

Original Article

## Cardiopulmonary effects of using mouthguards during medium and high intensities in elite Egyptian boxing athletes

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### Abstract:

The aim of this study was to examine the cardiopulmonary effects of using different types of mouthguards during medium and high intensities in elite Egyptian boxing athletes. Eighteen Egyptian elite male boxers (age range 18-24 years) registered in the Egyptian boxing federation, volunteered to contribute in the study. Participants were subjected to a cardiopulmonary exercise testing on a treadmill in three conditions (without mouthguard, NM; with stock mouthguard, SM; and with custom fitted mouthguard, CFM) during medium and high intensities. Heart rate HR, minute ventilation VE, Oxygen uptake Vo<sub>2</sub>, breathing frequency BF, and tidal volume TV were collected for each athlete. Repeated measures ANOVAs were used to determine statistical differences. Results showed that using CFM hasn't significant effect ( $P > 0.05$ ) on HR, VE, Vo<sub>2</sub>, BF, and TV while exercising at either medium or high intensity. Data noted significant effect ( $P > 0.05$ ) on Vo<sub>2</sub> mean ( $43.54 \pm 5.68$  mL.kg<sup>-1</sup>.min<sup>-1</sup>) while wearing SM at high intensity in comparison with NM and CFM respectively ( $50.37 \pm 5.34$  and  $49.48 \pm 3.65$  mL.kg<sup>-1</sup>.min<sup>-1</sup>). It can be concluded that boxing athletes can wear CFM during medium or high intensity exercises without negative effects on their cardiopulmonary performance. These statistics demonstrate extra support for governing bodies to encourage athletes to use CFM.

**Key words:** custom fitted mouthguard, exercise, oxygen uptake, boxing.

### Introduction

In recent decades, sports participation has become more competitive. It is distinguished that orofacial injuries have become amongst the most frequent and problematic implications sustained during competitive physical activities (Tuna and Ozel, 2014). Furthermore, numerous boxing and combat sport injuries are to the head and neck regions either deliberately or accidentally (Zazryn, McCrory, & Cameron, 2008). It has been demonstrated that contact to the head causes injuries such as concussion, soft-tissue lacerations, or fracture of the facial skeleton (Mantri, Mantri, Deogade, & Bhasin, 2014). Consequently, Mouthguards can supply guarding from concussion, dentoalveolar injury, and fractures of the facial skeleton (Saini 2011; Hendrick, Farrelly, & Jagger, 2008; Knapik et al., 2007; Mihalik et al., 2007).

It was stated by the American Academy of Pediatric Dentistry (2008) that mouthguards supposed to be utilized in 29 sports or exercise activities. As protective equipment, mouthguards are intended to be worn over front teeth and absorb the force connected with any clashes; subsequently reducing the incidence of dental/oral injuries (Bemelmans, & Pfeiffer, 2001; Lim, Robinovitch, & Goodman, 2005; Tuna & Ozel, 2014). Accordingly, rigidity of perioral lacerations and combat- connected dental injuries might be minimized by the usage of mouthguard.

Regarding to intraoral sports mouthguards, there are three basic types existing to supply guarding to athletes (Knapik et al., 2007; Bemelmans, & Pfeiffer, 2001; Maeda, Kumamoto, Yagi, & Ikebe, 2009). Type I—stock mouthguards (SM) designed for usage without adjustment. Type II—boil-and-bite mouthguards, a thermo-plastic fabric can be modified in shape to person's mouth. Type III—custom fitted mouthguards (CFM) are shaped on a dental model of person's mouth, fabricated by heat pressure or vacuum forming procedures (Newsome, Tran, & Cooke, 2001). Types I and II are more known by most athletes than type III CFM (Newsome et al., 2001). CFM type could protect or reduce facial and dentoalveolar trauma resulting from athletic activity (Berry, Miller, & Leow, 2005; Gardiner, & Ranalli, 2000), minimize the frequent dissatisfactions informed by instructors and athletes (Knapik et al., 2007; Craig, Godwin, 2002; Lim et al., 2005).

