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Do custom-made mouth guards have negative effects on aerobic performance capacity of athletes?

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Abstract – Mouth guards are considered an essential part of equipment for athletes participating in contact sports. The purpose of this study was to evaluate the effect of custom-made mouth guards on the ventilatory gas exchange effects of taekwondo athletes. The subjects were 22 elite athletes aged between 14 and 17 years. To determine the effect of mouth guard use during exercise, oxygen consumption (VO_2) was measured with a portable gas analysis system while an exercise tolerance test with a shuttle run test protocol was performed. Values with and without mouth guard were compared. Wilcoxon ranks test was used for the statistical analysis. The results show that wearing mouth guards has no significant effect on maximal oxygen uptake (VO_{2max}), minute ventilation (VE), tidal volume (VT) and respiratory exchange ratio (RER) while performing maximal exercise ($P > 0.05$). In conclusion, taekwondo athletes can use custom-made mouth guards without negative effects on their aerobic performance capacity.

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In Turkey, martial arts significantly increased in the mid-1980s, as in USA, and ranks second with 73 000 licensed athletes after football. Although several studies have reporting injury rates pertaining to the body parts of taekwondo athletes (1–5), the incidence of dental trauma has not been investigated comprehensively. One study reported dental injury incidence in martial arts at 32.1% (6) while another reported a 24% incidence in taekwondo players (7). As a preventive measure, mouth guards are designed to be worn over teeth and absorb the energy associated with any impacts; thus minimizing the occurrence and severity of dental and other oral injuries (8). With the introduction and widespread use of mouth guards, there has been a reduction in sports-related dental injuries (7–10). Ferrari and Ferreria de Mederios (6) reported awareness rates of 71.9% for martial arts but use of these protectors is still limited.

There are three types of mouth guards. 'Stock' and 'boil-and bite' types are known by the athletes, while type III, custom-made mouth guards are not well known (10).

Oxygen consumption increases with activity and there is an upper limit during exercise requiring maximal effort. This upper limit is defined as maximal oxygen uptake (VO_{2max}), which is the maximum rate at which an individual can utilize oxygen while breathing air at sea level (11). It has traditionally been used as the basic standard of cardiorespiratory fitness, as it is considered to be the single physiological variable that best defines the functional capacity of the cardiovascular and respiratory systems. However, it is more appropriate to consider it as an indicator of endurance performance potential (12).

The use of a maximal multi-stage 20-m shuttle run test to predict VO_{2max} was first proposed by Leger and Lambert (13). A maximal multistage 20-m shuttle run test was designed to determine the maximal aerobic power of schoolchildren, healthy adults attending fitness class and athletes (14). This test is now accepted as a valid method of estimating the maximal oxygen uptake indirectly (15). With the rapid development of technology, portable, automated and online, breath-by-breath gas analysis systems are available today. These systems allow the continuous measurement of gas volumes and concentrations and the immediate display of related information online supported with a software and PC. Therefore, the efficiency of the gas analysis procedure increases noticeably (16).

The aim of the present study was to examine the effect of custom-made mouth guards on the ventilatory gas exchange and maximal oxygen uptake values of taekwondo athletes during maximal exercise test.

Fig. 1. Thermal forming machine used for the fabrication of mouth guards.

Material and methods

Subjects

Twenty-two voluntary elite taekwondo athletes (11 male, 11 female, members of the Turkish young national team), who never wore a custom-made mouth guard, participated in the study. They were aged 14–17 (16 ± 1.11) years, had a training history of 4–8 (6.77 ± 2.53) 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 48 h following the first exercise.

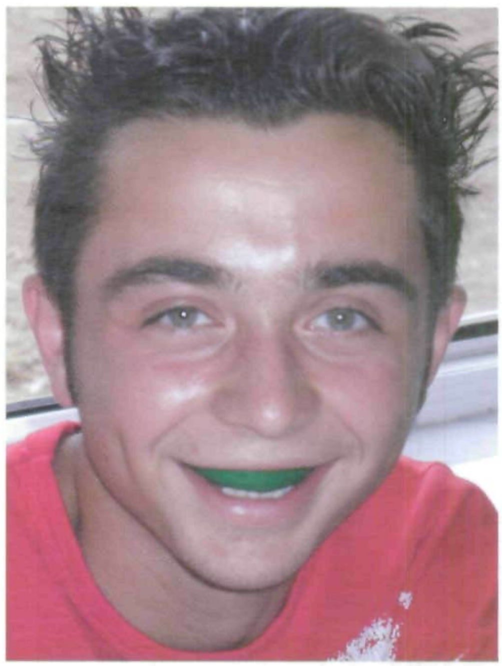

Fig. 2. Custom-made mouth guard in the mouth of the athlete.

