The effects of the use of the mask for gas analysis on the submaximal and maximal physiological and perceptual variables in response to an incremental test

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Abstract

This study aimed to determine the effects of using the mask to gas analysis on maximal and submaximal physiological and perceptual variables during an incremental test. We assessed 21 recreationally endurance trained runners (VO_{2max}: 54.0 ± 7.6 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) aged 30 to 49 years. These runners were submitted to two different incremental tests in randomized order to determination of maximum aerobic velocity (MAV), being used in one of them the equipment to gas analysis and not in the other. Peak velocity (V_{peak}) was determined based on Kuipers et al.[17] adjustment. It was also analyzed physiological (HR and $\%HR_{max}$) and perceptual (RPE) variables in each stage to comparison between protocols. Runners did a 10 and 15 km performance in field track to verify the relationship with maximal aerobic speed obtained in both protocols. The use of the mask for gas analysis reduced Vpeak, but did not modify HRmax and RPE_{max}. In regard to submaximal variables, HR was influenced mainly in initial stages in which values were higher in the test which the mask was used. However, when expressed as $\%HR_{max}$, runners remained in the majority of submaximal stages in higher percentages during the protocol with mask. For RPE, there was no significant difference, except in the stage of 10 $km{\cdot}h^{-1}$, which RPE was higher when the mask was used. MAV is reduced when mask is used to gas analysis and HR and $\%HR_{max}$ in submaximal stages are higher due to the use of this equipment especially in initial stages.

Key Words: Running; Oxygen consumption; Exercise test.

Introduction

The maximum aerobic velocity (MAV) predicts running performance of middle and long distance athletes[1-2]. Moreover, it can be used in the control and prescription of exercise training[3]. The MAV represents the minimum velocity associated with the maximum oxygen consumption (VO_{2max})[1] and, it is an indicative of the individual aerobic power.

In the 80th and 90th different methodologies have been proposed to determine the MAV. However, these methods have resulted in contradictory results (i.e., differences in velocity values)[9]. Moreover, the protocol selection can influence this measure[10-11]. Noakes et al.[2] demonstrated that the Scrimgeour et al.[7] method, based on peak velocity (V_{peak}), performed with an incremental protocol on a treadmill, is capable to predict runners' performance in long distance races (10 to 90 km). Additionally, the authors suggested that muscular factors related to power capacity, and not the cardiovascular system, limited this variable.

The use of V_{peak} to monitor athletes' performance during a season has many advantages for coaches and researchers, given that it can be determined without the mask for gas analysis and neither more invasive techniques, such as blood collection (e.g., blood lactate). However, several previous studies have determined the Vpeak with these procedures[2,12]. To the best of authors knowledge, only one study determined the V_{peak} with a "clean" protocol (that is, without the mask) and showed a correlation of 0.89 in a 16 km time-trial[1].

The effects of the use of a mask for gas analysis on V_{peak} are currently not clear; moreover, there are no information of such apparatus/equipment in other variables like heart rate (HR) and rating of perceived exertion (RPE), in submaximal- and maximal-stages during an incremental protocol. Given that these variables are frequently used for aerobic exercise prescription in different physiologic exercise zones[13-14], it is important to understand if there are any differences between a maximum incremental test with and without the gas analysis mask.

Thus, the present study aimed to determine the effects of the use of a gas analysis mask on physiological and perceptual submaximal and maximal variables in response to an incremental protocol. As individuals could increase the degree of vigilance and activation due to the discomfort caused by the gas analysis mask and, that vigilance, specifically, may affect HR[15], our hypothesis is that the use of a gas analysis mask would alter the cardiovascular system response, increasing the individuals' HR, especially in the submaximal stages.

Method

Participants

Twenty-one runners, aged between 30 to 49 years (age: 41.2 ± 6.9 years; body mass: 75.4 ± 11.4 kg; height: 173.9 ± 7.8 cm; body mass index: 24.8 ± 2.4 $kg.m^{-2}$ and; VO_{2max}: 54.0 ± 7.6 $mL.kg^{-1}.min^{-1}$), with running experience in the 5 and 15 km races (average time practice 10.9 ± 11.1 years) participated in the present study. All participants gave their informed consent before the enrollment in the study. The study was approved by the local Ethics Committee (n. 539/2011).