When athlete commences to exercise, breathing happens across both oral and nasal airways. During exercise, most of inhaled air comes into the lungs through the oral way (Amis, Di Somma, Bacha, & Wheatley, 2000). Therefore, mouthguards could show bigger obstacle to expiratory air flow during breathing.

Unfortunately, there are comparatively few studies available looking at the effect of using mouthguards during exercise on ventilation, and more studies are needed to cognize these associations.

Based on previous findings (Garner, Dudgeon, Scheett, & McDivitt, 2011; Gebauer, Williamson, Wallman, & Dawson 2011; von et al., 2008; Francis, & Brasher, 1991), the impact of using mouthguards on ventilation through exercise is still confused. Conducting experiments on this trend possibly will help to decide if using mouthguards affecting cardiopulmonary variables or not. For that reason, the aim of this study was to examine the cardiopulmonary effects of using different types of mouthguards during medium and high intensities in elite Egyptian boxing athletes.

## Method

### Participants

Twenty four men elite boxers belong to Zagazig sports clubs participated in regional and national competitions were recruited for the study. Six of them retreated through the experiments, remaining 18 participants [mean (SD) rang: age, 19.4 (2.01) 17.8–24.2 years; height, 1.74 (7.9) 165.3–1.96 cm; body mass, 74.5 (5.1) 62 .9–88.4 kg; hemoglobin, 14.8 (2.4) 13.7–15.9 g/dl; training age, 3.8 (1.77) 1.4–7.1 years]. Participants were given information concerning the study objectives, requirements, advantages, and risks prior to providing the written consent. Participants were volunteers, and they could withdraw from the study. The Review Board at Zagazig University, Egypt provided agreement for the study's procedures. Participants were healthy and fit to contribute in the study, based on the participants' physical activity readiness questionnaires, excluding anybody had any lifetime medical history of respiratory sickness, or were smokers. Sample blood was taken from an antecubital vein under fasting circumstances at clinical laboratory to determine the concentration of hemoglobin in order to exclude anemic.

### Fabrication of Custom Fitted mouthguards

The CFM mouthguards were designed by professional dentist center. Impressions were obtained by standard trays using an elastic irreversible impression material (mold) fabricated by the dentist, and then poured with dental stone cast of the mouth (maxillary arch) to get the working models. A thermoplastic mouthguard material was modified over cast with a dental vacuum forming device. Mouthguards fabricated from ethylene vinyl acetate copolymer sheets, with standard thickness 4 mm which is recommended for CFM (Maeda et al., 2009). Sheets were located in a thermal-forming device (Erkoform, Erkodent, Pfalzgrafenweiler, Germany). They were been softened under hot water and vacuumed under pressure. Once fabricated, they were placed and tried in the participant's mouth to affirm comfortably and exact fit.

### Cardiopulmonary exercise testing design & equipment utilized

All participants informed not to perform intense activity in the 2 days preceding a test session, and arrived at the laboratory not less than 2 h postprandial, in energetic and completely hydrated state. They were requested to consume same meals before each session to control alterations in respiratory exchange ratios. Each participant was examined at the equivalent time of day ( $\pm 2$  h) to reduce the effects of biological diversity. Initially each participant was assessed for height (cm), body mass (kg) using (Seca Digital Weight & Height Scale). They were familiarized with the procedures and apparatus prior to study beginning. All subjects performed exercise testing at the Applied Physiology Laboratory at Zagazig University. Participants contributed in 3 experimental attempts that were grouped and blindly randomized into an equitable treatment order, with almost one week interval between each test day (range, 6–10 days). The 3 attempts days consisted just one of three different conditions (exercise with no mouthguard, NM; with using stock mouthguard, SM; and with using custom fitted mouthguard, CFM), through two different intensities (medium and high).

