimize the incidence of orofacial injuries through the absorption of the energy during head and mouth trauma [1]. Besides this preventive role, several studies have investigated the effects of wearing these oral devices on metabolic [2][3][4][5], ventilatory [6][7][8][9], functional [10][11] or neuromuscular performance parameters, and this, concretely, has focused on strength [2][12][13][14][15][16][17][18][19][20][21][22][23][24][25][26][27], power [12][15][16][18][20][21][22][24][25][26][27][28][29][30][31][32][33][34], quickness [26][34][35] or agility [15][25][36]. The potential neuromuscular effects might be attributed to the postural repositioning of the temporomandibular structure and the subsequent muscular rebalancing [37]. This readjustment might promote a more balanced and powered occlusion, thus increasing the effects of the concurrent activation potentiation (CAP) elicited by the remote voluntary contraction (RVC) of the mandible muscles [21][31]. The neuromuscular benefits associated with a RVC might be explained by several mechanisms. One mechanism is based on the integrative function of the cerebral motor cortex and the intercortical connections between the different motor areas of the brain. Thus, when one part of the motor cortex is activated because of jaw clenching, the neural centers of the other parts of the brain are also activated. These centers send impulses to the prime movers which initiates the targeted actions [38]. Another mechanism underlines the increased excitability of spinal motor neurons while an individual clenches the jaw, amplifying the alpha motor neuron activity, gamma loops and muscle spindles, together with descending the cortical input and the stimulus invoked by the afferent input [38]. Furthermore, it is established that jaw clenching increases the excitability of the Hoffman reflex (H-reflex). Indeed, greater force levels in jaw clenching produce greater H-reflex facilitation in some muscle groups, which is evoked with both the descending influence from the cerebral cortex and the afferent input from the oral-facial region [39]. Although several studies [20][21] associated the ergogenic effects of CAP with jaw clenching independent of mouthguard use, others [2][14][24][25] demonstrated beneficial effects when wearing the oral device.

Overall, mouthguards can be classified into three types: standard (or stock), self-adapted (or boil and bite) and customized. The standard type is widely used because of its low cost even though is considered the most uncomfortable and worst adapted to the mouth structure. It is acquired ready to be used, and no fitting process is required. The self-adapted type is a thermoplastic liner that can be fitted to the maxillary teeth after being heated in boiling water to become more malleable. The customized type is the most expensive and requires the expertise of a professional dentist. It is created after an impression or scanning process of the dental structure of the teeth [40]. The use of a certain type or model may directly affect the repositioning of the temporomandibular structure [14] and the comfortability and ability to speak or breathe during exercise [14][29].

2. Current Insights on Effects of Wearing Bite-Aligning Mouthguards

The main objective of the present systematic review was to analyze the effects of wearing mouthguards on muscular power, strength, agility and quickness. Overall, the main findings described in the literature are inconclusive concerning the neuromuscular advantages of using mouthguards. These discrepancies might be associated with several factors, such as the differences in testing protocols, laboratory equipment, sample characteristics and mouthguard materials or the type used in each study. For instance, several studies used CMMs but others used SAMs or STNDMs. Despite using the same type, the lack of common standards in the manufacturing process produces different mouthguards in terms of design and materials. Therefore, the type of mouthguard used in each study might be a possible explanation for the mentioned discrepancies, as suggested by Bourdin et al. [28]. Furthermore, in some studies [2][12][15][20][21][23], the mouth scanning procedure and the mouthguard manufacturing were conducted by the researchers, while in the rest of the studies they were performed under the expertise of an expert dentist. Another important factor to take into consideration is the subject's familiarity with oral appliances. Some authors [15][22][35] detailed the previous regular use of mouthguards by the subjects in their studies, whereas others [2][12][17][24][25][33][34][41] indicated that athletes had null or poor experience with the oral devices. However, several studies [13][14][16][18][19][20][21][26][27][28][29][30][31][32][36] did not specify the previous subjects' experience with mouthguards, even though the practice and level of sport could entail its regular use [19][26][27]. It is possible that mouthguards, being unfamiliar and uncomfortable to most of the nonfamiliarized participants, generated awkward and distracting feelings, affecting the performance and thus leading to the observed differences among the studies. It is suggested that the lack of comfort might make powerful jaw clenching difficult and thus affect the CAP promotion. For this reason, future research should consider long familiarization periods with mouthguards to avoid discomfort and, additionally, to examine the possible long-term adaptations induced by these devices.

