Dental Traumatology

*Dental Traumatology* 2009; **25**: 272–276; doi: 10.1111/j.1600-9657.2009.00780.x

# Influence of custom-made mouth guards on strength, speed and anaerobic performance of taekwondo athletes

**Cem Cetin[1], Ayşe Diljin Keçeci[2], Ali Erdoğan[1], Metin Lütfi Baydar[1]**

[1]Department of Sports Medicine, Faculty of Medicine and [2]Department of Endodontics, Faculty of Dentistry, Suleyman Demirel University, Isparta, Turkey

Correspondence to: Cem Cetin, Iskender Mh. 2016 sk. Bayhanlar Sitesi B/8, 32040 Isparta, Turkey
Tel.: +0090 246 2112374
Fax: +0090 246 2370240
e-mail: cem@med.sdu.edu.tr

Accepted 23 January, 2009

**Abstract** – The purpose of this study was to test the influence of custom-made mouth guards on strength and anaerobic performance of taekwondo athletes. The study included 21 (11 male and 10 female) trained subjects participating in taekwondo. Anaerobic power and anaerobic capacity, isokinetic quadriceps and hamstring strength, handgrip strength, isometric lower extremity and back strength, 20 m sprint time, squat and counter movement jumping height were measured in two randomized conditions: with or without custom-made (CM) mouth guards. No significant differences were observed between the two conditions (with or without CM mouth guards) in 20 m sprint time, jumping tests, handgrip strength, isometric leg or back strength. On the other hand, peak power and average power in Wingate Anaerobic Test and Hamstring Isokinetic Peak Torque significantly increased as a result of wearing mouth guard ($P < 0.05$). In conclusion, we can suggest that taekwondo athletes can use CM mouth guards without any negative effects on their strength and anaerobic performance.

Taekwondo, the Korean martial art, is characterized by fast, high and spinning kicks. The name means 'the art of kicking and punching'. It is the most popular martial art in the world, studied in over 140 countries and practiced by a million participants of all ages every day (1).

Sport types having direct contact with rival (taekwondo, etc.) seems to be more effective on the increase of dental trauma compared with the non-contact sports (volleyball, etc.) with the 24% and 8% rates respectively (2, 3). These rates are belonging to the athletes which did not use mouth guards. The majority of injuries affect the upper jaw, with the maxillary incisors being most prone to injury, often accounting for as many as 80% of all cases (4, 5).

The damage caused by a traumatic impact to the dento-alveolar structures, can also result in facial bone fracture and more seriously neck or brain injury resulting from increased cranial pressure and deformation. The most common cause of concussion in sport is a blow to the mandible (6). Temporomandibular joint (TMJ) is also threatened by contact sports. Sports-related TMJ injuries may be discovered later or may result in permanent deformities if not diagnosed at that time or treated properly (7).

CM mouth guards are made using an impression of the individual's teeth to fit the individual according to specifications provided by a dental professional. This type of mouth guards has many advantages compared to the stock and boil and byte types. They show optimal comfort and wear ability (8, 9) and they are reported to have no negative effect on elite taekwondo athletes' satisfaction and are protective against orofacial injury (10–12).

Although the necessity of their use was underlined by many authors, sport dentists or Olympic committees and the awareness rates are relatively high (71.9%), many athletes find them difficult to tolerate in terms of verbal communication and breathing (13) or have a suspicion of a possible effect on their performance (12, 14). For this reason, additional studies are still necessary to prove their advantages and their comfortable use without a negative effect on performance.

The assessment of strength and power is fundamental to athletic and human performance. Accurate knowledge of an individual's present level of muscular strength is important for occupational functional capacity evaluation. Nevertheless, data concerning the impact of mouth guards on performance of athletes are scarce. Furthermore, most of these studies interested in effect of mouth guards to airflow dynamics and ventilation (15–18) and oxygen consumption in high-intensity exercise (12, 16, 17, 19).

Type of activity in taekwondo imposes high demands on short-term anaerobic performance capacity and ability to recover (20). Therefore, anaerobic abilities like strength, speed and reaction time are also of prime importance.

This study sought to investigate the influence of CM mouth guards on anaerobic abilities like strength, speed and various parameters generally associated with performance of taekwondo athletes.

