Oro-Nasal Mask versus Two-Way Non-Rebreathing Valves for Maximal Aerobic Capacity Testing in Astronauts

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Abstract
INTRODUCTION: Astronauts complete maximal aerobic capacity (VO2pk) testing as part of their annual fitness assessment (AFA). Once assigned to a mission, the International Space Station (ISS) astronauts will complete several VO2pk tests pre-flight, in-flight, and post-flight. The VO2pk data will be used to determine workloads (W) exceeding 300 W. The VO2pk test is conducted annually and requires the tested astronaut to discontinue the study, which can be stressful for the astronaut. VO2pk data is used to track fitness changes from year to year as well as during the astronaut’s mission (pre-, in-, post-flight).

METHODS: Each of 17 active astronauts completed at least 1 VO2pk test in 2019. A repeated-measures version of a Bland-Altman* plot was used to assess agreement between VO2pk data collected on the same astronauts within 1 year. The VO2pk of the 6 astronauts was consistent with observed changes in exercise habits during the year that the data was collected.

RESULTS: The VO2pk tests were conducted on cycle ergometers with a TrueOne2400 metabolic cart (Parsippany, NJ, USA). The nominal protocol started with a 3 minute warm-up at 50 W and increases 25 W every minute until voluntary exhaustion (light – 200 W, moderate – 400 W, heavy – 600 W).

CONCLUSIONS: The mask was accepted for use in all tests. If a leak is detected without resolve, the test will be repeated (if schedule allows) and remaining tests will be completed with the mouthpiece. The VO2pk data is used to track fitness changes from year to year as well as during the astronaut’s mission (pre-, in-, post-flight).

Introduction
• A maximal aerobic capacity (VO2pk) test is part of an astronaut’s annual fitness assessment (AFA). Once assigned to a mission, the International Space Station (ISS) astronauts will complete several VO2pk tests pre-flight, in-flight, and post-flight.
• The VO2pk data is used to determine workloads (W) exceeding 300 W.
• The VO2pk mask was checked for leaks prior to test start. The astronaut will seal the open of the mask and blow out CO2 until a leak is detected.
• The VO2pk testing is conducted annually, with measured VO2pk data collected on the same astronauts within 1 year.

Purpose
To assess the reliability and validity of mask vs. mouthpiece by comparing submaximal VO2 and VO2pk data collected on the same astronauts within 1 year.

Methods
• Seventeen active astronauts (13 M, 2 F) completed a VO2pk test with the mouthpiece (first) and the mask (second) for their AFA. These tests were conducted approximately one year apart.
• The VO2pk tests were conducted on cycle ergometers with a TrueOne2400 metabolic cart (Parsippany, NJ, USA). The nominal protocol started with a 3 minute warm-up at 50 W and increases 25 W every minute until voluntary exhaustion (light – 200 W, moderate – 400 W, heavy – 600 W).
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RESULTS
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The expected day-to-day variation (SD) was used as the threshold for determining agreement between tests, (Nicholas et al., 2000). Submaximal values were plotted and evaluated visually for deviations between mask and mouthpiece.

CONCLUSIONS
• Under the assumption that the two methods (mask & mouthpiece) are equivalent, about 95% of the observed differences in VO2pk data were within the threshold of agreement. Overall mean percentage bias was 4.55% (413/447), with most of the discrepancies occurring at the highest workloads.
• Most of the extreme under-estimates of VO2 at high workloads were seen in data from two of the subjects (Fig 3).

Statistical Analysis
• Paired measurements of VO2 for 17 subjects: first with mouthpiece and then with mask over a range of workloads (W).
• Model VO2 as a function of W using mouthpiece measurements (Fig 5). Estimate between-subject SD of the differences between VO2pk.
• Under the assumption that the mask-based method for measuring VO2 is just as accurate as the mouthpiece method, and that the SD of the differences is 0.5 (within-subject repeatability standard deviation multiplied by the square root of 2).

Results
• VO2pk values were more than 5% different, despite similar test times, between mouthpiece and mask in 6 of 17 comparisons (Table 3).
• VO2pk with the mouthpiece was lower than the mask in 3 cases.
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• The submaximal data did not indicate a leak in either apparatus during these tests.

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