### VO₂max

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<td>Alan Moore, Ph.D.</td>
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#### Evaluation of Maximal Oxygen Uptake (VO₂max) and Submaximal Estimates of VO₂max Before, During and After Long Duration ISS Missions

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- **Co-Investigators:**
  - Simon Evetts, Ph.D.
  - Alan Feiveson, Ph.D.
  - Stuart Lee, M.S.
  - Frank McCleary, M.S.
  - Steven Platts, Ph.D.
- **Lead Technician:** Poul Knudsen
- **Sponsoring Project Scientist:** Jeffery Ryder, Ph.D.
Background

- NASA’s Human Research Program Integrated Research Plan (HRP-47065) serves as a road-map identifying critically needed information for future space flight operations (Lunar, Martian)
- \( \text{VO}_2\text{max} \) (often termed “aerobic capacity”) reflects the maximum rate at which oxygen can be taken up and utilized by the body during exercise
- Lack of in-flight and immediate postflight \( \text{VO}_2\text{max} \) measurements was one area identified as a concern
- The risk associated with not knowing this information is: “Unnecessary Operational Limitations due to Inaccurate Assessment of Cardiovascular Performance” (HRP-47065)
Currently, VO₂max is estimated using HR response to submaximal exercise
Assumes VO₂ at each exercise stage during flight same as preflight
The validity of this technique has not been established during or after flight
Current data suggests a sharp decline in VO₂max early in-flight and a slow recovery with participation in exercise countermeasures.

- Large decline at R+5, but recovered to preflight fitness by R+30.

Do these changes in estimated VO₂max reflect true changes?

- Factors such as cycling efficiency can influence the HR and VO₂ response to exercise.
- Anything affecting exercise HR response also affects the VO₂max estimate.
Specific Aims

- To directly measure VO$_2$max during and following long duration missions
- To assess the validity of the current methods of estimating VO$_2$max change during and following ISS missions, and;
- To determine if the accuracy of estimating changes in VO$_2$max during and following ISS missions can be improved (e.g. addition of submaximal VO$_2$, cardiac output measures)
## Experiment Design

<table>
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<tr>
<th>Preflight</th>
<th>In-Flight</th>
<th>Postflight</th>
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<tr>
<td><strong>Peak Cycle Exercise Test</strong>&lt;br&gt;Nominal MEDB 4.1</td>
<td><strong>VO₂max Cycle Exercise Tests</strong>&lt;br&gt;FD 14 (± 2 days)&lt;br&gt;3.0 hours&lt;br&gt;(Repeated every 30 days)</td>
<td><strong>VO₂max Cycle Exercise Tests</strong>&lt;br&gt;R+1&lt;br&gt;1 hour&lt;br&gt;R+10 (± 2 days)*&lt;br&gt;1 hour&lt;br&gt;R+30 (± 2 days)&lt;br&gt;1 hour</td>
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<tr>
<td>L-270 ( 3 weeks)&lt;br&gt;1 hour</td>
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<tr>
<td><strong>VO₂max Cycle Exercise Test</strong>&lt;br&gt;– Preflight Trial 1*&lt;br&gt;L-60 (± 5 days)&lt;br&gt;1.5 hours</td>
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<tr>
<td><strong>VO₂max Cycle Exercise Test</strong>&lt;br&gt;– Preflight Trial 2§&lt;br&gt;L-30 (± 5 days)&lt;br&gt;1.5 hours</td>
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<td>§If L-60 is technically sound,&lt;br&gt;L-30 test will be waived.</td>
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*Represents test session not normally performed for MEDB 4.1
SESSION: **Peak Cycle Exercise Test** on L-270 (3 weeks)

Scenario: (1 hour)
- Measure VO$_2$max during a cycle protocol of increasing exercise intensity
- Heart rate, blood pressure, exercise workloads, and perception of effort will also be measured
- Data obtained from this test will be used to establish the protocol for the subsequent tests
- Session is identical to that performed by all crew members under MEDB 4.1
  - Data will be shared between PI and Med Ops to prevent necessity for redundant testing
Session Descriptions
Preflight/Postflight

SESSIONS: VO$_{2}$max Cycle Exercise Tests on L-60, L-30, R+1, R+10 and R+30

Scenario: (1.5 hours/test preflight, 1 hour/test postflight)
- Measure VO$_{2}$max using investigation specific protocol
- First 3 exercise stages are 5 min @ work rates eliciting ~ 25, 50 and 75% of L-270 VO$_{2}$max, remaining stages increase 25 W/min to maximal levels
- First 3 stages are identical to those used in MEDB 4.1 testing
- Blood pressure, oxygen uptake, heart rate, workloads and perception of effort will be measured
- Cardiac output will be measured using a rebreathing technique during last minute of the first 3 exercise stages
- Data obtained from L-60, R+1, R+30 will fulfill MEDB 4.1 testing requirements.
Session Descriptions
Preflight/Postflight