The potential effects of mouthguards might be related to the jaw repositioning of the temporomandibular joint and the vertical dimension of occlusion (VDO) [14][23]. The VDO has been defined as the interocclusal distance between dental arches in the maximum intercuspation [42]. It is suggested that an increase in posterior thickness will open the lower airway path and optimize afferent and efferent signaling from the sensorimotor system [14]. The effect of VDO magnitude is unclear and different between individuals [16]. Nonetheless, it is speculated that the distance to achieve the maximum occlusal bite force is about 8 mm between the first molars [37]. Despite the possible enhancing role of an adequate jaw repositioned mouth with the correct vertical dimension on the strength and power output of the prime movers, several studies [2][12][13][15][18][20][21][22][23][25][27][29][31][32][33][34][35][36][41] did not reveal specific manufacturing details such as the splint thickness or the occlusal space elicited by the oral appliances. Indeed, the relevant contribution of the mouthguard's thickness on the VDO should encourage future researchers to describe these issues. Additionally, the analyzed studies included upper, lower or both dental devices with full or partial coverage, which may also determine the jaw alignment and the distribution of the clenching forces. It has been shown that full coverage, with anterior dental contacts, produces a higher TMJ force because of a longer lever arm [17]. Thus, the different mouthguard designs may influence the mechanical orientation of the jaw, thereby improving physical performance [34][35].

Several authors have demonstrated the relationship between the use of mouthguards with an increased force and muscle activation of the mandible muscles, thus increasing the neuromuscular effects [13][14]. For this reason, future investigations should provide sufficient information about the amount of jaw clenching, both with and without the mouthguard. Indeed, despite not quantifying the forces generated, some authors [20][21][24][25][31][32] encouraged athletes with a specific instruction (i.e., clench as powerfully as possible). However, other authors [12][17][35] did not encourage athletes with any specific instruction about the magnitude of jaw clenching, whereas others [12][15][16][19][22][23][26][27][28][29][30][33][34][36][41] did not mention which instruction was given. Thus, it is difficult to draw a solid conclusion associated with the clenching magnitude while wearing mouthguards. Additionally, while several studies [19][22][41] used placebos or different type of mouthguards [2][12][13][23][24][25][26][31][32], others only compared the use and nonuse of mouthguards. In the latest,, the athletes knew under which condition the test was being performed, and this could affect the subject's predisposition toward the respective action. Future research could consider a double-blind study design comparing different types of mouthguards with a no-mouthguard condition.

2.1. Muscle Power

One of the main findings of the present review was the beneficial effect of jaw clenching while wearing a mouthguard on jump ability. Indeed, 60% of the studies assessing vertical jump reported a meaningfully higher performance when athletes used the intraoral device. Interestingly, all of these studies included the CMM in their testing protocols. Thus, it could be speculated that the lower limb muscle power, measured through vertical jump, might be positively influenced by the use of a CMM. The authors attributed these findings to the potential effect of CAP, which is elicited through the remote voluntary contraction of the mandible muscles [31]. It is believed that the RVC generates a multiphase response characterized by an initial intercortical connection, followed by a supraspinal facilitation, an enhanced H-reflex and a concomitant decrease in the reflex intensity [32][38]. Thus, during power actions, which involve fast stretch-shortening cycles (SSC) and rapid force generation changes, sensory neurons from the muscle spindle send signals through motor neurons to the spine, which communicates with the brainstem. When this information overflows, the stretch reflex is activated, as shown, for instance, during the CMVJ. Muscle spindles are activated during the countermovement because the large muscle groups in the lower limbs are quickly lengthened during the eccentric phase. The muscle spindles communicate to the central nervous system (CNS), which transfers the stimulus to the lower body muscles and promotes a forceful and explosive vertical jump [43]. Nevertheless, Duarte-Pereira et al. [29] reported a performance decrease associated with the use of mouthguards. Although they found beneficial effects on a CMVJ test, the authors reported a significant decrease on 15s-RJ height when recreational rugby players wore a CMM compared to a NoMG condition. This performance decrease might be related to the uncomfortable and restrictive expiratory effects of the mouthguards used, which could negatively impact the airflow path during the 15-RJ test and, thereby, the performance.

Although some authors [20][21] attributed the ergogenic effects of CAP to jaw clenching beyond the use of oral appliances, others [2][24][25] showed enhanced performance when wearing the oral device. In fact, Gage et al. [14] demonstrated that is not possible to produce a maximal jaw contraction with a bare mouth, since depressor muscles are active during clenching to protect the teeth. Moreover, when athletes clench with uncovered teeth, possible imbalances in the temporomandibular musculature could be magnified [10][44]. Thus, clenching bite-aligning intraoral devices seems to produce changes in condylar position and better redistribution of the clenching forces, thus leading to a more highly powered occlusion and further increasing the neuromuscular effects of the jaw clenching [24]. Moreover, this balanced occlusal force distribution, derived by the use of mouthguards, could involve changes in the peripheral proprioceptive input of the orofacial region that may affect the CNS through the trigeminal nerve, after which the CNS transfers the modified output signal via spinal nerves and autonomic nerves to the musculoskeletal system [16].