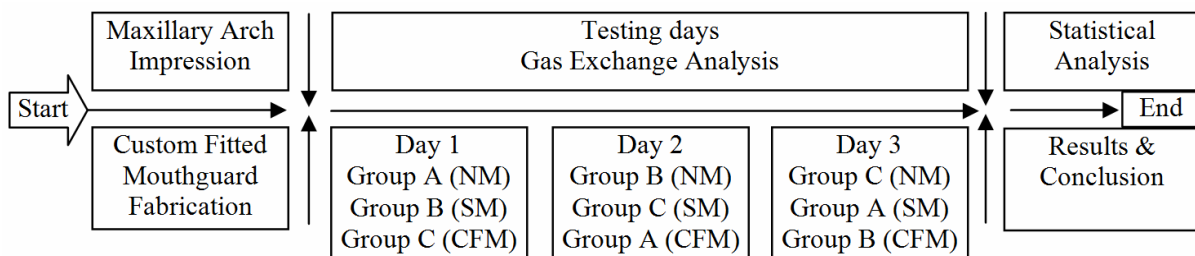


Figure 1. Design Methodology Flow Chart

Each exercise test attempts consisted of running on a motorized treadmill (Quinton Instrument Co., Seattle, WA, USA) for a 20-min period with two different intensities (medium and high). The sequencing of the 20-min exercise period was divided into two 10-min plateau phases, 1-min apart. 1<sup>st</sup> plateau phase with medium intensity consisted of: 2-min graded speed (started from 8 km.h<sup>-1</sup> to 12 km.h<sup>-1</sup>, adding 1 km.h<sup>-1</sup> each 30 s), subsequently 5-min stage founded on the intensity workload of 12 km.h<sup>-1</sup> with using/or not a mouthguard, followed by 3-min recovery period. 2<sup>nd</sup> plateau phase with high intensity consisted of: 2-min graded speed

(started from 10 km.h<sup>-1</sup> to 14 km.h<sup>-1</sup>, adding 1 km.h<sup>-1</sup> each 30 s), subsequently 5-min stage founded on the intensity workload of 14 km.h<sup>-1</sup> with using/or not a mouthguard, followed by 3-min recovery period. The last minute of each 5-min stage founded on the intensity workload was considered to represent cardiopulmonary parameters. Heart rate (HR) was recorded continuously using a radio telemetry HR monitor (Polar Electro Sportster, Kempele, Finland) was band worn around participant's chest next to the skin. Breath-by-breath measurements were executed during exercise using a computerized automated gas system (COSMED, Quark CPET Ergo, Rome, Italy). Volume and gas calibration were checked previous and subsequent to each test with standard calibration gases (O<sub>2</sub>, 16%; CO<sub>2</sub>, 4%). Heart rate HR (beats/min), minute ventilation VE (L.min), Oxygen uptake Vo<sub>2</sub> (mL.kg<sup>-1</sup>.min<sup>-1</sup>), breathing frequency BF (1/min), tidal volume TV (L) were measured during the exercise test executed on the treadmill.

#### Statistical analysis

The collected data were analyzed using the Statistical Package for the Social Sciences SPSS (SSPN Inc., Chicago, IL, USA). Repeated measures ANOVAs with post hoc comparisons were used to analyze (HR, VE, Vo<sub>2</sub>, BF, and TV) with 3 conditions (NM, SM, and CFM) and 2 intensities (medium and high). Differences were considered statistically significant when  $P < 0.05$ .

