



Effects of jaw clenching wearing customized mouthguards on agility, power and vertical jump in male high-standard basketball players

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ABSTRACT

Background: Basketball players commonly use mouthguards for protecting their mouths from collisions with other players. Besides, literature reports that specific types of mouthguards may become an ergogenic device that facilitates a powerful jaw clenching, and a subsequent concurrent activation potentiation through this remote voluntary contraction of the mandible muscles.

Methods: A randomized within-subjects design was used to study the effects of this mechanism on muscular performance (vertical jump, agility, bench press power and leg press power) into two different conditions (mouthguard and no mouthguard) in high-standard basketball players ($n = 13$). A mean differences analysis and a responder analysis were conducted.

Results: Significant improvements were found ($p < 0.05$) in all vertical jump protocols using the mouthguard when compared to the no mouthguard conditions. However, no significant differences were found between the two conditions in agility and power (except in one load of bench press). Nevertheless, p -values were closer to statistical significance when analyzing the total time for the agility T-Test than when the first split time was under consideration ($p = 0.111$ and $p = 0.944$, respectively).

Conclusion: This study demonstrated that the use of custom-made, bite-aligning mouthguard had an ergogenic effect on jump outcomes and inconclusive results in agility T-Test in professional basketball players. From the results obtained in the present study, the use of this type of mouthguards seems to be more justified in power actions on the court than in the strength and conditioning sessions at the gym in well-trained players.

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1. Introduction

In basketball, the players are continuously connecting accelerations, sprinting, changing of direction, jumping, and throwing. Together with these actions, players collide with opponents in different situations (e.g. pick and roll). In this context, some basketball players use different types of mouthguards to prevent dental injuries and to protect the maxillofacial structure from possible violent contacts during matches or training sessions. Different bodies and organizations recommend the use of mouthguards in sports such as judo, boxing, football, soccer, basketball,

karate or field hockey.^{1–3} With these mouthguards, players usually feel protected, but not always comfortable. Customized mouthguards manufacturing, requires dental impressions or scanning processes of the dental structure of an individual's teeth and are the most expensive ones available in the market. Two other types of mouthguards are also common in sports: standard and self-adapted. The standard type is initially ready to be used, and it does not require any fitting process. The standard type is a low-cost solution with great athlete acceptance, but it is also considered among the most uncomfortable types of dental guards.^{4,5}

Beyond the protecting function of the mouthguards, possible benefits of jaw clenching maneuvers while wearing mouthguards on strength, jump height and muscular power are in the literature. Remote voluntary contraction (RVC) from a clenched jaw provokes a concurrent activation potentiation (CAP) mechanism that is the

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possible cause of an ergogenic effect. Furthermore, wearing mandibular orthopedic repositioning appliances has been shown as a CAP contributor.^{6,7} The neuromuscular effects of jaw-repositioning and contraction of the mandible muscles may translate to improved neuromuscular responses in the agonist muscles of the sports movements. As a consequence, the activation of different muscles, like jaw muscles, contributes to strength movements like rowing, pedaling, running, or jumping.⁸ Indeed, a contraction of the mandible muscles might improve the neuromuscular responses of the main muscles involved in the performance action. For instance, when analyzing the muscle activation via electromyography in a group of healthy and active men and women, the muscles involved in an RVC are more active; this increase in activity results in a greater activity in the prime movers in isokinetic knee extension-flexion.⁹ The link between RVC and powerful and rapid movements is fairly clear. A sensory neuron from the muscle spindle communicates with a motor neuron in the spine, which sends the signal to the brainstem when performing rapid movements and changes of force production. Thus, performing a countermovement vertical jump (CMVJ), the stretch reflex is activated because the information from the muscle spindles and the central nervous system during the eccentric braking phase of these actions flows and promotes the subsequent powerful propulsion.^{6,10} Although agility movements are also high demanding tasks on neuromuscular system, the complexity of the different agile movements seem to be clear.¹¹ The variety of factors contributing to agility performance and the neuromuscular differences between a simple strength/power muscular action, in respect to a complete agility task, might explain the lack of consistent relationship between both paradigms of neuromuscular action.¹²