Other studies assessing lower body dynamic strength focused on cycle-ergometer and knee extension tests. From the five studies including cycle-ergometer tests, two [22][26] found positive effects and three [16][28][33] reported no significant differences when comparing the use and nonuse of mouthguards. It is possible that the mouthguard design used in the latest studies did not produce an optimal VDO to elicit the CAP effects. Fischer et al. [33] did not detail the occlusal space promoted by the mouthguards, but Bourdin et al. [28] and Jung et al. [16] reported a 2 mm increase in VDO when the athletes wore the oral device. This value differs from the 8 mm presented by Arima et al. [37]. In this vein, Bourdin et al. [28] did not find differences between conditions (SAM, CMM and NoMG) on airflow dynamics nor on oxygen uptake (VO_2), which reinforces the hypothesis that mouthguards did not promote an adequate VDO. From the four studies including knee extension actions, three [2][32][35] reported beneficial effects, and one [25] reported no significant differences. The three studies which found positive effects involved recreational athletes, whereas the study that found no differences involved high-standard athletes. In the last study, professional basketball players performed a leg press test with different loads. The results revealed no significant differences when comparing the use and nonuse of a CMM in any of the leg press loads. The authors attributed these findings to different factors, such as the power test duration (which makes continuous jaw clenching impossible), the different ages of the athletes or the years of experience in weightlifting training. Although the three studies reporting beneficial effects were performed with recreational athletes and the one reporting negative effects was performed with high-standard athletes, it is not possible to conclude that the training standard constitutes a crucial factor for the knee extension actions when athletes used CMMs.

In terms of the upper body dynamic strength, it is difficult to find a relationship between the use of mouthguards and neuromuscular performance. All the studies investigated the effects of wearing mouthguards on the bench press and bench throw actions. Two out of six studies [25][35] reported beneficial effects. However, these two studies showed different results. Concretely, Dunn-Lewis et al. [35] found significantly higher performance in bench throw power and force when wearing a CMM compared to a SAM or NoMG in recreational athletes. Nonetheless, with the SAM, the athletes experienced a significant decrease in power output compared to the NoMG condition. Additionally, Buscà et al. [25] reported higher mean power with the CMM compared to NoMG on a 50 kg bench press test in elite basketball athletes. However, they did not find differences in 30, 40 or 60 kg loads. It is speculated that potential discomfort, reported by some athletes, and the variable response of elite athletes to high neurological activations [45] support this lack of consistency among the final results.

2.2. Isometric Strength

From the eight studies examining the isometric muscle strength, four [17][18][23][24] reported positive effects when the athletes used an oral appliance, whereas the other four [19][20][21][26] did not find significant differences. On the one hand, focusing on the lower body strength, only one study [18] found positive effects, and four [19][20][21][26] did not reveal significant differences. Concretely, Cetin et al. [26] found no differences when comparing the use and nonuse of mouthguards on isometric leg and back strength in elite taekwondo athletes. The authors attributed these results to the fact that subjects had never worn a CMM before the study, and no chronic adaptations could be generated. On the other hand, six studies [17][19][23][24][26] examined upper body muscle strength. From these studies, four [17][18][23][24] found beneficial effects due to mouthguard use in recreational or physically active athletes. Concretely, Limonta et al. [17] investigated the effects of two different SAM occlusal splints (1 and 3 mm) with respect to the NoMG condition on the isometric contractions of elbow flexors. Their findings indicated that the use of mouthguards enhanced the maximum isometric strength, lowering force decay and promoting a better neuromuscular efficiency. Additionally, when comparing the 3 mm thick SAM (full coverage) with the 1 mm thick SAM (only posterior coverage), the authors found a lower force decrease in a prolonged maximum contraction for the 3 mm thick SAM condition. The authors maintained that higher mandibular stability may promote a better length and realignment of the occlusion muscles, leading to a higher MVC with a similar EMG activity. Moreover, the authors stated that jaw repositioning can be associated with better postural control, functional proprioception and spinal alignment, promoting higher neuromuscular coordination. Battaglia et al. [23] examined differences between the use and nonuse of mouthguards during an isometric handgrip test in different martial arts athletes. The authors observed a significant increase in peak force while wearing an occlusal splint with the dominant hand, whereas only significant differences were found with the nondominant hand in regular mouthguard users. The authors attributed these findings to better long-term adaptations and to the fact that mouthguards may reinforce more effective regulation on the efferent motor pathways via potentiation of an afferent stimuli from the periodontal mechanoreceptors and muscle spindle fibers activated during teeth clenching with balanced occlusion. In contrast to these findings, two studies conducted with professional athletes [19][26] revealed no significant differences in upper body isometric strength. It is speculated that that the VDO increase promoted by the mouthguard design was less effective in eliciting the CAP effects.

