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Letter to Editor

The facemask produces higher peak minute ventilation and respiratory rate measurements compared to the mouthpiece

Dear Editor-in-Chief,

The mouthpiece is the gold-standard for measuring oxygen uptake (VO_2) during incremental exercise tests, however this device alters breathing patterns during exercise (Amis et al., 1999) and often causes subjects to experience dry-mouth, dysphagia and throat irritation (Baran et al., 2001; Bart and Wolfel, 1994). This is a problem in clinical populations: discomfort due to the mouthpiece often causes incremental exercise tests to be stopped prematurely, limiting the ability to measure a true peak oxygen uptake (VO_{2peak}). The Hans-Rudolph facemask is a comfortable alternative that permits a more normal breathing pattern and reduces irritation so that patients may exercise longer and a true or predicted VO_{2peak} can be accurately assessed. As exercise intervention studies and exercise prescriptions become more common in clinical populations such as cancer patients and heart failure patients, the need for feasible and accurate exercise testing becomes more relevant. The facemask has been validated in clinical populations and elite athletes, however these populations typically exercise at very low or very high intensities, which may not necessarily represent the average healthy population. The facemask has not been validated in a group of healthy adults, nor has it been validated across a spectrum of exercise intensities so that it can be used across a broader range of studies. This study aimed to examine the validity and reliability of the facemask compared to the mouthpiece in healthy individuals at peak power, 75% peak power, and 25% peak power.

Twenty-eight healthy adults (15 males and 13 females, age: 25 ± 11 yrs [mean ± *s*], BMI: 23.67 ± 2.57 $kg \cdot m^{-2}$) consented to complete 3 incremental exercise tests on a cycle ergometer (Ergometrics er800s; Ergoline, Bitz, Germany). One test was completed using a mouthpiece (Hans Rudolph T-Shape Series 2700 two-way non-rebreathing valve), 2 tests were completed using a facemask (Hans Rudolph 7400 Vmask Series Oro-Nasal MASK) and all tests were conducted using the Vmax breath-by-breath system (Vmax; SensorMedics, Yorba Linda, CA). Each test consisted of a 2-minute rest period, followed by a 2-minute warm-up at 25 W. Power was increased by 25-75 W every 2 minutes thereafter, depending on the participant's rating of perceived exertion, until participants reached exhaustion (i.e. cadence fell below 50 rpm for longer than 30 seconds). We compared VO_2, minute ventilation (V_E) and a variety of other ventilatory parameters at peak power, 75% of peak power and 25% of peak power using 2-way repeated measures ANOVA and Bland-Altman plots (Bland and Altman, 1986). We assessed validity of the facemask by comparing the mouthpiece trials to the first facemask trials; we assessed reliability by comparing the 2 facemask trials. Further, we stratified participants into high or low cardiovascular fitness categories depending on whether their VO_{2peak} greater or less than the group median and reassessed validity and reliability within each group. Statistical significance was accepted at $p < 0.05$.

Participants' V_{Epeak} with the mouthpiece was 10% lower than their V_{Epeak} with the facemask (79.4 ± 19.9 $L \cdot min^{-1}$ vs. 88.1 ± 24.7 $L \cdot min^{-1}$; $p < 0.001$), as shown in Table 1. When participants were stratified by cardiovascular fitness level, V_{Epeak} remained lower with the mouthpiece compared to the facemask for participants in the high cardiovascular fitness group (n = 14) (V_{Epeak} 90.7 ± 19.8 $L \cdot min^{-1}$ vs. 106.0 ± 18.5 $L \cdot min^{-1}$; $p < 0.001$). Although V_{Epeak} was lower for the mouthpiece compared to the facemask, Bland-Altman analysis did not reveal any significant differences between apparatuses. As seen in Figure 1, ninety-five percent of the differences (i.e. 27

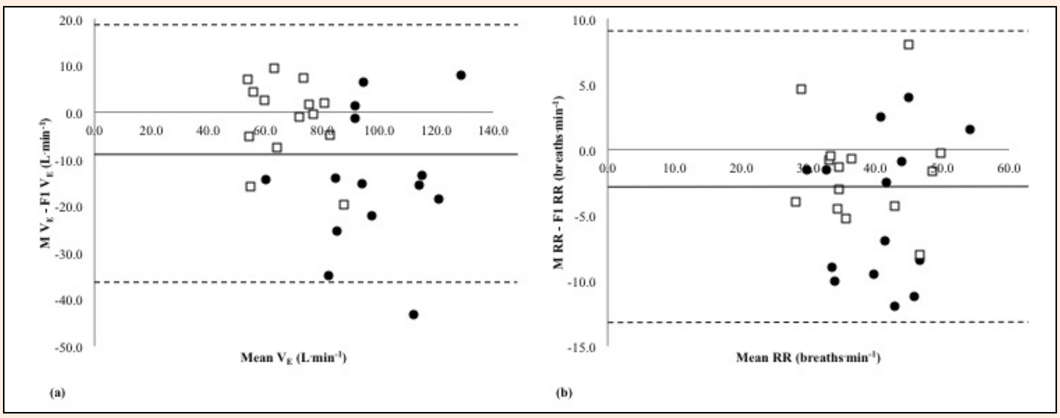

Figure 1. Bland-Altman plot of (a) V_{Epeak} and (b) peak respiratory rate (RR_{peak}) for the mouthpiece vs. the facemask; filled circles = high cardiovascular fitness group, open boxes = low cardiovascular fitness group; solid line = bias, dashed lines = +/- 1.96·*s*.