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 (EVA) sheets (Ultradent, Salt Lake City, UT, USA) (0.15 × 5 × 5 inch) were used to fabricate the mouth guards. Sheets were placed in a thermal-forming machine (MiniSTAR; Scheu-Dental, Iserlohn, Germany). They were softened for a period of 150 s and vacuumed 100 s under pressure (2 bar) (Fig. 1). 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 (Fig. 2).

Portable gas analysis system

The respiratory gas exchange parameters were measured using a portable gas analysis system (Oxycon Mobile; Jaeger, Hoechberg, Germany) (Fig. 3). The expired gas was sampled continuously 'breath-by-breath' for the measurement of oxygen consumption. Volume and gas calibration of the gas analysis system was checked immediately before and after each test with standard calibration gases (16% O_2 and 4% CO_2). Volume calibration was checked via a 2-l air pomp which was in a receiver unit. A heart rate (HR) monitor (Polar Electro Sportester, Kempele, Finland) was secured around the subject's chest and a portable gas analyzer was attached to a chest belt. The gas analyzer was interfaced with a personal portable computer to calculate and store breath-by-breath ventilatory gas exchange variables

Fig. 3. Portable gas analysis system used during shuttle run test.

Fig. 4. Breath-by-breath data collected through a face mask and sent to a host computer system via wireless transmission (telemetry).

(VO_2, VCO_2, VE, Vt, RER). HR recording was interfaced with the gas analyzer using a short-range radio telemetry system (Fig. 4).

VO_2 values were considered maximal when two of the following three criteria were met:

1. VO_2 plateau defined as a failure of oxygen uptake to increase by >2.0 ml min^{-1} kg with running speed increase.
2. HR > 95% from the predicted individual of maximum (220−age).
3. RER > 1.05 (16).

20 m shuttle run test

Each athlete was tested with and without mouth guards using the 'shuttle run test' according to Leger et al. (14). In this test subjects had to run back and forth on a 20-m course gymnasium and touch the 20 m line; at the same time a sound signal was emitted from a prerecorded tape. Frequency of the sound signals was increased 0.5 km h^{-1} each minute from a starting speed of 8.5 km h^{-1}. Subjects were given verbal encouragement throughout the test and they continued until they could not reach the cones three times consecutively after the bleep sounds (Fig. 3).

Statistical analysis

Two related samples tests (Wilcoxon) were used to compare the repeated measures on values obtained with and without mouth guards. A paired *t*-test was used to determine the significance between gender and any of the measured variables. $P < 0.05$ was considered significant.

Results

None of the ventilation and gas exchange values was significantly changed as a result of wearing mouth guard ($P > 0.05$; Table 1). Gender had no significant effect on the measured variables ($P > 0.05$; Table 2).

Discussion

A universal finding of dental trauma is that most of the injuries affect the upper jaw, with the maxillary incisors being most prone to injury, often accounting for as many as 80% of all cases (7, 17, 18). Dental trauma incidence of taekwondo athletes in Turkey was reported to be 24% (7). To reduce this rate, maxillary mouth guards can be protective

Table 1. Mean values and standard deviations (SD) of the measurements in all athletes ($n = 22$) with (M) and without mouth guard (WM)

	WM	M	P-value
HR_{max} (beat min^{-1})	198 ± 1.41	198 ± 1.83	0.910
VO_{2max} (ml min^{-1} kg^{-1})	51.79 ± 2.12	52.73 ± 1.81	0.846
VE_{max} (l min^{-1})	106.32 ± 5.75	108 ± 4.41	0.664
Vt_{max} (l min^{-1})	1.91 ± 0.08	1.88 ± 0.07	0.733
RER	1.11 ± 0.01	1.12 ± 0.01	0.649

against orofacial trauma as recommended by many authors (10, 19, 20). Most of the athletes had a prejudice against mouth guard usage in that it would negatively affect their performance and hinder kiyaping (yelling in taekwondo) and breathing. All of them were aware of stock or boil and bite types and seven of them had used them, but none of them was aware of custom-made ones. Our results showed that the prejudice against mouth guards was possibly because of the previous experiences with 'stock' or 'boil and bite' types. As custom-made mouth guards are superior to the other two types, which are bulky and lack proper retention (10, 21, 22), they were chosen for this study.

Another important factor is mouth guard thickness in terms of energy absorption. Westerman et al. (23) recommended a thickness of EVA material around 4 mm and added that increased thickness results in less comfort and dissatisfaction of the user. A similar EVA material (0.150 inch = 3.810 mm) was selected for this study.