Overall, according to the collected data, it could be hypothesized that the use of mouthguards might improve the upper body isometric strength in recreational athletes or physically active subjects, whereas the studies with high-standard athletes did not reveal significant differences. Nevertheless, no adverse effects were described in any of the reviewed studies.

2.3. Isokinetic Muscle Strength

Five studies investigated isokinetic muscle strength, two [19][41] focusing on the upper body and three [13][16][26] on the lower body. One the one hand, the two upper body studies, which were performed with college athletes, found no significant differences. On the other hand, two out of three studies assessing the lower body isometric strength found beneficial effects when wearing a CMM on knee extension actions, whereas one reported no significant differences. The latter [16] did not find significant differences between jaw clenching without a mouthguard and with a full-coverage CMM (2 mm VDO increase) in any of the variables assessed. Indeed, four studies included CMM in their protocol (one also included PLAM), three of which reported no significant differences and one which reported beneficial effects. One study included SAM and also reported beneficial effects. Moreover, four out of five studies involved experienced athletes, with two reporting beneficial effects and two reporting no differences. For this reason, it is difficult to attribute the training standard or the mouthguard type as a relevant factor in determining enhanced isokinetic muscle strength performance. However, an adequate VDO might be considered an important factor in isokinetic strength to be taken into consideration when using mouthguards. Nonetheless, more well-designed studies with accurate information about the mouthguards used and the VDO promoted by these devices are required to search for more solid conclusions in both recreational and high-standard athletes.

2.4. Agility/Quickness

Any analyzed study in this systematic review reported beneficial effects on agility because of the use of mouthguards. For instance, Buscà et al. [25] found no significant differences between the use and nonuse of a CMM in the agility t-test in professional basketball players. These findings are in line with Queiroz et al. [36], who tested a shuttle-run with ball test in female soccer players, and Golem and Arent [15], who also found no significant differences between conditions in a HEX agility test in collegiate male athletes. The authors attributed these results to the complexity of the neuromuscular processes and the coordinative demands during agility tests. Moreover, the duration and the nature of these kinds of tests makes the continuous RVC of the mandible muscles and the consequent potential effects of the CAP impossible.

In terms of quickness, two out of three studies found no significant differences in a 10 and 20 m sprint test, while one reported positive effects in a 40 m test. In this vein, Martins et al. [34] sustained a potential correlation between vertical and horizontal power production and maximal speed. In fact, the authors also found a nonsignificant 3% increase in vertical power and a significant 2% in horizontal power, thus explaining the decrease in 40 m sprint. This is in line with the nonsignificant differences reported by Cetin et al. [26] on a 20 m sprint test, which also showed no benefits in horizontal and vertical lower limb power.

All tests included the CMM in their testing protocol, so it is difficult to draw a solid conclusion related to mouthguard use in agility or sprint actions. Moreover, three tests were performed with high-standard athletes and three with recreational athletes. Thus, it is also difficult to link the training standard to any potential ergogenic effect on agility or sprint ability.

3. Conclusions

After conducting a detailed systematic review, the authors conclude that the acute effects of jaw clenching while wearing mouthguards on muscle strength, power, agility and quickness are inconclusive. It is shown that the use of mouthguards might promote beneficial effects in lower limb muscular power, especially in jump ability and knee extension actions. These findings are not extensive to agility, quickness or isometric or isokinetic muscular actions, the studies of which did not report consistent results about the potential benefits of wearing mouthguards on athletic performance. This lack of conclusiveness might be related to several factors, such as differences among the testing protocols, poor control or quantification of the jaw magnitude and different mouthguard designs.

The present systematic review might also conclude that custom-made mouthguards showed better results than self-adapted or standard types and, overall, do not negatively affect athletic performance. Thus, in addition to their protective role, clinicians and practitioners can consider the use of dentistry-designed mouthguards in sports, mainly in those for which lower limb muscular power is required.

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