Several studies have focused the efforts in figuring out the ergogenic effects of wearing a jaw-repositioning mouthpiece on strength and muscular power performance. Jaw clenching shows positive effects on isometric, dynamic, and isokinetic strength of lower limbs in young population in some studies.^{13–17} However, other authors have not found any significant beneficial effects.^{18–21} Nevertheless, very few studies have studied the effects in high-standard athletes. Subject's profile and training status highly influence the response of the neuromuscular system in different actions such as CMVJ or agility.^{22–24} For this reason, it is necessary to study the effects of RVC of the mandible using a jaw-repositioning appliance on jumping and agility performance in this type of population. In this direction, Duarte-Pereira et al.²¹ found no significant increases in the CMVJ and 15 s rebound jump test mean power when comparing the acute effects on performance of three conditions tested in elite taekwondo athletes (no mouthguard, self-adapted, and customized pieces). Additionally, elite taekwondo athletes showed no significant improvements in CMVJ and 20 m sprint when comparing mouthguard (MG) and no-mouthguard (NO-MG) conditions. However, significant improvements wearing MG were found in Wingate Anaerobic Test peak power.²⁵ Collares et al.²⁶ found no significant adverse effects on the aerobic performance, regarding ventilation and VO₂max, for soccer and futsal players. In a different study performed with NCAA Division I players, a significantly higher mean performance in knee extension isokinetic force of 6.2%–12.5% was found when comparing RVC conditions and NO-RVC.²⁷ The RVC conditions included the use of a self-adapted mouthguard. Duddy et al.²⁸ did not find significant improvements in a 3-stroke maximum strength when using a mouthguard in well-trained rowers either. Likewise, Queiroz et al.²⁹ did not find significant improvements of using different types of mouthguards in an agility test (shuttle-run test) in female soccer players.

To the best of our knowledge, no studies about the effects of wearing customized mouthguards on jump, power, and agility have

been conducted in basketball players where these devices are frequently used.^{1,30} The aim of this study was to investigate the acute effects of jaw clenching on different measurements of agility, leg press power, bench press power, and CMVJ performance parameters among high-performance male basketball players, wearing or not a customized bite-aligning mouthpiece. Mouthpieces were made using a new scanning method that simplifies its manufacturing and reduces the final cost.

2. Methods

2.1. Study design

A randomized within-subjects design was used to examine the acute ergogenic effects of jaw clenching using a bite-aligning mouthguard in jump, agility and muscular power in high-standard basketball players. Subjects participated in two testing sessions. In the first session the subjects provided informed consent, their mouth structure was scanned. In the second session, an expert dentist finished the fitting process for all subjects, the subjects were familiarized with testing protocols and the performance data was collected. Mouthguards were designed to promote mandible arch's stability in a long centric position. Several head movements were performed to neutralize a possible postural or neuromuscular disorder that might influence the mandible position with respect to cranium and the cervical muscle activation. The mouthpieces were built with minimal dentoalveolar discrepancy regarding the morphology of the mouth structure of each subject. All subjects were also asked to refrain from participating in any activity that would negatively impact the outcome of the assessments. Subjects were also asked not to drink alcohol or any other type of drug or stimulant before testing, or abnormal eating or sleeping.

A within-subject comparison between the two conditions, mouthguard (MG) and no-mouthguard (NO-MG), in CMVJ, CMVJ with arms (CMVJa), time of the first tranche of agility T-test (Tt-Time1), the final time of agility T-Test (Tt-Time), the power of the bench press (BP30, BP40, BP50, BP60) and leg press (LP190, LP220, LP235 and LP250) in different loads. Strength, jump and agility test have been widely used to assess performance among basketball players.^{31–33}

2.2. Subjects

Thirteen high-standard male basketball players (age: 21.07 ± 4.11 years, height: 1.98 ± 7.31 m, weight: 91.05 ± 10.92 kg) participated voluntarily in this study. All participants were involved in a Spanish 'ACB-Liga Endesa' club and participated in at least, five training sessions and an official match per week. All of them took part in at least ten regular games under FIBA rules. According to FIBA ranking, 'Liga endesa' is best national league in Europe and the second in the world. Eleven players were from Spain, one from Macedonia and one from Montenegro. All of them have played in their national team (junior or senior teams). After being fully informed verbally and in writing of the purposes and potential risks of the study, all subjects gave their written consent to participate in the study. Only one subject regularly declared an irregular use of self-adapted mouthguards but not in all training sessions or matches. The study and its protocol was reviewed and approved by the institution's internal review board and conducted in accordance with the Declaration of Helsinki (revised in 2013) on Ethical Principles for Research. The participants had the option to withdraw from the study at any time voluntarily.