## Material and methods

### Subjects

Twenty-one voluntary elite taekwondo athletes (11 male and 10 female), who never wore a CM mouth guard, participated in the study. They were aged 15–18 (17 ± 1.34) years, had a training history of 5–8 (7.07 ± 2.84) years, and trained 9–10 h per week. Before testing, they were informed of the test procedures and were required to provide written consent. In addition, immediately before the test, all subjects were examined by a physician to determine their health status. To eliminate learning bias, the trials were performed randomly with and without mouth guards. Each athlete was tested after 24 h following the first test day. All procedures were approved by the Local Ethical Committee of Suleyman Demirel University School of Medicine.

### Fabrication of mouth guards

Impressions were taken by standard trays using alginate impression material and poured with dental stone to get the working models. Ethyl vinyl acetate sheets (Ultradent, Salt Lake City, UT, USA) (0.15 × 5 × 5 inch) were used to fabricate the mouth guards. Sheets were placed in a thermalforming machine (MiniSTAR; Scheu-Dental, Iserlohn, Germany). They were softened for a period of 150 s and vacuumed 100 s under pressure (2 bar). Following the contouring of the mouth guards on the models, they were tried in the mouth of each athlete in terms of margin adaptation, stability and retention.

### Test procedures

*Anaerobic power*

Anaerobic power and capacity were determined using the Wingate Anaerobic Test (WnAT). A Monark cycle ergometer fitted with a photoelectric cell to count the number of revolutions of the pedals was used. Seat height was adjusted to suit the subject and toe clips were used to prevent the feet from slipping off the pedals. Subjects warmed up by pedalling for three minutes against a 2 kpm load. At the end of each minute, they were required to pedal as fast as possible against the actual relative resistance that they would be working against for a 5-s duration. During the 3-min test period, the subjects were instructed to pedal as fast as possible from the beginning of the test and to try to maintain maximum pedalling speed throughout the 30 s period. At the beginning of the test, the subjects were instructed to pedal as fast as possible against unloaded resistance which was increased to a predetermined load within 3 s. The resistance applied was adjusted relative to body weight (0.075 × body weight in kg) (21). When this load was reached, the pedal revolutions were recorded mechanically for 30 s by a cycle monitor. Anaerobic power was calculated as the highest power output reached over a 5-s interval, and anaerobic capacity was calculated as the total work output during the 30 s test (22).

*Isokinetic measurements*

Isokinetic dynamometry (Humac Norm, CSMI, Boston, USA) was performed to evaluate quadriceps and hamstring peak torque and work strength of the dominant leg. Leg dominance was identified by asking the subject to kick a ball. Maximal concentric force was measured by determining maximal concentric force moment (peak torque) during flexion and extension. The dynamometer was calibrated as part of the regular schedule for maintenance of equipment used for this testing device (23).

The knee to be tested was placed on the knee flexion extension plate of the isokinetic device, according to the manufacturer's instructions for isolating knee flexion and knee extension, and was secured with Velcro straps. The length of the dynamometer was adapted to the length of the knee of each subject. To familiarize themselves with the testing device, subjects were instructed to perform three active repetitions of knee movement ranging from maximal flexion to maximal extension. Standard stabilization strapping was placed across the distal thigh and chest, and placements were limited to grasping the waist stabilization strap. Before the testing session started, the subject was allowed a 10-min warm up at a light intensity (less than 50 W) on a cycle ergometer, followed by a 30-s stretch of the quadriceps and hamstring muscles. The same investigator performed all the tests. Subjects were instructed to give 100% effort and received positive feedback during testing. They were allowed three submaximal contractions of the quadriceps and hamstring muscle group at the beginning of the test condition to familiarize themselves with the test conditions. They were given five maximal contractions at 60° $s^{-1}$ and 20 maximal contractions at 240° $s^{-1}$ for each test condition. The best peak torque and power contraction of the five and 20 test contractions for each test condition were collected for data analysis. Between each condition, the subjects were allowed to rest for 1 min and gravitational corrections were performed.

*Handgrip strength*

Handgrip strength was measured with the Takei handgrip dynamometer (Takei Scientific Instruments, Tokyo, Japan). The dominant hand was used for testing. Hand dominance was ascertained from the subject. The position used was 45° of shoulder flexion with the elbow extended. After one practice trial of a firm grip, the subject was asked to grip firmly and release. The measurement was recorded in kg. Subjects were told to grip the dynamometer and give a maximal effort for 3 s. The best score of following three repetitions was recorded.