Experimental design

Initially, participants were familiarized with the ergometer (automatic ergometer treadmill, IBRAMED Super ATL, Porto Alegre - Brasil). Then, all participants performed in a randomized order two continuous maximum incremental test, with inclination fixed at 1%, to determine the MAV. Participants were instructed not to feed two hours before tests, abstain from caffeine or alcohol and do not perform any strenuous physical exercise 48 hours before test. A 48-hour interval was allotted between each test.

Maximum oxygen consumption (VO_{2max}) and peak velocity with the mask for gas analysis (V_{peak}—C)

Firstly, participants warmed-up for three minutes at 7 $km.h^{-1}$ on a treadmill. Then, the incremental protocol started at 9 $km.h^{-1}$ and, the velocity were incremented at 1 $km.h^{-1}$ every three minutes. The protocol was performed to maximum voluntary exertion and participants were verbally encouraged throughout the test. At the end of each stage, the HR (Polar RS800, Kempele - Finlândia) and RPE on a 6 to 20 Borg scale were recorded[16]. The percentage of maximum heart rate ($\%HR_{max}$), considered the highest value attained during the incremental test, was also recorded for analysis.

The gas analysis was performed with an open ergoespirometry system Fitmate (COSMED®, Roma - Italy), which provide values regarding the ventilatory and respiratory every 15 seconds. VO_{2max} were considered the maximum value attained during the incremental test. All test were performed until voluntary exertion and participants were verbally encouraged to perform the test as long as possible. To be considered valid, participants must have meet a RPE ≥ 19 on the Borg scale[16].

The V_{peak}—C with the gas analysis mask was considered as the maximum running velocity attained during the incremental test. If participant was not able to reach the last stage, V_{peak} was estimated based on the partial time in the last attained stage, with the equation proposed by Kuipers et al.[17]:

V_{peak} = vcompleted + t/T*incremental velocity
vcompleted = velocity ($km.h^{-1}$) in the last completed stage;
t = total time (seconds) in the last incomplete stage;
T = total duration (seconds) of the completed stage (ex.: 180 s);
Incremental velocity = increase velocity rate in each stage ($km.h^{-1}$).

Determination of peak velocity without gas analysis mask (V_{peak}—S)

The V_{peak}—S was determined with the same protocol as for the VO_{2max}, however, without the gas analysis mask. Participants were instructed to perform the maximum effort as long as possible. The criteria for V_{peak}_S were the same as for the VO_{2max} with gas analysis mask described above.

The V_{peak}_S was considered the maximum running velocity attained during the incremental test. If any participant was not able to reach the last stage, the V_{peak}_S was calculated with the same criteria adopted for the V_{peak}_C according to the Kuipers et al.[17] equation.

Field test: 10 and 15 km performance

Two field test (i.e., practical test) were performed in order to verify the average velocity of the runners in a 10 and 15 km trials. Similar to the laboratory tests, interval between the two field tests were at least 48 hours apart. The field tests were performed in an official athletics track (400 m) after a 10 minutes warm-up. The mean velocity was calculated according to the total time to complete the test.

Statistical analysis

Data are present as mean ± standard deviation (SD). All data were analyzed with the Statistical Package for the Social Science 13.0 software (SPSS, Inc., USA). Data normality were verified with the Shapiro-Wilk test. The maximum variables (MAV, HR_{max} and maximum RPE [RPE_{max}]) as well as the submaximal (HR and RPE in the submaximal stages) were compared with a dependent t-test (i.e., with mask vs. without mask). The correlation between V_{peak}_C and V_{peak}_S with the performance in the 10 and 15 km trials were performed with Pearson correlation test. Significance level was set at $p < 0.05$.