2.3. Measurements

Each subject participated in two sessions. The first session was used to obtain informed consent, to assess anthropometric measurements, and to scan the mouth structure. A health screening was completed with each subject in accordance with the American College of Sports Medicine exercise testing procedures. In the second session, subjects were familiarized with the tests protocols during a learning session, including power, agility and jump tests. After a familiarization, participants completed a 15-min warm-up including 10-min of jogging, 5 min of calisthenic exercises, and 5 min of warm-up tests trials. The order of the tests was the following: jumps, agility, bench press and leg press. Researchers distributed the tests conditions (MG and NO-MG) randomly. The subjects performed two trials of each test and condition: wearing a mouthguard and without a mouthguard with a minimum rest time of 3 min. The analyses included only the best trials. The subjects were asked to wear the mouthguards where the conditions required it. In all testing conditions, subjects were encouraged to clench their jaws as powerfully as possible.

2.4. Mouthguard

For this study, the subjects wore CleverBite® mouthpiece (Cleverbite SL, Terrassa, Spain), a Class III mouthguard.³⁴ The manufacturing of the mouthpieces included a digital recording obtained by scanning both the maxillary and mandibular dental arches using the 3Shape Trios System (3Shape Inc. Copenhagen, Denmark). Additionally, the process incorporated a digital recording of the interocclusal relation associated with the resting position of the mandible (Fig. 1).

2.5. Agility T-test

The agility T-test was administered using the protocol outlined by Semenick.³⁵ The player starts at the base of the 'T,' the tester gives a signal to go and when the player crosses the photocell gate, the time begins. The player runs to the central cone and touches it passing the second photocell gate (Tt-Time1). Then the player sidesteps 5 m to the right cone and touches it. Then the player sidesteps 10 m to the left to the far cone and touches that one. After that, the player sidesteps 5 m back to the middle cone and touches it. Finally, the player runs 10 m backward and crosses the photocell gate at the base of the 'T' concluding the test and stopping the timing system (Tt-Time). To detect the beginning, the end of the trial and the intermediate step after the first run, the first photocell gate PME10D Velleman (Velleman, Inc., Gavere, Belgium) was connected to a Chronojump System 0.9.3 (Bosco System, Barcelona, Spain) and was located at the base of the 'T.' The second gate was placed close to the middle cone at 1.3 m from the ground level. This height is recommended to avoid interference of arm action in this type of measurements.³⁶

2.6. Power tests

Participants performed a specific warm-up with a free load bench press and a leg press machine (Technogym, S.p.A. Inc., Gambettola, Italy). Researchers asked the subjects to perform two maximal power repetitions with 30, 40, 50 and 60 kg in the bench press (BP30, BP40, BP50 and BP60 respectively) and with 190, 220, 235 and 250 kg in the leg press (LP190, LP220, LP235 and LP250 respectively). The loads described were usually used in team's strength training sessions during the in-season period and could be lifted by all the subjects being all below 80% individual 1RM, and could be lifted at least six times per set at the moment of the tests.

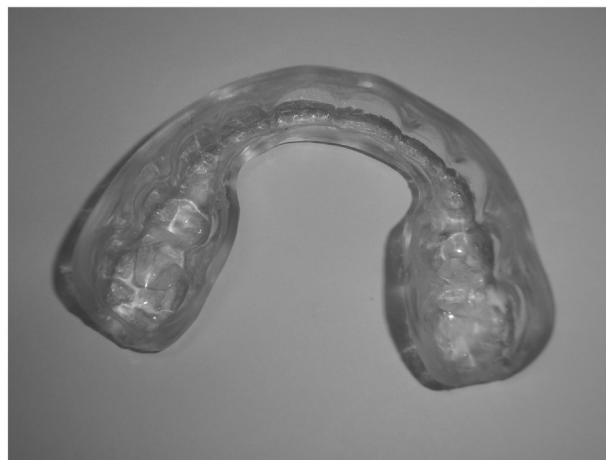


Fig. 1. Mouthguard used in this study.