Constraints:
• No max exercise 24 hrs prior to testing; no regular exercise 8 hrs prior to testing
• No food 2 hrs prior to test
• No caffeine, alcohol, or nicotine 8 hrs prior to test
• No Neutral Buoyancy training 48 hours prior to test; prefer 72 hours
• ECG monitoring (up to 3 Leads) is required for tests
• No physical testing or physical training will be conducted with the crewmembers within 72 hours of returning from overseas travel
• No physical testing or physical training will be conducted with the crewmembers within 48 hours of domestic travel unless approved by the Crew Surgeon
Session Descriptions
In-Flight

SESSIONS: $\text{VO}_2\text{max}$ Cycle Exercise Tests on FD 14 and every 30 FDs subsequent (same schedule as MEDB 4.1)

Scenario: (3.0 hours/test, includes equipment and subject preparation, exercise and stowage time)

- Same test protocol as performed preflight
- ECG is down-linked real time during test (Ku coverage necessary during exercise) and viewed by Surgeon for medical monitoring purposes only
- Cardiac output will be measured using a rebreathing technique during last minute of the first 3 exercise stages
- Data other than ECG will be down-linked following session
Session Descriptions

In-Flight

Constraints:

- No max exercise 24 hrs prior to testing; no regular exercise 8 hrs prior to testing
- No food 2 hrs prior to test
- No caffeine, alcohol, or nicotine 8 hrs prior to test
# Experiment Training

<table>
<thead>
<tr>
<th>Session Title</th>
<th>Schedule</th>
<th>Duration</th>
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<tr>
<td>MEC OV*</td>
<td>L-1 year</td>
<td>1 hour</td>
</tr>
<tr>
<td>CMS Ops 1*</td>
<td>L-1 year</td>
<td>1.5 hours</td>
</tr>
<tr>
<td>PPFS Hardware Overview</td>
<td>L-365/180 days</td>
<td>2 hours</td>
</tr>
<tr>
<td>VO$_2$max Integrated Training</td>
<td>L-160/120 days</td>
<td>2 hours</td>
</tr>
<tr>
<td>VO$_2$max Refresher Training</td>
<td>L-90/45 days</td>
<td>1.5 hours</td>
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MEC OV – Medical Equipment Computer Overview  
CMS Ops – Countermeasure Systems Operations  
PPFS – Portable Pulmonary Function System  

* Scheduled training is performed as outlined in MEDB 4.1
Data Distribution

- In-flight real time data (ECG, HR, etc.) will be viewed by hardware support team to verify proper hardware configuration
- Experimental data will not be used to assess crew health
- Any data sharing will be captured in the Data Sharing Plan specific to that subject’s flight
Possible Risks or Discomforts

- Study designated as “Reasonable Risk” by NASA CPHS
- Many of these are already associated with MEDB 4.1

  - **Muscle cramping, fatigue or soreness**
    - Cycling rarely produces soreness
    - Warm-up and cool-down procedure mitigates risk
    - Subjects encouraged to stretch following the activity

  - **Rash or irritation of the skin**
    - Due to adhesive sensitivity (electrode site)
    - Request that electrode sites be washed/wiped following test

  - **Saddle Soreness (pre/post only)**
    - Padded gel seat used to minimize discomfort

  - **Mouth/throat dryness**
    - Drink water prior to and following test
Possible Risks or Discomforts

- **Electrical shock**
  - All testing equipment has passed both NASA safety inspections and manufacturing electrical tests.

- **Heart problems**
  - Vigorous exercise always carries this risk
  - Sudden death ~ 1:15,000 per year in recreational joggers, ~1:50,000 per year in marathon participants (majority are medically unscreened individuals)
  - Risk is mitigated by the amount of screening/testing astronauts receive
  - Medical monitoring will be used (pre/post flight, flight surgeon will be present; inflight ECG monitoring/downlink will be used)
Possible Risks or Discomforts

- **Dizziness Following Exercise**
  - Most likely to occur on R+1, potential to occur during other ground tests
  - May be due to blood pooling in legs, active cool down helps mitigate this
  - Will monitor blood pressure and symptoms
  - If necessary, subject will be moved to supine position for recovery

- **Perception of “air hunger”**
  - Cardiac output measure done with rebreathing technique
  - Elevation in bag CO₂ may cause “air hunger” symptoms
  - Mitigated by elevation of oxygen concentration in rebreathing gas
  - Rebreathing period is short: \( \leq 30 \text{ seconds} \); may be aborted safely if discomfort is extreme

- **Accident Due to Improper Handling of Compressed Gas**
  - Crew and investigators will be/are trained on handling of compressed gas


VO₂max

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Experiment Success

Defined by:

- Direct and accurate measures of VO₂max during and following long duration missions accomplished
- Determination of the accuracy of estimating VO₂max using submaximal test results (workload vs. HR; VO₂ vs. HR)
- Determination of added benefit of cardiac output to estimates of VO₂max from submaximal test results
Experiment Benefits

- Direct measures of VO$_2$max will establish the “space normal” response of VO$_2$max to long duration space flight. This will aid in future mission planning and act as a baseline for countermeasures assessment.
- Data will allow NASA to determine if submaximal tests provide accurate information to assess VO$_2$max. This may have implications on the future of routine tests conducted on the ISS and interpretation of data previously collected during long duration missions.
- Will determine if the addition of the non-invasive measurement of cardiac output improves the estimate of VO$_2$max derived from submaximal test results.