Results

The comparison with mask vs. without mask for maximum aerobic velocity (MAV), total incremental test time, maximum heart rate (HR_{max}) and rating of perceived exertion at the end of the test (RPE_{max}) are described in TABLE 1. Eighteen out of twenty-one participants showed higher V_{peak}_S values as compared with V_{peak}_C, just one demonstrated otherwise, while the remaining two presented similar values. The statistical analysis showed V_{peak}_S were significantly higher as compared with V_{peak}_C (1.9 ± 1.7 %), given that participants remained more time in the V_{peak}_S protocol. There were no significant differences for HR_{max} neither RPE_{max}.

TABLE 1 - Mean ± standard deviation (SD), absolute difference (absolute Diff) and relative difference (relative Diff) for the comparison with mask vs. without mask: maximum aerobic velocity (MAV), incremental test total time, maximum heart rate (HR_{max}) and rating of perceived of exertion at the end of the test (RPE_{max}) (n = 21).

	With mask	Without mask	Absolute Diff	Relative Diff	p
MAV ($km \cdot h^{-1}$)	14.9 ± 1.4*	15.2 ± 1.4	-0.3 ± 0.3	-1.9 ± 1.7	< 0.001
Total time (min)	20.7 ± 4.1*	21.5 ± 4.2	-0.8 ± 0.9	-4.0 ± 4.3	< 0.001
HR_{max} (bpm)	183.7 ± 12.7	182.9 ± 12.9	0.9 ± 4.9	0.5 ± 2.7	0.431
RPE_{max} (6-20)	19.4 ± 0.6	19.5 ± 0.6	-0.1 ± 0.6	-0.5 ± 3.3	0.493

*$p < 0.05$ as compared with the without mask group.

TABLE 2, 3 and 4 describes the comparison for submaximal variables: HR, percentage of HR (%HR) and RPE. Data are presented for all stages up to 18 $km.h^{-1}$, as this represents the last velocity that more than one participant attained.

The with mask group showed higher HR values than the without mask one at stages 9, 10, 11 and 13 $km.h^{-1}$, with percentage differences for these velocities between 2.0 ± 3.1 % and 4.9 ± 7.4 %. The percentage difference between HR reduced as the test velocity increased, except for the transition between 12 and 13 $km.h^{-1}$ and 15 and 16 $km.h^{-1}$.

The comparison for %HR at submaximal stages showed, similar to the HR, significantly higher values for the with mask group as compared with the clean one (i.e., without the mask). However, the differences were observed in more velocities (9, 10, 11, 13, 14, 16 and 17 $km.h^{-1}$). The percentage differences in %HR between protocols at velocities in which there were statistical differences varied between 0.6 ± 1.3 % and 4.4 ± 7.0 %, whereas the initial stages showed the higher percentage differences.

Regarding RPE at submaximal stages of the incremental test, the only statistical difference observed was at the 10 km.h^{-1}, in which the perception of effort was higher for the gas analysis mask. The range for differences were -1.7 ± 2.9 % to 8.3 ± 4.8 %, whereas the first three stages showed the highest differences (5.4 ± 14.1 %; 8.3 ± 14.8 % and; 4.7 ± 11.9 %, respectively).

TABLE 2 - Mean ± standard deviation (SD), absolute difference (absolute Diff) and relative difference (relative Diff) for the comparison with mask vs. without mask at stages 9 to 18 km.h^{-1}.