Standard loads are commonly used to compare among subjects in tests sets such as NBA pre-draft combine.^{37,38} The technique for the bench press and leg press exercise, as described by Zatziorsky and Kraemer,³⁹ was explained to the participants and corrected. The motion range was individually adjusted before the leg press test for each participant. The loads included were of regular use in the player's conditioning training sessions. The protocol guaranteed 3 min of rest between trials. Average power, average force, average velocity, time to peak power and peak velocities were assessed using a linear encoder connected to a Muscledlab System (Ergotest Technology, Langesund, Norway).

2.7. Jump tests

In the CMVJ protocol, participants started in a standing position, kept their hands on their hips throughout the measurement and jumped vertically as much as possible doing a previous countermovement. In the CMVJa, the protocol was the same but participants were allowed to perform a countermovement with their arms to reach an additional impulse for the taking off. Jumps were assessed using a contact mat connected to a Chronojump System® (Bosco System, Barcelona, Spain).

The Chronojump System recorded the output data of flight time, initial velocity, average power, and jump height. Each jump was also recorded using a high-speed video camera (i.e., Casio Ex-F1) at 1000 frames per second. All video files were analyzed to determine the knee angle of flexion. The analysis only considered jumps with a maximum deviation of $\pm 5\%$ on a 90° angle of flexion.

2.8. Statistical analyses

Standard statistical analysis methods were used to calculate means and standard deviations. We assumed that distributions were normal and that variances were homogeneous because our data met all of the criteria to use linear statistics. A one-sample *t*-test (significance accepted at the level of $p \leq 0.05$) and Cohen's *d* effect size (ES) were used to test the pairwise differences between the performances in MG and NO-MG conditions. Threshold values for ES statistics were ≤ 0.2 (trivial), > 0.2 (small), > 0.6 (moderate), > 1.2 (large), > 2.0 (very large), and > 4.0 (extremely large).⁴⁰ Statistical analyses were performed using the statistical software package SPSS (Version 22.0 for Windows, SPSS, Inc., Chicago, IL). We also estimated the typical error of measurement (TE) and the small-standardized effect based on Cohen's effect size principle

(smallest worthwhile change (SWC); calculated as $0.2 \times$ between-subject SD), to check if there could be improvements despite non-significant levels of p values.^{40,41} Furthermore, data were also plotted and investigated by using Bland and Altman's 95% limits of agreement, as described by Atkinson and Nevill.^{42–44}

An individual responder analysis was carried out as a secondary analysis in the three groups of tests: bench press, leg press, and jumps. Since we had no previous data, smallest worthwhile differences (SWD) were used as a cut-point to investigate if some individuals could benefit from the use of mouthguards while others not.^{45,46} Players with improvements in all modalities/loads or some of each test in any group with no negative effect were considered positive responders, i.e. if a subject performed better with a mouthguard considering loads of 30, 40 and 50 kg with no effect in the 60 kg load, was considered as a responder.

3. Results

Statistical analyses tested mean contrast for all dependent variables through the use of a t -test for related samples. Results showed a significantly higher performance ($p < 0.05$) of MG for the CMVJ and CMVJa height and CMVJ power values. No significant differences appeared when comparing MG and NO-MG performances in the agility T-Test and the CMVJa power (Table 1). Nevertheless, p -values were closer to statistical significance when analyzing the total time for the agility T-Test than when the first split time was under consideration ($p = 0.111$ and $p = 0.944$, respectively) (Table 1).

The results of the bench-press and leg-press tests were also tested using the t -test for related samples, providing statistically significant results favoring the use of MG exclusively in the 50 kg load bench-press test average power. None of the leg press loads nor the rest of bench-press loads seemed to be influenced positively by the use of MG (Table 2). Those loads are commonly used during strength training in the in-season and can be lifted more than six times per set. No significant differences were found in the other variables (average force, average velocity, time to peak power and peak velocities) except in BP50.

Additionally, an individual responder's analysis using the results' difference between MG and NO-MG bouts was conducted for all the tests. In the case of jumps, the use of mouthguards in seven out of thirteen subjects, improve in one or both jumps over the set cut point. Regarding the agility T-test and acceleration time, only four out of twelve players can be considered as responders (Fig. 2). For the bench press, three players were responders, while one of them was the only responder for the leg press. Considering the overall response, all of the players responded positively in at least one of the tests, and only two subjects seemed to benefit more of the mouthguard use, responding positively in four out of six tests.