*Assessment of isometric leg strength*
Subjects, wearing training shots, stood on the foot-plate of the Takei Back and Leg dynamometer (Takei Scientific Instruments) with the scapulae and buttocks positioned flat against a wall. The back of the foot-plate was approximately 15 cm from the wall. Subjects flexed the legs, sliding down the wall until the leg extension angle equalled 135°. Subjects then reached down with the elbows fully extended. The pull-bar of the dynamometer was placed in the hands and the chain length was adjusted appropriately. Subjects were instructed to extend the legs with maximal effort, pulling the bar simultaneously without 'jerking'. The highest score from three was recorded.

*Assessment of isometric back strength*
Subjects stood on the foot-plate of the Takei Back and Leg dynamometer (Takei Scientific Instruments), initially in the same manner as for the measurement of leg strength. The legs were, this time, kept straight and the back was flexed at the hip. Flexion continued until, with fully extended elbows, the tips of the index fingers reached the patellae. The pull-bar of the dynamometer was then placed in the hands and the chain length was adjusted. A reverse grip was adopted for the measurement of back strength to deter the use of shoulder muscles during the 'pull'. Subjects were also instructed to keep the head up during measurement. The highest score from three pulls was recorded.

*20 m sprint time*
Sprint measurements were carried out by using telemetric photoelectric cells placed at 0 and 20 m (Chronometre Prosport ESC TX02, Tümer Engineering, Ankara, Turkey). The athletes stood 1 m behind the starting line, started on a verbal signal, and then ran as fast as they could to complete the 20 m distance. They repeated the test thrice with 30-s rest periods in between. The fastest of 3 trials were recorded.

*Jumping tests*
Jumping capacity was evaluated using Takei jump meter (Takei Scientific Instruments). The athletes performed a squat jump (SJ) and a counter movement jump with the arms kept akimbo to eliminate any contribution from them. The best result of three tests was recorded for further analysis.

*Statistical analysis*
Two related samples tests (Wilcoxon) were used to compare the repeated measures on values obtained with and without mouth guards. A $P$-value of $< 0.05$ was considered significant.

## Results

The mean values for Isokinetic measurements, WnAT, 20 m sprint time, jumping tests, handgrip strength, isometric leg and back strength, are summarized in Table 1. No significant differences were observed between the two conditions (with or without CM mouth guards) in 20 m sprint time, jumping tests, handgrip strength, isometric leg or back strength. However, peak power (PP) and average power (AP) in WnAT and Hamstring Peak Torque (PT) were detected to be significantly increased as a result of wearing mouth guard ($P < 0.05$). Individual isokinetic hamstring strength and WnAT results are given on Table 2.

## Discussion

In a previous study, we had demonstrated that wearing CM mouth guards do not significantly affect aerobic performance capacity on elite taekwondo athletes (19). Further investigation including anaerobic performance capacity should be performed to accomplish the data, because taekwondo athletes tended to show high anaerobic capability (1, 20). Physiological profiles of elite young taekwondo athletes were reported to show them to possess above average anaerobic abilities, aerobic fitness, strength, and flexibility and low levels of body fat compared with population norms (20). Marković et al. (24) suggested that the performance of taekwondo athletes primarily depends on the anaerobic alactic power, explosive power expressed in the stretch-shortening cycle movements, agility and aerobic power.

*Table 1.* Mean values and standard deviations (SD) of the measurements in all athletes ($n = 21$) with (M) and without mouth guard (WM)

| Type of the test (unit) | WM (mean ± SD) | M (mean ± SD) | $P$-value |
|---|---|---|---|
| SJ (cm) | 43.18 ± 5.87 | 43.47 ± 6.21 | 0.218 |
| CMJ (cm) | 47.18 ± 6.43 | 47.06 ± 6.34 | 0.715 |
| Handgrip (kg) | 34.25 ± 7.49 | 34.28 ± 9.06 | 0.981 |
| Isometric leg strength (kg) | 91.79 ± 34.00 | 93.09 ± 35.15 | 0.352 |
| Isometric back strength (kg) | 95.79 ± 32.42 | 96.68 ± 30.60 | 0.443 |
| 20 m sprint time (s) | 3.53 ± 0.35 | 3.54 ± 0.35 | 0.798 |
| WnAT peak power (W $kg^{-1}$) | 9.09 ± 1.49 | 9.54 ± 1.52 | 0.013* |
| WnAT average power (W $kg^{-1}$) | 7.01 ± 0.88 | 7.24 ± 0.99 | 0.024* |
| Peak torque-Quadriceps (Nm) | 209.00 ± 20.25 | 207.18 ± 24.83 | 0.955 |
| Peak torque-Hamstring (Nm) | 146.43 ± 16.82 | 154.29 ± 21.47 | 0.014* |
| Ratio Hamstring/Quadriceps | 72.43 ± 10.2 | 75.93 ± 12.27 | 0.019* |
| Fatique Index-Quadriceps | 23.00 ± 13.38 | 21.00 ± 12.21 | 0.268 |
| Fatique Index-Hamstring | 21.76 ± 12.40 | 22.00 ± 13.35 | 0.842 |

*Significantly different.