Table 1. Values of cardiopulmonary parameters for the three experimental conditions (n=18)

| Parameter                         | Intensity | NM                | SM                                               | CFM                                | Difference               |        |                         | P           |
|-----------------------------------|-----------|-------------------|--------------------------------------------------|------------------------------------|--------------------------|--------|-------------------------|-------------|
|                                   |           | Mean $\pm$ SD     | Mean $\pm$ SD                                    | Mean $\pm$ SD                      | SM/NM                    | CFM/NM | CFM/SM                  |             |
| <b>HR<sup>‡</sup></b>             | MI        | 164.15 $\pm$ 9.41 | 166.24 $\pm$ 10.11                               | 165.31 $\pm$ 9.73                  | 2.09                     | 1.16   | -0.93                   | 0.52        |
|                                   | HI        | 178.54 $\pm$ 8.62 | 179.64 $\pm$ 12.95                               | 177.73 $\pm$ 11.32                 | 1.1                      | -0.81  | -1.91                   | 0.43        |
| <b>VE<sup>§</sup></b>             | MI        | 77.84 $\pm$ 7.98  | 76.94 $\pm$ 8.22                                 | 78.14 $\pm$ 9.67                   | -0.9                     | 0.3    | 1.2                     | 0.4         |
|                                   | HI        | 99.51 $\pm$ 13.42 | 92.74 $\pm$ 11.26                                | 95.71 $\pm$ 14.82                  | -5.77                    | -3.8   | 2.97                    | 0.17        |
| <b>Vo<sub>2</sub><sup>¥</sup></b> | MI        | 35.61 $\pm$ 3.81  | 34.84 $\pm$ 4.24                                 | 35.37 $\pm$ 3.45                   | -1.77                    | -1.24  | 0.53                    | 0.28        |
|                                   | HI        | 47.37 $\pm$ 5.34  | <b>40.54 <math>\pm</math> 5.68<sup>*,†</sup></b> | <b>46.48 <math>\pm</math> 3.65</b> | <b>-5.83<sup>*</sup></b> | -0.89  | <b>4.94<sup>†</sup></b> | <b>0.02</b> |
| <b>BF<sup>#</sup></b>             | MI        | 37.21 $\pm$ 5.45  | 38.03 $\pm$ 4.35                                 | 37.41 $\pm$ 4.01                   | 0.82                     | 0.2    | -0.62                   | 0.56        |
|                                   | HI        | 43.54 $\pm$ 4.85  | 45.21 $\pm$ 5.04                                 | 44.77 $\pm$ 3.89                   | 1.67                     | 1.23   | -0.44                   | 0.63        |
| <b>TV<sup>ψ</sup></b>             | MI        | 1.93 $\pm$ 0.25   | 1.89 $\pm$ 0.33                                  | 1.91 $\pm$ 0.29                    | -0.04                    | -0.02  | 0.02                    | 0.33        |
|                                   | HI        | 2.38 $\pm$ 0.49   | 2.34 $\pm$ 0.52                                  | 2.35 $\pm$ 0.55                    | -0.09                    | -0.01  | 0.03                    | 0.19        |

<sup>‡</sup>HR = heart rate (beats/min), <sup>§</sup>VE = minute ventilation (L.min), <sup>¥</sup>Vo<sub>2</sub> = oxygen uptake (mL.kg<sup>-1</sup>.min<sup>-1</sup>), <sup>#</sup>BF = breathing frequency (1/min), <sup>ψ</sup>TV = tidal volume (L), MI = medium intensity (10 km.h<sup>-1</sup>), HI = high intensity (14 km.h<sup>-1</sup>), NM = no mouthguard, SM = stock mouthguard, CFM = custom fitted mouthguard, \*statistical difference ( $P < 0.05$ ; ANOVA) to NM values, †statistical difference ( $P < 0.05$ ; ANOVA) to CFM values.