None of the participants appeared to improve in the entire test set proposed because of the use of a mouthguard. In addition, respondents were not clearly identified neither for their role in the game nor for years of experience.

4. Discussion

This study found significant differences in several variables of the assessed athletes' performances. The use of MG was beneficial for the height and power outcomes (except in CMVJa power) when performing jump tests, agility T-test and during the execution of the bench-press test under moderate load conditions. Additionally, the analysis was inconclusive regarding response to the use of MG compared to NO-MG conditions for the high loads of bench-press, all loads of leg-press and the first split of the agility test. These findings may hold practical relevance for athletes whose sports require anaerobic efforts, and especially for those athletes who need mouth protection, as is the case in basketball. Furthermore, although comfortability and quality of speaking were not studied, most of the players declared higher comfortability and less difficulties in speaking from the experience of using a custom-fitted mouthguard provided in the present study.

Some evidence sustains the beneficial effects of jaw clenching while wearing a mouthguard^{14–16} and others just promoting the CAP^{6,27} on jump performance. According to the authors, the present study shows significant improvements in both jump types (CMVJ and CMVJa). The control of the RVC (jaw clenching) in an isolated action might facilitate the promotion of CAP in jumping protocols. The player might be able to focus on clenching maneuver and, thus, taking benefit of this RVC. Besides, all of the players were asked to clench the jaws during the test, reinforcing the activation of the prime movers. This evidence supports the fact that most of the players (10 out of 13) were responders in both types of jump (Fig. 1).

These findings are inconsistent with the results found in the first tranche of the agility T-test because no significant differences were found between both conditions and a few number of responders were found in this initial acceleration (6 out of 12 and no effects). Different types of accelerations, brake actions, and COD with different angles reflect the vertical and horizontal forces that characterized the majority of the agility tests. This nature of the agility tests, including its superior duration, makes impossible the CAP maintenance throughout the test derived from the jaw clenching. Players should open the mouth to breathe. Moreover, the complexity of the activation-relaxation of the neuromuscular processes during an agility test and its coordinative requirements could dilute a supposed positive effect of jaw clenching, and this promoting the CAP, in the different moments of the test. In basketball, several studies showed the relationship between strength, vertical jump, sprint and agility tests including COD.^{47–49}

Table 1
Mean differences (t -Test) between both conditions (MG and NO-MG) in jump and agility tests.

	NO-MG		MG		t	p	SWC	TE	Diff	ES	
	Mean	SD	Mean	SD							
Tt-Time1 (s)	2.08	0.08	2.09	0.10	0.072	0.944	0.02	0.02	0.00		
Tt-Time (s)	10.57	0.50	10.32	0.62	-1.731	0.111	0.10	0.14	0.25	-0.44 (small)	†
CMVJ (cms)	35.8	5.3	36.9	5.2	2.197	0.048	1.05	0.50	1.80	0.21 (small)	*†
CMVJ (W)	1160	114	1184	116	2.509	0.027	22.7	9.60	34.6	0.21 (small)	*†
CMVJa (W)	44.6	5.4	46.2	6.6	2.423	0.032	1.08	0.65	2.35	0.26 (small)	*†
CMVJa (W)	1306	142	1324	153	1.896	0.082	28.5	9.45	34.1	0.12 (trivial)	†

MG = mouthguard condition; NO-MG = no mouthguard condition; CMVJ = countermovement vertical jump; CMVJa = countermovement vertical jump with arms; Tt-Time = final time in T-test; Tt-Time1 = time of the first tranche of T-test; W = watts.

* $p \leq 0.05$.

† $\text{diff} \geq \text{swc/te}$.

Table 2

Mean differences (t-Test) in the average power between both conditions (MG and NO-MG) in bench press and leg press tests.

	NO-MG		MG		t	p	SWC	TE	Diff	ES
	Mean	SD	Mean	SD						
BP30 (W)	473	75	486	75	1.168	0.265	15.0	11.3	13.2	
BP40 (W)	470	81	483	87	0.764	0.460	16.2	17.4	13.3	
BP50 (W)	453	93	477	111	2.651	0.021	18.6	9.3	24.7	0.24 (small)
BP60 (W)	408	135	405	100	-0.144	0.888	26.9	14.7	-2.1	*†
LP190 (W)	1641	313	1629	274	-0.463	0.653	62.5	26.2	-12.1	
LP220 (W)	1581	306	1590	320	0.363	0.724	61.3	22.8	8.3	
LP235 (W)	1602	284	1605	283	0.088	0.931	56.8	31.9	2.8	
LP250 (W)	1651	250	1659	257	0.302	0.768	50.1	28.3	8.6	

MG = mouthguard condition; No-MG = no mouthguard condition; BP = bench press; LP = leg press; W = watts.