	N	With mask	Without mask	Absolute Diff	Relative Diff	p
HR - 9 km·h^{-1} (bpm)	21	138.4 ± 19.7*	131.8 ± 15.4	6.6 ± 10.1	4.9 ± 7.4	0.007
HR - 10 km·h^{-1} (bpm)	21	146.6 ± 19.1*	141.2 ± 16.5	5.4 ± 6.9	3.8 ± 4.7	0.002
HR - 11 km·h^{-1} (bpm)	21	154.4 ± 18.9*	151.1 ± 17.2	3.3 ± 6.6	2.2 ± 4.2	0.031
HR - 12 km·h^{-1} (bpm)	21	161.5 ± 18.9	159.1 ± 17.9	2.4 ± 6.7	1.6 ± 4.2	0.111
HR - 13 km·h^{-1} (bpm)	21	169.8 ± 18.1*	166.5 ± 17.9	3.3 ± 5.3	2.0 ± 3.1	0.010
HR - 14 km·h^{-1} (bpm)	21	175.7 ± 17.1	173.8 ± 17.1	1.9 ± 4.9	1.1 ± 2.8	0.097
HR - 15 km·h^{-1} (bpm)	14	174.9 ± 12.3	173.3 ± 12.5	1.6 ± 5.3	1.0 ± 3.0	0.263
HR - 16 km·h^{-1} (bpm)	11	178.1 ± 11.7	176.1 ± 11.7	2.0 ± 5.4	1.2 ± 3.0	0.246
HR - 17 km·h^{-1} (bpm)	4	180.3 ± 9.2	180.0 ± 11.7	0.3 ± 4.7	0.2 ± 2.7	0.922
HR - 18 km·h^{-1} (bpm)	3	180.7 ± 10.0	181.3 ± 11.0	-0.7 ± 4.0	-0.3 ± 2.3	0.802

*$p < 0.05$ as compared with the without mask group.

TABLE 3 - Mean ± standard deviation (SD), absolute difference (absolute Diff) and relative difference (relative Diff) for the comparison with mask vs. without mask: maximum heart rate percentage (%HR) at stages 9 up to 18 km.h^{-1}.

	N	With mask	Without mask	Absolute Diff	Relative Diff	p
%HR$_{max}$ - 9 km·h^{-1}	21	75.1 ± 7.0*	72.0 ± 5.4	3.2 ± 4.9	4.4 ± 7.0	0.008
%HR$_{max}$ - 10 km·h^{-1}	21	79.6 ± 6.3*	77.1 ± 5.5	2.5 ± 3.3	3.3 ± 4.3	0.002
%HR$_{max}$ - 11 km·h^{-1}	21	83.9 ± 6.1*	82.5 ± 5.5	1.4 ± 2.6	1.7 ± 3.1	0.025
%HR$_{max}$ - 12 km·h^{-1}	21	87.8 ± 6.2	86.8 ± 5.8	0.9 ± 2.3	1.1 ± 2.7	0.083
%HR$_{max}$ - 13 km·h^{-1}	21	92.3 ± 5.3*	90.9 ± 5.9	1.3 ± 2.0	1.6 ± 2.4	0.006
%HR$_{max}$ - 14 km·h^{-1}	21	95.5 ± 4.7*	95.0 ± 5.1	0.6 ± 1.2	0.6 ± 1.3	0.048
%HR$_{max}$ - 15 km·h^{-1}	14	96.8 ± 3.4	96.2 ± 4.1	0.6 ± 1.2	0.7 ± 1.2	0.074
%HR$_{max}$ - 16 km·h^{-1}	11	98.6 ± 2.1*	97.7 ± 3.4	0.9 ± 1.3	1.0 ± 1.4	0.048
%HR$_{max}$ - 17 km·h^{-1}	4	99.3 ± 1.0*	98.0 ± 1.8	1.3 ± 0.8	1.3 ± 0.8	0.046
%HR$_{max}$ - 18 km·h^{-1}	3	100.0 ± 0.0	99.8 ± 0.3	0.2 ± 0.3	0.2 ± 0.3	0.423

*$p < 0.05$ as compared with the without mask group.

TABLE 4 - Mean ± standard deviation (SD), absolute difference (absolute Diff) and relative difference (relative Diff) for the comparison with mask vs. without mask: rating of perceived exertion (RPE) at stages 9 up to 18 km.h^{-1}.