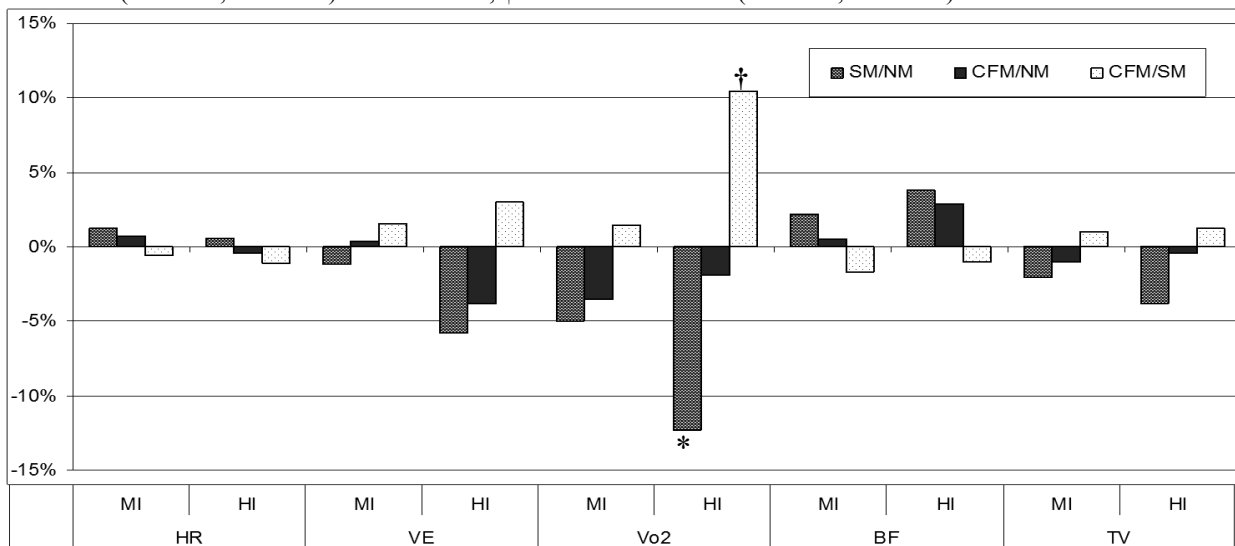


Figure 2. Percentage differences for cardiopulmonary parameters between the three experimental conditions. <sup>‡</sup>HR = heart rate (beats/min), <sup>§</sup>VE = minute ventilation (L.min), <sup>¥</sup>Vo<sub>2</sub> = oxygen uptake (mL.kg<sup>-1</sup>.min<sup>-1</sup>), <sup>#</sup>BF = breathing frequency (1/min), <sup>ψ</sup>TV = tidal volume (L), NM = no mouthguard, SM = stock mouthguard, CFM = custom fitted mouthguard, MI = medium intensity (12 km.h<sup>-1</sup>), HI = high intensity (14 km.h<sup>-1</sup>). \*statistical difference ( $P < 0.05$ ; ANOVA) to NM values, †statistical difference ( $P < 0.05$ ; ANOVA) to CFM values. Percentage difference =  $[(\text{value}_2 - \text{value}_1) / (\text{value}_1)] \times 100\%$ .

#### Results

Table 1 and Figure 2 illustrate no statistical significant differences ( $P > 0.05$ ) were observed in all of the cardiopulmonary parameters (HR, VE, Vo<sub>2</sub>, BF, and TV) between the three experimental conditions (NM, SM,

and CFM) during the medium intensity workload. On the other hand, data noted that  $\text{VO}_2$  mean at the high intensity workload reduced significantly ( $P > 0.05$ ) while wearing the SM ( $43.54 \pm 5.68 \text{ mL.kg}^{-1}.\text{min}^{-1}$ ) in comparison to NM and CFM respectively ( $50.37 \pm 5.34$  and  $49.48 \pm 3.65 \text{ mL.kg}^{-1}.\text{min}^{-1}$ ). Results are showed in Table 1 and Figure 2.

## Discussion

Athletes have worn mouthguards throughout participating in sports specially contact sport that presents injury risks to guard from dentoalveolar injury, concussion, facial trauma, and skeleton fracture (e.g. tooth fractures, lip lacerations and mandibular damage) (Hendrick et al., 2007; Mihalik et al., 2007). Though, enlarged awareness of using mouthguards for athletic performance development is a novel orientation in exercise and sport science. International Boxing Association rules for competition equipment confirming on wearing mouthguards during the official competitions. Accordingly, it is forbidden for a boxer to take the mouthguard off during the contest either deliberately or unintentionally, and if boxer does so, he/she will be warned or deemed to have lost by disqualification (AIBA, 2013). Boxing activity requires high demands of both aerobic and anaerobic capacities with ability to recuperate between rounds (El-Ashker, 2012). Consequently, boxing anaerobic capacity is important to perform specific physical fitness components (e.g. muscular strength, muscular speed, and reaction/response time). Additional investigations on factors affecting these requirements should be conducted throughout both aerobic and anaerobic activities.