*Table 2.* Isokinetic Hamstring Strength and Wingate Anaerobic Test values of athletes

| | Isokinetic Hamstring Strength (Nm) | | | Wingate Anaerobic Test (W $kg^{-1}$) | | |
|---|---|---|---|---|---|---|
| Athletes no. | PT-WM | PT-M | Difference | PP-WM | PP-M | Difference |
| 1 | 173 | 188 | 15 | 10.53 | 10.53 | 0 |
| 2 | 143 | 147 | 4 | 8.63 | 8.65 | 0.02 |
| 3 | 137 | 173 | 36 | 11.6 | 11.65 | 0.05 |
| 4 | 134 | 131 | −3 | 8.24 | 8.63 | 0.39 |
| 5 | 125 | 134 | 9 | 9.23 | 10.22 | 0.99 |
| 6 | 134 | 152 | 18 | 7.09 | 8.85 | 1.76 |
| 7 | 158 | 160 | 2 | 6.84 | 6.75 | −0.09 |
| 8 | 146 | 158 | 12 | 8.4 | 8.73 | 0.33 |
| 9 | 164 | 158 | −6 | 10.68 | 11.71 | 1.03 |
| 10 | 164 | 185 | 21 | 10.39 | 10.91 | 0.52 |
| 11 | 131 | 140 | 9 | 8.61 | 9.46 | 0.85 |
| 12 | 167 | 191 | 24 | 10.46 | 10.19 | −0.27 |
| 13 | 110 | 116 | 6 | 6.82 | 6.84 | 0.02 |
| 14 | 167 | 149 | −18 | 6.63 | 7.9 | 1.27 |
| 15 | 167 | 173 | 6 | 9.14 | 10.11 | 0.97 |
| 16 | 134 | 131 | −3 | 8.97 | 10.14 | 1.17 |
| 17 | 152 | 161 | 9 | 11.35 | 10.5 | −0.85 |
| 18 | 131 | 131 | 0 | 8.46 | 8.56 | 0.1 |
| 19 | 140 | 143 | 3 | 8.75 | 7.56 | −1.19 |
| 20 | 146 | 137 | −9 | 9.96 | 10.5 | 0.54 |
| 21 | 152 | 182 | 30 | 10.26 | 11.84 | 1.58 |
| Mean | 146.43 | 154.29 | 7.86* | 9.09 | 9.54 | 0.43** |

PT-WM, peak torque without mouth guard; PT-M, peak torque with mouth guard; PP-WM, peak power without mouth guard; PP-M, peak power with mouth guard.
$^{*}P = 0.014$; $^{**}P = 0.013$.

Anaerobic power and capacity represent energy production from phosphagen and from combined phosphagen use and glycogenolysis respectively (25).

The vertical jump (VJ) test is the primary test to assess muscular power in the legs (26). Unfortunately, there are a variety of procedures and types of VJ reported in different studies (27). There are two primary forms of the VJ test: the SJ and the counter-movement jump (CMJ). In the SJ, subjects lower themselves into a squat position and after a brief pause, jump upwards as quickly and as high as possible. No down motion is allowed immediately prior to jumping upwards. In contrast, in the CMJ subjects start in a standing position, drop to a squatting position (counter-movement), and with no pause jump upwards as high as possible from the bottom of the squat. SJ and CMJ are the basic tests of speed strength and they can be applied well to many sport events. Performance in these tests describes jumping ability and explosive force production of the lower extremities (28).

It is a positive finding that wearing CM mouth guards do not alter the most of the anaerobic test scores like 20 m sprint time, jumping tests, handgrip strength, isometric leg or back strength. In a related study, it was reported that force, velocity and power output measured during explosive exercise were not significantly altered by wearing a mouth guard (12).

WnAT is intended to measure anaerobic power of the lower body, it has been accepted in laboratories around the world to assess muscle power, muscle endurance and fatigability (29). It is an exhausting test that should be used with a population accustomed to strenuous vigorous exercise. The resulting data is an indirect measure of the ability of a subject's lower body to produce high levels of power. Test results are divided into six equal periods of 5-s where PP, in Watts, is the highest AP output during any one 5-s period and average power is the mean of all six 5-s periods (26).