	N	With mask	Without mask	Absolute Diff	Relative Diff	p
RPE - 9 km·h^{-1}	21	9.2 ± 1.5	8.8 ± 1.6	0.4 ± 1.2	5.4 ± 14.1	0.162
RPE - 10 km·h^{-1}	21	10.6 ± 1.8*	9.9 ± 1.8	0.7 ± 1.5	8.3 ± 14.8	0.036
RPE - 11 km·h^{-1}	21	12.1 ± 2.1	11.6 ± 2.2	0.4 ± 1.3	4.7 ± 11.9	0.154
RPE - 12 km·h^{-1}	21	13.4 ± 2.5	13.5 ± 2.5	-0.1 ± 1.5	-0.2 ± 10.9	0.883
RPE - 13 km·h^{-1}	21	15.6 ± 3.0	15.2 ± 3.0	0.4 ± 1.5	3.2 ± 10.7	0.268
RPE - 14 km·h^{-1}	21	17.3 ± 2.7	17.2 ± 3.0	0.1 ± 1.5	1.5 ± 10.8	0.771
RPE - 15 km·h^{-1}	14	17.9 ± 3.1	17.5 ± 3.3	0.4 ± 1.4	2.6 ± 9.0	0.373
RPE - 16 km·h^{-1}	11	18.8 ± 1.7	18.4 ± 1.9	0.5 ± 0.7	2.7 ± 4.3	0.053
RPE - 17 km·h^{-1}	4	19.5 ± 0.6	19.0 ± 1.4	0.5 ± 1.0	2.9 ± 5.9	0.391
RPE - 18 km·h^{-1}	3	19.7 ± 0.6	20.0 ± 0.0	-0.3 ± 0.6	-1.7 ± 2.9	0.423

*$p < 0.05$ as compared with the without mask group.

The correlation between V_{peak}_C and V_{peak}_S protocol was 0.98 ($p < 0.05$). FIGURES 1 and 2 presents the correlation between V_{peak}_C and V_{peak}_S with the 10 and 15-km performance trials, respectively. It was observed a slightly lower correlation for the V_{peak}_C when compared with the V_{peak}_S, for the 10 km ($r = 0.75$ and $r = 0.77$) and the 15 km trial ($r = 0.72$ and $r = 0.75$).

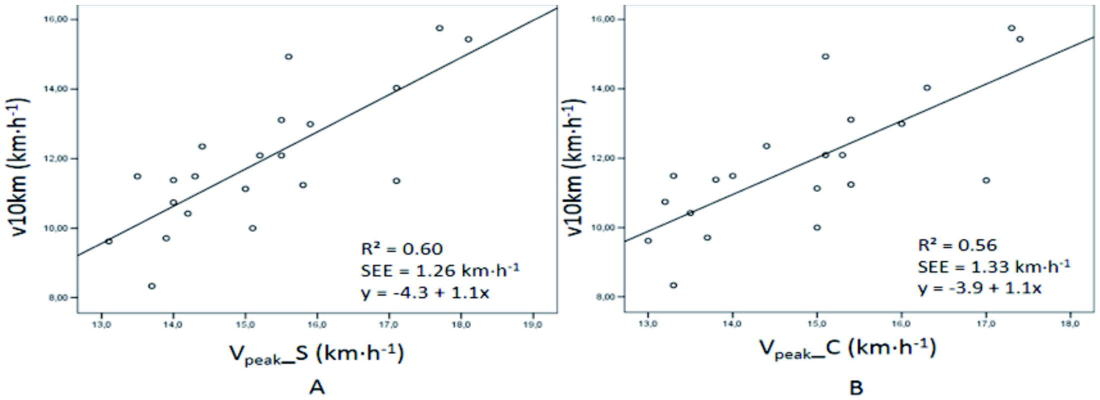

FIGURE 1 - Correlation between the V_{peak}_S and performance in the 10 km (A) an between the V_{peak}_C and the same trial (B) in 21 subjects.