*p ≤ 0.05.

† diff ≥ swc/te.

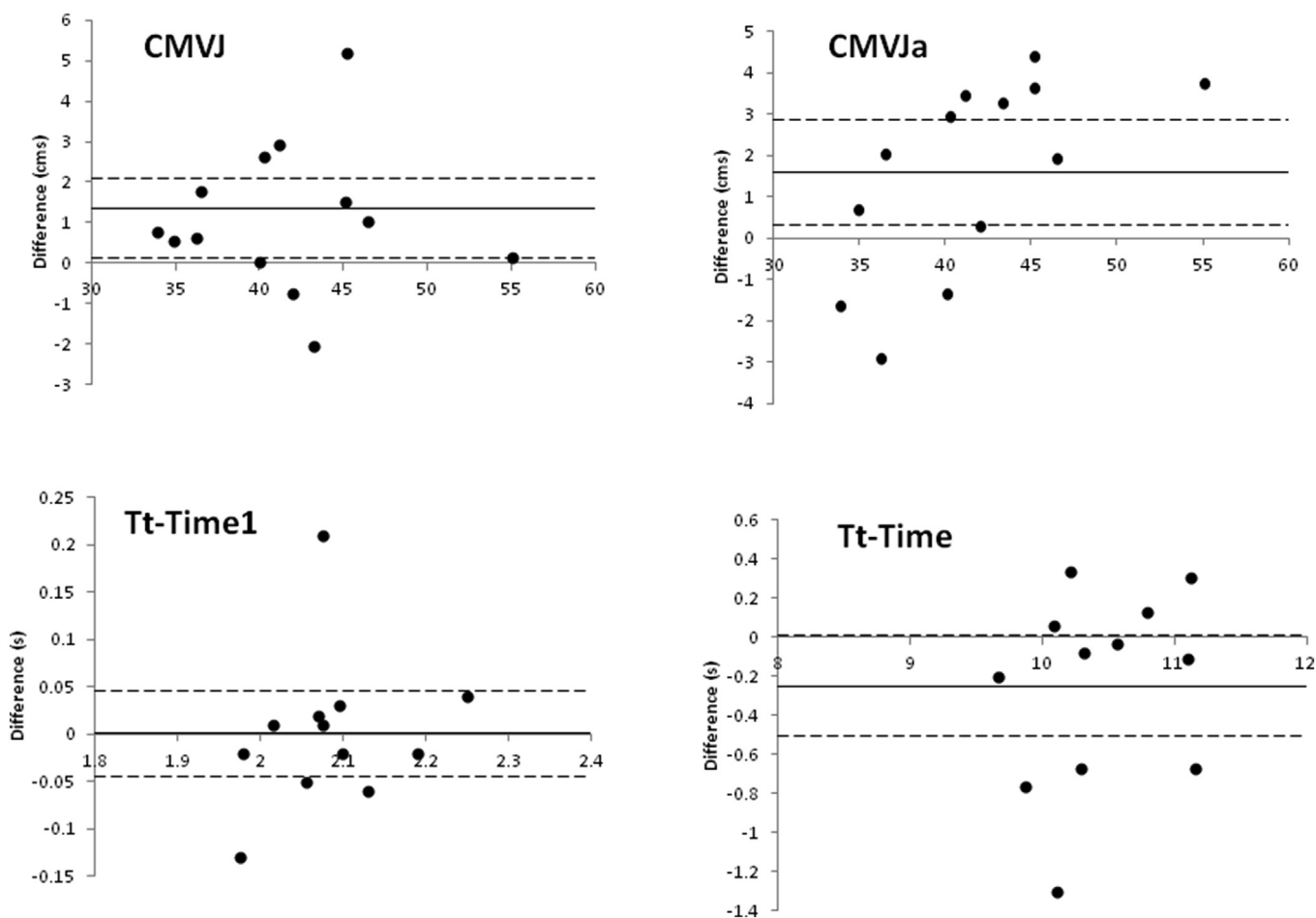


Fig. 2. Bland-Altman plot showing the differences between both conditions (MG and NO-MG) of jump and agility tests.