Isokinetic exercise represents a match between mechanically imposed velocity and the subject's movement (e.g. knee extension). The reliability of isokinetic testing has been measured repeatedly and found to be high (26). A wide range of performance variables are available for isokinetic data analysis. Of these, three are particularly important for strength and power testing. Peak torque is defined as the product of mass, acceleration and lever arm length. It is the maximum torque produced anywhere in the ROM and is easily identified as the top of the torque curve (i.e. graphic display of dynamic torque vs position). While peak torque provides the exercise professional with information regarding the greatest torque output of the limb tested, and is an excellent indicator of the subject's maximum strength level.

In this study, we have detected that WnAT scores and concentric Hamstring PT values have increased by wearing CM mouth guards. To the best of our knowledge, only one study explored the influence of increase in the vertical dimension of occlusion on explosive performance in athletes without occlusion problems (30). The authors observed that performance in the VJ was significantly increased by 5% when wearing a bite positioner (increase in vertical dimension of around 2–3 mm), but with no significant increase in lower limb strength. This discrepancy could be related to the non-randomized experimental conditions (systematically, first without and second with a mandibular orthopaedic repositioning appliance), subjects who improved their VJ performance by improved coordination. In addition effect of mandibular orthopaedic repositioning appliances on the increased athletic performance like muscular strength has been reported also in other previous studies (31, 32). The results of Bourdin et al. (12) did not corroborate the hypothesis that increasing the vertical jaw dimension in subjects without occlusion problems with maxillary mouth guards would increase strength during explosive exercise. On the contrary, in this study we have detected significant higher WnAT and Hamstring PT values by increasing the vertical jaw dimension with CM mouth guards. Furthermore, in a recent study, although von Arx et al. (33) have reported statistically significant higher scores ( = improved performance) with the CM mouth guard on the cyclo-ergometer compared to without, we cannot rule out the higher motivation during exercise testing with a mouth guard, like the authors have also mentioned. In addition, to eliminate the possibility of training effects as a reason for the test results we performed the measurements randomly without and with the mouth guard as mentioned in the previous studies (19, 33). On the other hand, a blinded placebo-controlled study was not feasible in this context. For this reason, although we have also detected significantly increased test values, the explanation that this increase is due only to mouth guards is questionable.

While the upper body (handgrip) and leg muscles isometric strength test values were unchanged with or without using mouth guards, performance improvement with using mouth guard was detected only for lower extremity dynamic strength tests. On the other hand, the limitation of this study was the absence of the upper extremity dynamic tests. Thus, there is a need for further studies evaluating upper body dynamic strength with and without using mouth guard.

In this study, our main target was to investigate if there is any negative effect of the use of mouth guards on the performance of taekwondo athletes. Thus, we did not seek for the presence of any occlusion problem among the athletes in the study group. For this reason, we cannot suggest that the use of CM mouth guard provides healing of occlusion problem, in consequence improvement in muscle strength. On the other hand, in respect of our results, we can suggest that improvement in the WnAT and Hamstring PT values may be associated with the increase in vertical dimension. However, this statement needs to be supported with other studies, investigating the influence of the use of mouth guard and similar appliances on athletic performance of athletes with and without occlusion problems.

## Conclusion

Wearing a CM mouth guard does not affect the main anaerobic performance parameters generally associated with performance of taekwondo athletes. It can be concluded that taekwondo athletes can use CM mouth guards without any negative effects on their strength and anaerobic performance.