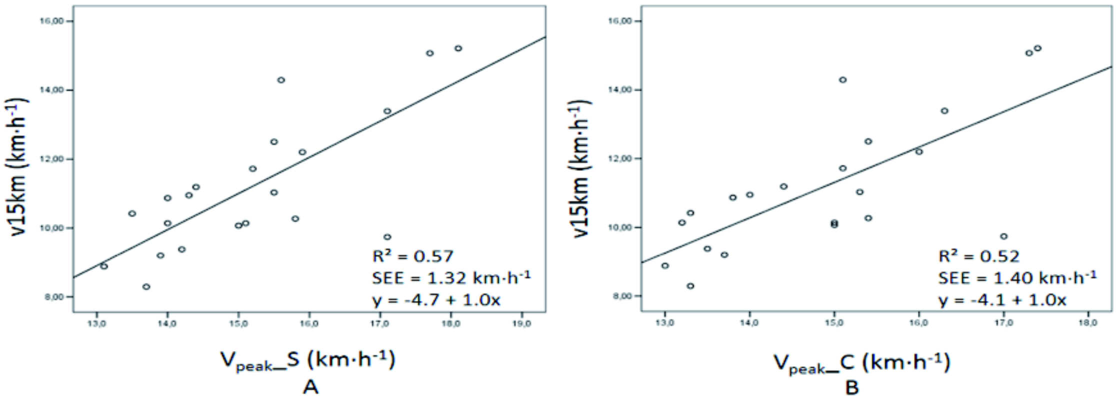

FIGURE 2 - Correlation between the V_{peak}_S and performance in the 15 km (A) an between the V_{peak}_C and the same trial (B) in 21 subjects.

Discussion

The present study aimed to determine the effects of the use or not of the gas analysis mask on physiological and perceptual submaximal and maximal variables in response to an incremental test. The main result was the use of the gas analysis mask reduced V_{peak} (i.e., MAV) values, however, it did not influence neither HR_{max} nor RPE_{max}. Regarding submaximal variables, HR was mostly influenced at initial stages, in which the gas analysis mask group showed higher HR values. However, expressing HR as percentage (%HR) showed participants remained mostly with higher values at submaximal stages when the gas analysis mask were used. For RPE, there was no significant difference between protocols, except to stage 10 $km.h^{-1}$, in which the RPE showed higher values for the gas analysis mask as compared with the without mask group. It seems important to highlight RPE values were systematically higher with the use of the mask at all stages, except to stage 12 $km.h^{-1}$. In addition, V_{peak}_S demonstrated a slightly higher correlation with the performance test of 10 and 15 km when compared with V_{peak}_C.

Previous studies demonstrated V_{peak} is a reliable variable in a test-retest protocol, with high intraclass correlation coefficient and low bias risk[18-20]. However, these studies measured V_{peak} in association with VO_{2max} (i.e., using gas analysis mask) and blood collection (i.e., to assess lactate threshold). Only few studies have evaluated the V_{peak} with a clean protocol without using any equipment for gas analysis neither blood samples[1] and, to the best of authors knowledge, the specific impact of the use of such equipment associated with V_{peak} had not been studied. In light with the results from the present study, it seems interesting to suggest gas analysis mask induce a discomfort to participants, anticipating test interruption, on average, 0.8 ± 0.9 minutes earlier.

It is possible that this discomfort increases the degree of surveillance and participants' activation. Specifically, surveillance seems to alter %HR[15]; thus, the responses induced by the discomfort associated with the use of the mask could explain the HR and $\%HR_{max}$ during submaximal stages of the incremental test. Apparently, the use of the gas analysis mask stimulates the cardiovascular response, increasing participants' HR and $\%HR_{max}$, particularly at the initial submaximal stages of the incremental test. The differences in $\%HR_{max}$ during the final submaximal stages may be explained by differences in HR_{max} response between protocols. Although not statistically significant, the average HR_{max} was 0.9 ± 4.9 bpm lower without the mask as compared with the use of the mask.

Albeit HR during exercise be determined by neural mechanism related to the sympathetic nervous system activity[21], the mechanisms associated with the earlier effort interruption, due to the uncomfortable perception induced by the mask, needs further elucidation. Although the perceived of exertion during exercise be regulated by central mechanisms[22], SMIRMAUL[23] suggests that other unpleasant sensations, such as temperature and pain, may influence the afferent sensorial response. Thus, it is possible that the discomfort induced by the mask was associated with an efferent sensorial response.

Previous studies suggest that HR at submaximal stages has a high reliability; however, their values tend to be lower in the re-test[20,24-26], possibly due to a subjects' familiarization to the protocol[25]. Nevertheless, in the present study, the tests protocols (i.e., with or without the mask) were performed in a randomized order, reducing potential bias associated with this factor.

