



Influence of Vertical Dimension of Occlusion on Peak Force During Handgrip Tests in Athletes

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Abstract

Background: In contact sports, such as martial arts, protection from oral injuries is generally recommended. Several authors have focused on the effects of wearing such oral protective gear on sports performances and, in particular, occlusal devices. Although many studies have shown improvements in athletic performance, especially in maximal isometric strength, to date there is still no consensus on the issue.

Objectives: The aim of our study was to evaluate differences in isometric handgrip before and after the application of an occlusal splint (OS) in martial arts athletes.

Methods: A repeated measures within-subjects design was adopted for the study. Twenty-five young martial arts athletes, specifically of taekwondo (n = 9), ju-jitsu (n = 10) and karate (n = 6), were enrolled in order to study the effects on handgrip peak force while wearing an occlusal splint under two different handgrip test conditions (OS: with occlusal splint vs. NO OS: without occlusal splint), testing both dominant and non-dominant hands.

Results: For the dominant hand, comparisons showed a significant increase in handgrip strength under the OS condition (P = 0.01), whereas no significant differences were found for the non-dominant hand for the whole sample. The differences between the OS and NO OS conditions for the dominant hand were present in taekwondo (+8.33%), ju-jitsu (+1.05%) and karate (+2.97%). However, Bonferroni post hoc test showed statistical significance (P = 0.04) only for the taekwondo group.

Conclusions: The benefits found with the occlusal splint were statistically significant only during dominant-hand handgrip tasks. Therefore, realignment of the temporomandibular joint (TMJ) via occlusal splints could play a significant role in increasing handgrip peak force only for the dominant hand.

Keywords: Isometric Strength, Peak Force, Handgrip, Vertical Dimension of Occlusion, Occlusal Splint, Martial Arts

1. Background

Athletes of contact sports, especially martial arts like taekwondo, karate and ju-jitsu, require peculiar kinanthropometric characteristics, as well as high levels of technical skills, agility, strength and coordination in order to obtain the best possible result during competitions (1). Intense physical efforts exerted within short time periods are typical of these athletes (2).

In combat sports, mouthguards are obligatory or optional based on the specific martial art. Scientific research has demonstrated the musculoskeletal connections between the cranio-cervical-mandibular structures and the spinal column and the relative effects on body posture (3-5). In particular, several authors have investigated the relationship between the stomatognathic system and sports performance (6, 7). Scientific literature has examined the

effects of oral devices, such as mouthguards and occlusal splints, on performance variables and exercise capacity (7-15). Some authors have found that by restoring a better occlusal balance with splints, sports performances may be improved (16-21), whereas others have reported contrasting findings (11, 22, 23). D'Erme et al. (16) documented higher performances in every test conducted on athletes wearing occlusal splints, regardless of the sport they practiced.

In athletes wearing a mouthguard, performance measures have demonstrated significant improvements in vertical jump height, as reported by Arent et al. (24). In contrast, the same authors found no difference in submaximal bench press performance or mean power during the Wingate test while wearing a mouthguard or not. Similarly, Cetin et al. (11) evaluated customized mouthguards

on various strength and power endpoints in taekwondo athletes. When athletes wore a custom-fit mouthguard, even though no significant differences were described in some strength measures, such as handgrip test, significant improvements were reported for other parameters, e.g. the Wingate test. Allen et al. (12) assessed CMVJ and bench press 1RM, in a group of trained amateur college students, under 2 test conditions: using a commercial mouthpiece and with no mouthpiece. Although not significant, all results showed some degree of improvement in performances while wearing the mouthpiece.

Literature findings suggest that occlusal splints (OS), which increase VDO, may in fact enhance mandibular stability (25, 26).

Mouthguards are generally recommended in contact sports with an opponent (martial arts, etc.). Nevertheless, many athletes find that oral devices hamper their verbal communication, swallowing and breathing or have concerns in regard to the possible effect on their performance (8, 16, 27).