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Table 1. Ventilatory parameters. Data are means (±*s*).

	Peak power		
	M	**F1**	**F2**
Power (W)	240 (75)	243 (77)	253 (82)
VO_{2peak} (mL·kg^{-1}·min^{-1})	42.0 (9.9)	42.3 (9.0)	42.8 (9.3)
V_{Epeak} (L·min^{-1})	79.1 (20.2) *	87.1 (24.5)	87.2 (25.0)
Vt_{peak} (L)	2.712 (.559)	2.687 (.571)	2.656 (.570)
RR_{peak} (breaths·min^{-1})	38 (7) *	41 (7)	41 (8)
Exercise time (min)	10.32 (2.59)	10.58 (2.35)	10.74 (2.52)
HR (beats·min^{-1})	172 (16)	176 (16)	175 (16)
RER	1.24 (.13)	1.29 (.25)	1.26 (.12)
	75% peak power		
Power (W)	169 (49)	175 (53)	173 (53)
VO_2 (mL·kg^{-1}·min^{-1})	31.4 (7.0)	32.0 (7.5)	31.9 (7.4)
V_E (L·min^{-1})	49.2 (11.5)	51.7 (13.8)	51.5 (14.7)
Vt (L)	2.333 (.505)	2.363 (.493)	2.295 (.506)
RR (breaths·min^{-1})	27 (7)	28 (7)	29 (7)
Exercise time (min)	7.83 (1.92)	8.01 (1.90)	8.06 (2.06)
HR (beats·min^{-1})	151 (16)	156 (15)	155 (18)
RER	1.10 (.10)	1.14 (.17)	1.11 (.09)
	25% peak power		
Power (W)	63 (43)	67 (45)	66 (44)
VO_2 (mL·kg^{-1}·min^{-1})	15.6 (5.5)	15.5 (5.2)	15.5 (5.0)
V_E (L·min^{-1})	22.6 (8.7)	21.9 (8.5)	22.3 (7.9)
Vt (L)	1.416 (.549)	1.470 (.553)	1.468 (.504)
RR (breaths·min^{-1})	21 (5)	20 (4)	20 (4)
Exercise time (min)	4.00 (2.12)	3.95 (2.14)	4.17 (2.23)
HR (beats·min^{-1})	107 (12)	109 (14)	111 (16)
RER	.91 (.09)	.89 (.09)	.91 (.08)

M: mouthpiece; F1: first facemask trial; F2: second facemask trial; Vt: tidal volume; HR: heart rate; RER: respiratory exchange ratio. * denotes a significant difference from F1 and F2.

participants) fell between +/- 1.96 standard deviations of the bias. There were no significant differences between the 2 facemask trials for any of the ventilatory parameters at peak power, at 75% peak power or at 25% peak power.

The difference in V_E may be attributed to the fact that symptoms of discomfort associated with the mouthpiece become exacerbated at high power when subjects are undergoing strenuous exercise. Subjects have reported actively attempting to lower their ventilation rate to alleviate this discomfort (Askanazi et al., 1980). Furthermore, since nasal breathing is occluded when using the mouthpiece and breathing is restricted to the oral pathway, it may be more difficult for participants to reach greater V_E values (O'Kroy et al., 2001). The mouthpiece also prevents pursed-lips breathing, a natural response to strenuous exercise that relieves dyspnea. A study on chronic obstructive pulmonary disease (COPD) patients revealed that participants who were permitted to engage in pursed-lips breathing were able to exercise for a longer duration compared to those instructed to use a mouthpiece (Faager et al., 2008). We observed no difference in VO_{2peak} between the facemask and the mouthpiece, despite the marked difference in V_{Epeak}. This may be attributed to the fact that although V_E and VO_2 are tightly correlated at low-moderate exercise intensities, at peak power larger increases in V_E are required to stimulate a concurrent increase in VO_2 (Gastinger et al., 2010). It is possible that in subjects who are able to obtain a higher V_E at peak power than was observed in this study, VO_2 differences might become significant.

In the present study we observed that the facemask allowed participants to attain consistently higher peak power during the incremental exercise test compared to the mouthpiece (data not presented). The differences in peak power between facemask and mouthpiece trials in the present study were not statistically significant but may have required participants to exchange gas at different rates, contributing to significant differences in V_E. Taking these differences into consideration, we conclude that the facemask is an appropriate alternative for exercise testing in healthy populations.

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