On the other hand, except for the 10 $km.h^{-1}$ stage, RPE responses were not statistically different between protocols. Given that RPE has some reliability issues as previously demonstrated[25, 27-28], it is hard to drawn precise conclusions regarding the effects of the use or not of the mask on this variable. We highlight, however, that for most of the submaximal loads, the RPE values tended to be higher in the mask protocol as compared with the without mask one.

Previous studies demonstrated that the V_{peak} predicts performance in middle and long distance races[1, 12, 29], especially if evaluated with a three minutes protocol[29]. In the present study, V_{peak}_S assessed with a "clean" protocol (no mask for gas analysis) showed slightly higher correlations with the 10 and 15 km trials performance when compared with the V_{peak}_C, highlighting the importance to use protocols with similar characteristics to evaluate the MAV.

Although the lactate concentrations is considered the gold-standard method to determine the anaerobic threshold[30], the present study could not verify the effects of the mask on this parameter. This was mainly due to the characteristics of the clean protocol to assess V_{peak} used herein. In this sense, the analysis of the lactate threshold would compromised the protocol characteristics. Even though, future studies should investigate the effects of the gas analysis mask on the lactate concentrations, as well as its respective threshold, given that this is a common practice utilized to optimize participants' assessment. We also suggest the necessity to investigate the possible effects of the mask between the running velocity and HR and, its precision on training prescription, that usually is performed without the mask. In other words, training velocity determined without the mask may underestimate the velocity at a specific HR target zone, if prescription was based on a protocol with the gas analysis mask.

Therefore, we concluded that V_{peak} is reduced due to the use of the gas analysis mask and, that HR and %HR in submaximal stages are higher owing to the use of such equipment, especially in the first stages of the incremental test. Additionally, V_{peak}_S showed slightly higher correlations with the 10 and 15 km trials performance when compared with the V_{peak}_C, suggesting the use of these protocols to assess athletes' performance throughout competitive season.

Resumo

Efeitos do uso da máscara para análise de gases sobre variáveis fisiológicas e perceptuais máximas e submáximas durante um teste incremental

Este estudo teve como objetivo determinar os efeitos do uso da máscara para análise de gases sobre variáveis fisiológicas e perceptuais máximas e submáximas durante um teste incremental. Foram avaliados 21 corredores recreacionais de "endurance" (VO_{2max}: 54,0 ± 7,6 $mL \cdot kg^{-1} \cdot min^{-1}$) com idade entre 30 e 49 anos. Os mesmos foram submetidos a dois diferentes testes incrementais em ordem aleatória para determinação da MVA, sendo utilizado em um deles o equipamento para análises de gases e no outro não. A velocidade pico em esteira foi determinada com base no ajuste de Kuipers et al.[17]. Foram também analisadas variáveis fisiológicas (FC e $\%FC_{max}$) e perceptuais (PSE) a cada estágio para comparação entre os protocolos. Os corredores realizaram uma performance de 10 e 15 km em pista de atletismo para verificar a relação com a máxima velocidade aeróbia obtida nos dois testes. O uso da máscara para a análise de gases reduziu a V_{pico}, mas não modificou a FC_{max} e a PSE_{max}. Em relação às variáveis submáximas, a FC foi influenciada principalmente nos estágios iniciais em que os valores foram maiores no teste em que a análise de gases foi feita. Porém, quando expressa em $\%FC_{max}$, os atletas permaneceram na maioria dos estágios submáximos em percentuais maiores durante o protocolo com o uso da máscara. Para a PSE, não houve diferenças significativas, com exceção do estágio a 10 $km \cdot h^{-1}$, em que a PSE foi maior quando se utilizou a máscara. A V_{pico} é reduzida devido à utilização da máscara para análise de gases e a FC e o $\%FC_{max}$ em estágios submáximos são maiores devido ao uso desse equipamento, especialmente nos estágios iniciais.

Palavras-chave: Corrida; Consumo de Oxigênio; Teste de exercício.

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