In this study we aimed to examine whether changes in peak muscular force would occur by applying an occlusal splint to martial arts athletes. Therefore, the aim of our study was to evaluate any changes on isometric handgrip, before and after the application of an occlusal splint, in martial arts athletes.

2. Methods

2.1. Experimental Design

A repeated measures within-subjects design was adopted on a sample of martial arts athletes to study the effects on isometric strength (i.e. peak force) while wearing an occlusal splint during handgrip tests. The participants were studied during two testing sessions, both with (OS) and without (NO OS) the use of the occlusal splint. They were randomly assigned to either condition to avoid the potential confounding effects of fatigue and test-learning.

2.2. Participants

The sample size was determined by inviting sports associations of Palermo city of taekwondo, karate and ju-jitsu to participate, in a voluntary form, in this research. However, only thirty young volunteer athletes were initially enrolled, five of which were excluded from the study since they failed to meet the following inclusion criteria: red- or black-belt status for taekwondo; brown- or black-belt status for karate and ju-jitsu; more than 3 consecutive years of sports activity prior to enrolment. Participants were excluded from the study in the presence of musculoskeletal injury.

A total of 25 eligible subjects (age: 20.9 ± 7.06 years; height: 170.5 ± 5.7 cm; weight: 75.1 ± 7.3 kg) were included in the study. All participants were subjected to both test conditions. All the participants were practitioners of martial arts, specifically taekwondo ($n = 9$), ju-jitsu ($n = 10$) and karate ($n = 6$). All participants provided written consent prior to participating in the study by undersigning an institutionally approved informed consent form. However, written informed consent from a parent or legal guardian was required in the case of minors.

The study received approval by a local ethics committee (minutes no. 1/2018) in conformity with the criteria for the use of persons in research as defined by the Declaration of Helsinki.

2.3. Procedures

Anthropometric measurements were performed on a predetermined date, prior to the collection of the data. Body weight was assessed using a Seca electronic scale (maximum weight recordable 300 kg; resolution 100 g; Seca; Hamburg, Germany) with the participants wearing only undergarments. Height was measured by a standard stadiometer (maximum height recordable 220 cm; resolution 1 mm) with the participants barefoot and standing upright.

Both testing sessions took place before starting a regular training session, at the same time of the day, separated by exactly 48 hours. On day one, each participant was instructed to exert their maximum handgrip strength on an isometric mechanical dynamometer, repeating the same task, alternating their dominant and non-dominant hand. The participants were randomly assigned to perform the tasks with the occlusal splint, at the first session, and without it 48 hours later or vice versa. In the OS condition, participants wore a rigid wax rim (100-mm-long and 10-mm-thick) positioned between their dental arches. The preformed wax device (Zeta[®]-Industria Zingardi srl, Novi Ligure, Alessandria, Italy) is non-rigid with a certain degree of plasticity and a melting point of 59°C. The standardized procedure for maximal handgrip strength task is as follows: Participants were instructed to exert maximum force on the handgrip dynamometer while standing barefoot, feet at shoulders' width apart and head in neutral position gazing forward, arms extended laterally alongside the trunk, (Kern Map model 80K1-Kern[®], Kern & Sohn GmbH, Balingen, Germany). Participants were not allowed make any other ancillary bodily movements during the handgrip task. Each participant exerted 3 seconds of maximal isometric force with each hand, alternating the dominant and the non-dominant hand, for a total of 3 trials with a 3-minute rest between trials on the 2 successive test days

(OS and NO OS, respectively). Trials were scored as the maximal isometric strength expressed in kgf units, using the best performance out of the 3, for both OS and NO OS, for data analysis.

2.4. Statistical Analyses

Mean values and standard deviations were calculated according to standard statistical analysis methods using Statistica Software 12 (StatSoft®, TIBCO® Software Inc., Palo Alto, CA, USA).