## References


1. Melhim AF. Aerobic and anaerobic power responses to the practice of taekwon-do. Br J Sports Med 2001;35:231–5.
2. Scott J, Burke FJ, Watts DC. A review of dental injuries and the use of mouthguards in contact team sports. Br Dent J 1994;176:310–4.
3. Keçeci AD, Eroğlu E, Baydar ML. Dental trauma incidence and mouthguard use in elite athletes in Turkey. Dent Traumatol 2005;21:76–9.
4. Cavalleri G, Zerman N. Traumatic crown fractures in permanent incisors with immature roots: a follow-up study. Endod Dent Traumatol 1995;11:294–6.
5. Davis GT, Knott SC. Dental trauma in Australia. Aust Dent J 1984;29:217–21.
6. Newsome PR, Tran DC, Cooke MS. The role of the mouthguard in the prevention of sports-related dental injuries: a review. Int J Paediatr Dent 2001;11:396–404.
7. Camp J. Emergency dealing with sports-related dental trauma. JADA 1996;127:812–5.
8. DeYoung AK, Robinson E, Godwin W. Comparing comfort and wearability: custom made vs. self adapted mouthguards. J Am Dent Assoc 1994;125:1112–8.
9. Eroğlu E, Keçeci AD, Baydar ML. Elite taekwondo athletes' satisfaction with custommade mouthguards. Dent Traumatol 2006;22:193–7.
10. Bemelmanns P, Pfeiffer P. Shock absorption capacities of mouthguards in different types and thicknesses. Int J Sports Med 2001;22:149–53.
11. Padilla R. Overcoming objections: providing professionally made custom mouthguards. Dent Today 2000;19:84–9.
12. Bourdin M, Brunet-Patru I, Hager PE, Allard Y, Hager JP, Lacour JR et al. Influence of maxillary mouthguards on physiological parameters. Med Sci Sports Exerc 2006;38:1500–4.
13. Ferrari CH, Ferreria de Mederios JM. Dental trauma and level of information: mouthguard use in different contact sports. Dent Traumatol 2002;18:144–7.
14. Gardiner DM, Ranalli DN. Attitudinal factors influencing mouthguard utilization. Dent Clin North Am 2000;44:53–65.
15. Amis T, Di Somma E, Bacha F, Wheatley J. Influence of intraoral maxillary sports mouthguards on the airflow dynamics of oral breathing. Med Sci Sports Exerc 2000;32:284–90.
16. Delaney JS, Montgomery DL. Effect of noncustom bimolar mouthguards on peak ventilation in ice hockey players. Clin J Sport Med 2005;15:154–7.
17. Francis KT, Brasher J. Physiological effects of wearing mouthgards. Br J Sports Med 1991;25:227–31.
18. Luke R, Taylor G, Kaplan R. The effect of a mouthguard on airflow. Diastema 1982;10:56–7.
19. Keçeci AD, Cetin C, Eroglu E, Baydar ML. Do custom-made mouth guards have negative effects on aerobic performance capacity of athletes? Dent Traumatol 2005;21:276–80.
20. Heller J, Peric T, Dlouha R, Kohlikova E, Melichna J, Novakova H. Physiological profiles of male and female taekwon-do black belts. J Sports Sci 1998;16:243–9.
21. Adams GM. Exercise physiology laboratory manual. Dubuque, IA: Wm C Brown Publishers; 1990.
22. Vandewalle H, Peres G, Monod H. Standard anaerobic exercise test. Sports Med 1987;4:264–89.
23. Ronkonkoma NY. Cybex Norm Int Inc: Testing and rehabilitation system: pattern selection and set up: automated protocols. User's guide. New York: Blue Sky Software Corporation; 1995.
24. Markovic G, Misigoj-Durakovic M, Trninic S. Fitness profile of elite Croatian female taekwondo athletes. Coll Antropol 2005;29:93–9.
25. Jacobs I, Bar-Or O, Karlsson J et al. Changes in muscle metabolites in females with 30 seconds of exhaustive exercise. Med Sci Sports Exerc 1982;14:457–60.
26. Lee Brown E, Weir JP. Asep procedures recommendation I: accurate assessment of muscular strength and power. J Exerc Physiol 2001;4:1–21.
27. Harman EA, Rosenstein MT, Frykman PN, Rosenstein RM, Kraemer WJ. Estimates of human power output from vertical jump. J Appl Sport Sci Res 1991;5:116–20.
28. Aura O, editor. Testing of force and speed production Finland: Newtest Oy; 2000.
29. Inbar O, Bar-Or O, Skinner JS. The Wingate Anaerobic Test. Boston: Human Kinetics Publishers; 1996.
30. Bates RE Jr, Atkinson WB. The effects of maxillary MORA's on strength and muscle efficiency tests. J Craniomandibular Pract 1983;1:37–42.
31. Yates JW, Koen TJ, Semenick DM, Kuftinec MM. Effect of a mandibular orthopedic repositioning appliance on muscular strength. J Am Dent Assoc 1984;108:331–3.
32. Schubert MM, Guttu RL, Hunter LH, Hall R, Thomas R. Changes in shoulder and leg strength in athletes wearing mandibular orthopedic repositioning appliances. J Am Dent Assoc 1984;108:334–7.
33. von Arx T, Flury R, Tschan J, Buergin W, Geiser T. Exercise capacity in athletes with mouthguards. Int J Sports Med 2008;29:435–8.