Although aerobic and anaerobic measurement verifies athletic performance, in addition to  $\text{VO}_2$  importance as a considerable index using to monitor cardiorespiratory functions (Larsen et al., 2002), no articles investigated the cardiopulmonary effects of using mouthguards in boxing athletes. In Egypt, the majority of combat athletes had oppression opposite to mouthguard utilization in that it might influence their performance and expiratory flow rates negatively. Most of them were aware of SM which sold prepared to be utilized without any modification, however few numbers are aware of CFM.

To clarify the potential mechanisms concerned with mouthguards utilization during exercise, we investigated some respiratory gas exchange variables in NM, SM, and CFM conditions. In previous studies Gebauer et al. (2011) and Delaney & Montgomery (2005) examined the effect of mouthguard usage on respiratory performance in athletes. The results of these studies were comparable with present statistics, as we considered no significant differences along with gas exchange variables, and HR results among the three experimental trials NM, SM, and CFM during the two different intensities.

Surprisingly, there were a small number of articles have searched the association between cardiopulmonary variables and mouthguard utilization (Francis, & Brasher, 1991; Bourdin et al., 2006; Delaney, & Montgomery 2005; Von et al., 2008). Francis and Brasher (1991) evaluated the physiological impacts of wearing mouthguards through low/high intensity work out for a period of 5 minutes on a cycle ergometer. For the first intensity, participants cycled at two different loads regarding to sex (1<sup>st</sup> load, 100 and 75 watts for 10men and 7women respectively; 2<sup>nd</sup> load, 150 and 125 watts for 10men and 7women respectively). Our results agree with Francis and Brasher (1991) and others (Von et al., 2008; Gebauer et al., 2011) where weren't any significant differences while wearing mouthguards during practicing at moderate intensity.

On the subject of the using mouthguards through executing high intensity workload, our article demonstrated that SM might be inappropriate and uncomfortable for high intensity, as it can restrict air flow and make breathing difficult. These results agree with Francis and Brasher (1991) outcomes, which stated that using SM at high intensity might cause obstruction to breathing route and create difficulty with breathing. On the other hand, results demonstrated that CFM type is more likely with breathing at both moderate and high intensities. These findings match with previous (Gebauer et al., 2011) which showed no significant differences at high loads on VE,  $\text{VO}_2$ , and HR variables when skating on treadmill using CFM. Then, the mainly interesting feature of this study is that wearing CFM did not negatively influence any of the investigated cardiopulmonary parameters throughout the test performed on treadmill either during medium or high intensity workload, this indicates that no restrictions of respiration happened as a result of wearing CFM mouthguards.

## Study limitations

Current study has some potential limitations. The results would necessitate to be established by further investigations on a bigger number of participants, in an attempt to be adequately powered statistically. Potential studies are needed to strengthen current results, scrutinize extra probable parameters, and finally examine other topics might be significant (e.g. immunological, psychological, or neuromuscular). Women were ruled out from investigations because results confirmed that men are more represented in accident and emergency units than women, because of not using protecting apparatus through athletic activities.

## Conclusions

In summary, based on the results of this study, we can deduct that using mouthguards hasn't negative impact on boxing cardiopulmonary performance capacities during medium intensity. Custom fitted mouthguards are preferable in both medium and high intensity exercises compared with stock mouthguards. We recommend that national governing bodies should mandate the mouthguards usage especially custom fitted types throughout contact sport activities to decrease the occurrence of facial trauma, skeleton fractures, and concussions.

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