Differences between handgrip test data under OS and NO OS conditions, for both hands, were analysed via paired-sample *t*-tests for comparisons. The a priori alpha level was set at $P < 0.05$ for all analyses. Finally, Bonferroni post hoc tests were used to calculate pairwise differences between performances, for each sports group, provided the *P* score was significant.

3. Results

For the dominant hand, a significant increase in handgrip strength resulted from pairwise comparisons for the OS condition ($P = 0.01$), whereas no significant differences were found between OS and NO OS conditions for the non-dominant hand for the entire sample, as reported in Table 1.

Although the differences between the OS and NO OS conditions for the dominant hand were present in taekwondo (+8.33%), ju-jitsu (+1.05%) and karate (+2.97%), when analysed by martial art, Bonferroni post hoc test showed statistical significance ($P = 0.04$) only for the taekwondo group, as shown in Table 2.

Table 1. Values of the Peak Force on Handgrip Tests in All the Sample

	NO OS, kgf	OS, kgf	P Value
DH	37.77 ± 9.15	39.39 ± 9.29	0.01
Non-DH	36.9 ± 9.51	36.44 ± 9.17	N.S.

Abbreviations: DH, dominant hand; Non-DH, non-dominant hand; NO OS, no occlusal splint; OS, occlusal splint.

Table 2. Values of the Peak Force on DH Handgrip Test for Sports Groups

	NO OS, kgf	OS, kgf	P Value
Taekwondo	42.03 ± 9.12	45.53 ± 7.93	0.043
Ju-jitsu	37.31 ± 7.51	37.7 ± 6.79	N.S.
Karate	32.03 ± 9.74	32.98 ± 10.36	N.S.

Abbreviations: DH, dominant hand; NO OS, no occlusal splint; OS, occlusal splint.

4. Discussion

In the past several years, a number of researchers have focused on the effects of wearing occlusal devices considering measures of strength and muscular power in the context of sports performances (11, 12, 18, 19, 21). Although many studies have demonstrated such increases (21), particularly in maximal isometric strength, to date there is still no unanimity on the issue (11, 12).

The hypothesis we aimed to examine in this study was whether changes in peak muscular force, as measured by handgrip strength tests, occur by applying an occlusal splint to martial arts athletes. The differences found comparing the 2 conditions adopted in this study, i.e. NO OS and OS, were statistically significant. In particular, benefits were observed on dominant-hand handgrip tasks while wearing the occlusal splint, whereas no differences between the OS and NO OS condition in the non-dominant hand were recorded. When analyzed by martial arts, the results of each showed a certain degree of increase in isometric strength, albeit reaching statistical significance only for taekwondo. In order to explain as to why our results showed a significant difference only for taekwondo athletes, we tentatively suggest that, respect to the other athletes of this sample, taekwondo athletes probably underwent a training regime with the occlusal splint that induced better long-term adaptations compared to the other athletes (28).

Other authors had previously found that by achieving a more balanced dental occlusion, sports performances may be improved (16, 21), corroborating our findings, herein described.

Occlusal splints entail forward and downward jaw repositioning, thus promoting centric occlusion and optimal mandibular positioning (21). Occlusal splints, in fact, realign the temporomandibular joint (TMJ), thereby reducing occlusal imbalance (14), thus playing a role in motor activity and sports performances (19, 29). Indeed, proper occlusion bolsters muscle balance of jaw muscles extending to the neck and shoulders, as well as those of the lower limbs (30, 31). Our results are in agreement with Churei, who suggests an influence of oral motor functions on maximal grip strength for the dominant hand (32). Several prior studies had reported an increase in isometric muscular strength in subjects wearing an occlusal splint (21, 30, 33) as confirmed by our experimental findings. Nevertheless, not all studies have found this ergogenic effect (34, 35). In fact, in contrast to our findings, Allen et al. showed no difference in strength performance using occlusal splints compared to no splint in symptomatic subjects as well as in physically active men, the latter probably enrolled to study recreationally trained participants (12,

34). Similar, Dunn-Lewis et al. have reported no changes on strength and power in trained males and females, but the limit of their study was to require participants to perform the task naturally, with no specific instructions regarding clenching (36). Kececi et al. (37) found no significant differences in handgrip test, with and without mouthguards, in professional taekwondo athletes. This is probably because mouthguards per se simply protect the teeth and gums from sports-related oral injuries, with no significant increase in vertical dimension of occlusion (VDO), i.e. the distance between dental arches (21).