The above-mentioned studies have investigated physical properties of mouth guards. Few studies have researched the effects of mouth guards on physiological systems. The measurement of anaerobic and aerobic capacity determines the performance of the athletes as regards exercise physiology. VO_2 at maximal exercise is considered the best index of aerobic capacity and cardiorespiratory function. Maximal VO_2 is defined as the point at which no further increase in measured VO_2 occurs despite an increase in work rate (a plateau is reached) during graded exercise testing (11, 24, 25). Direct measures of VO_2 are reliable and reproducible and provide the most accurate assessment of functional capacity. This method was reported to be helpful in evaluating the functional capacity during exercise (16, 26, 27).

The energy demands of the event and physiological responses of taekwondo athletes are not well documented in the exercise physiology and sports medicine literature (28). Thompson and Vinueza (29) reported only a minimal effect of taekwondo training on cardiorespiratory fitness in contrast to Drobnic et al. (30), who reported high aerobic and anaerobic capacities of competitors. Maximum oxygen uptake in the males (54 ml min^{-1} kg^{-1}) reported by Heller et al. (28) was higher than that reported by Thompson and Vinueza (29; i.e. 44 ml min^{-1} kg^{-1}), but lower than that observed by Drobnic et al. (30; i.e. 57–63 ml min^{-1} kg^{-1}). Several physiological characteristics of elite female and male taekwondo athletes were reported by Heller et al. (28): HR_{max} (188 ± 8 and 183 ± 3 beats min^{-1}), VE_{max} (90.4 ± 8.9 and 118 ± 17.4 l min^{-1}), VO_{2max} (41.6 ± 4.2 and 53.9 ± 4.4 ml min^{-1} kg^{-1}). Our results were: HR_{max} (197 ± 6 and 199 ± 7 beats min^{-1}), VE_{max} (87.3 ± 17.5 and 125.4 ± 20.6 l min^{-1}), VO_{2max} (43.6 ± 6.1 and 60 ± 5 ml min^{-1} kg^{-1}).

In our study, the higher values might be due to the study design and the athletes' younger ages. Besides, our study was performed in a gymnasium, i.e. under sport-specific training conditions. This is also advantageous when compared with a cycle ergometer, as athletes use larger muscle mass.

In the other two studies with effects of mouth guards on some physiological parameters, the subjects were not athletes and test designs were not similar to the present study. The study by Francis and Brasher (31) included measurement of oxygen consumption and minute ventilation during light and heavy exercise. Three different stock types of mouth guards were compared. The authors concluded that wearing mouth guards might produce an effective pattern of respiration during brief periods of heavy exercise, which may improve tissue oxygenation and lower metabolic cost. Terence et al. (32) measured oral airflow resistance in normal subjects wearing two different custom-made mouth guards. Some of the subjects demonstrated a large drop in airflow resistance while wearing either

Table 2. Mean values and standard deviations (SD) of males and females with (M) and without mouth guard (WM)

	Male		Female	
	WM	M	WM	M
HR_{max} (beat min^{-1})	199 ± 7.24	197 ± 9.75	197 ± 5.99	198 ± 7.65
VO_{2max} (ml min^{-1} kg^{-1})	59.95 ± 4.99	59.13 ± 6.20	43.64 ± 6.01	46.34 ± 4.72
VE_{max} (l min^{-1})	125.36 ± 20.59	123.09 ± 17.71	87.27 ± 17.49	92.91 ± 9.08
Vt_{max}(l min^{-1})	2.08 ± 0.42	2.06 ± 0.33	1.74 ± 0.27	1.71 ± 0.24
RER	1.12 ± 0.06	1.11 ± 0.04	1.11 ± 0.07	1.13 ± 0.04

mouth guard, whereas others exhibited increased airflow resistance, and in some no change was observed. Their results suggest that although mouth guards do cause obstruction to the oral breathing route, this effect is evident predominantly during resting breathing and when the degree of mouth opening is restricted. Consequently, it appears that maxillary mouth guards are unlikely to interfere with breathing at high ventilatory rates and where recruitment of compensatory mechanisms is possible.

The type of activity in taekwondo imposes high demands on short-term anaerobic performance capacity and ability to recover (28). Therefore, anaerobic abilities like strength, speed and reaction time are also of prime importance. Further studies should be performed during anaerobic activities.

Conclusion

The results of this study indicate that wearing custom-made mouth guards do not significantly affect aerobic performance capacity by using maximal field test on elite taekwondo athletes until they reached VO_2max. This result does not support the prejudice of the elite taekwondo athletes about the negative effects on their performance.

However, other factors have to be researched for the satisfaction of the athletes, like longevity of mouth guard retention, possible effects on saliva secretion, kiyaping or speaking.

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