In the present study, the time of the first tranche of the agility T-test does not reflect the whole first COD phase because the light gates only reflect the time from the start to the first cone. This not happens when considering the total time of the test, which takes into account the full ability for agility movements, and where a lightweight benefit of jaw clenching while using mouthguards can be glimpsed. Indeed, a trend towards improvement in the total time of the agility test can be discerned ($p = 0.111$ and $ES = -0.44$, considered small). Although more evidence is necessary, it seems that the performance in the cumulative braking and acceleration (COD actions) during the test could be reinforced by the promotion

of CAP, partially thanks to the use of the mouthguard (8 out of 12 players were responders in T-test time). The lack of larger differences could be either attributable to the different coordinative demands of the test, beyond the importance of the neuromuscular activity in braking and acceleration phases that, theoretically, could be more CAP sensitive. The differences in the playing position, together with anthropometrics and muscular profile of the players tested, constitute an additional argument for explaining the weak differences between both conditions in the agility T-test. The group of players tested was not homogeneous in age and experience. Therefore neuromuscular characteristics probably differ. Thus,

while there is some evidence of the benefits of CAP on an isolated action like a jump and other type of powerful actions,^{15,27} the benefits of jaw clenching while wearing a mouthguard (if the players use it during the consecutive efforts of the agility T-test) are not clear. Results found in agility test are in line with the study of Queiroz et al.²⁹ that tested this ability using a shuttle-run protocol in female soccer players. Likewise, Golem and Arent,⁵⁰ found no significant differences between the tested conditions in HEX agility test in collegiate male athletes.

Although similar results can be expected from bench-press and leg-press tests, in contrast to other studies reporting power enhancements,^{15,25,51} the results of the present study did not show significant differences between both conditions in power variables using different loads. Though in the most part of the loads the mean was higher in MG condition, the individual response to the use of mouthguards prevails over a generalized benefit. Moreover, the power tests duration makes impossible a continuous jaw clenching and, thus, a continuous RVC and CAP promotion. Another possible source of variability in the results is the different ages and years of experience of the players in weightlifting training (player's age ranged from 17 to 33 years old). Furthermore, no patterns of consistent improvement through the tests were observed in the response of any of the subjects due to the use of a mouthguard. The lack of consistency of the effects of jaw-clenching in elite athletes could also be due to a variable response to a higher neurological activation observed in highly trained subjects.^{52–54} Other studies have reported differences between traditional boil-and-bite and custom-fitted mouthguards.¹⁵ In the present study, one limitation is that only the differences between MG and NO-MG conditions were established. Another limitation is that a third condition (open mouth avoiding jaw clenching) could have been included in the jump and power tests. Furthermore, no comparison between different types of mouthguard was conducted. However, in this study should be noted that the mouthguard fitting process provides a precise adjustment and comfortable design and resulted in good conditions for powerful jaw clenching and taking benefits of the CAP. Therefore, the possible effects of jaw repositioning mouthguards are limited to those requiring a fitting process conducted by an expert dentist ensuring a perfect stabilization of the mandible arch in a long centric position.¹⁴

In conclusion, this study demonstrated that the use of custom-made, bite-aligning mouthguard had an ergogenic effect on jump outcomes and promising results in agility T-Test in professional basketball players. However, results were inconclusive in bench-press and leg-press power production in different loads. This effect has important implications for athletes engaged in anaerobic efforts that cause jaw-clenching, and for those who need to reduce the incidence of dentoalveolar trauma.

The players of a sport requiring strength power, agility and strenuous contact actions like basketball may consider the use of custom-fitted mouthguards not only because they improve safety and the quality of occlusion, but also because it promotes an ergogenic effect in jumping ability and, possibly, in agility. From the results obtained in the present study, the use of this type of mouthguards seems to be more justified in specific power actions on the court than in the strength and conditioning sessions at the gym in well-trained players. Therefore, the present study suggests the idea that customized mouthguards protect the teeth and can also improve sports performance in certain powerful actions during games and training sessions.

Conflicts of interest

The authors have no conflicts of interest relevant to this study.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jesf.2017.11.001>.

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