Our findings lend further support to the notion that occlusal splints may reinforce more effective regulation of efferent motor pathways, most likely via potentiation of afferent stimuli from periodontal mechanoreceptors and muscle spindle fibers, activated during teeth clenching with balance occlusion (13). Indeed, literature findings suggest that by wearing an occlusal splint mandibular stability may be increased (16).

According to one research hypothesis, the improvements in the performance of athletes wearing an occlusal device, that increases VDO and modifies cranio-cervical-mandibular posture, might, in part, be due to an optimization of neuro-muscular coordination (16). However, this improvement, due to the increase in VDO, is not independent of the thickness of the splint. Chakfa et al. (38) investigated the effects of occlusal splints of varying thicknesses on isometric strength of deltoid and cervical muscles finding significant improvements when increasing VDO, up to a certain distance, but reductions in isometric strength thereafter. Likewise, Limonta et al. (39) tested the effects of two kinds of occlusal splints of different thicknesses during isometric contractions of elbow flexors comparing electromyographic and force parameters with respect to a control group wearing no splint. Their results indicated that splint usage produced increases in maximum isometric strength. Moreover, the thicker the splint, the greater the increase. They posit that the thicker splint induces a further lengthening of masticatory muscles and, consequently, a possible reduction in proprioceptive feedback. Indeed, even in healthy subjects, masticatory-muscle repositioning in the vertical axis and jaw repositioning has shown positive ergogenic effects (15, 39, 40).

Another hypothesis that supports our results concerns the Hoffmann-reflex (H-reflex). A previous study had shown increases of the H-reflex activity of lower extremity muscles when subjects performed jaw clenching (41). A recent research has demonstrated similar increases for hand muscle H-reflexes (42). The latter, in turn, could explain the differences found in strength and, in particular, on handgrip testing. All the more, Takahashi et al. (43) demonstrated H-reflex facilitation of forearm muscles during vol-

untary teeth clenching in proportion to the magnitude of biting force. Moreover, Miyahara et al. (41) and Kawakubo et al. (42) identified the role of central motor command of the trigeminal motoneurons innervating the jaw-closing muscles, afferent impulses from periodontal mechanoreceptors as well as muscle spindles in this facilitation.

4.1. Limitations

Admittedly, the main limits of our study regard the small sample size and the single category of sports investigated (i.e. martial arts). Nonetheless, the statistical significance was demonstrated despite these limits. It is necessary to note that the participants used in this study were not professional athletes. For these reasons, the results warrant further investigation to confirm the hypothesis that using an occlusal splint may increase dominant-hand handgrip tasks.

4.2. Conclusions

The benefits found with the occlusal splint were statistically significant only on dominant-hand handgrip tasks. Therefore, realignment of the temporomandibular joint (TMJ) with occlusal splints could play a significant role in increasing handgrip peak force only for the dominant hand. In conclusion, the results seem to indicate that the use of an occlusal splint may benefit performance measures in competitive sports.

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Footnotes

Authors' Contribution: Study concept and design: Antonio Palma, data acquisition; data analysis and interpretation, drafting of the manuscript and critical revision of the manuscript for important intellectual content: Giuseppe Battaglia, Valerio Giustino, Giuseppe Messina; statistical analysis and administrative, technical, material support and study supervision: Daniele Zangla, Matteo Barcellona, Angelo Iovane. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

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