Evaluation of Maximal Oxygen Uptake (VO_2max) and Submaximal Estimates of VO_2max Before, During and After Long Duration ISS Missions

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Background

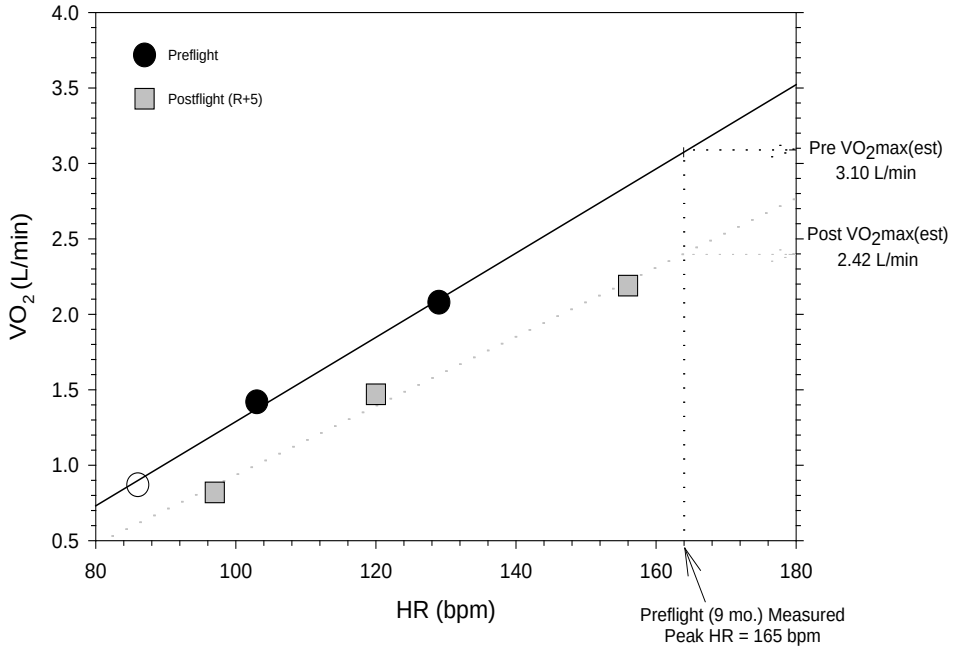
- NASA's Human Research Program Integrated Research Plan (HRP-47065) serves as a road-map identifying critically needed information for future space flight operations (Lunar, Martian)
- VO_2max (often termed "aerobic capacity") reflects the maximum rate at which oxygen can be taken up and utilized by the body during exercise
- Lack of in-flight and immediate postflight VO_2max 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)

VO_2max

Human Research Program Informed Consent Briefing

Alan Moore, Ph.D.

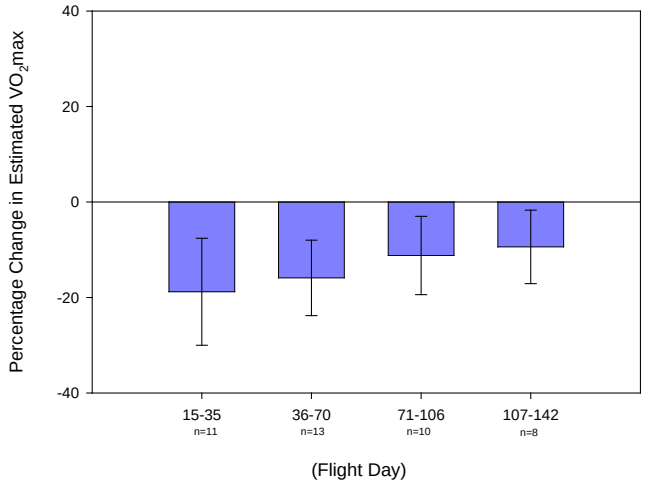
Background

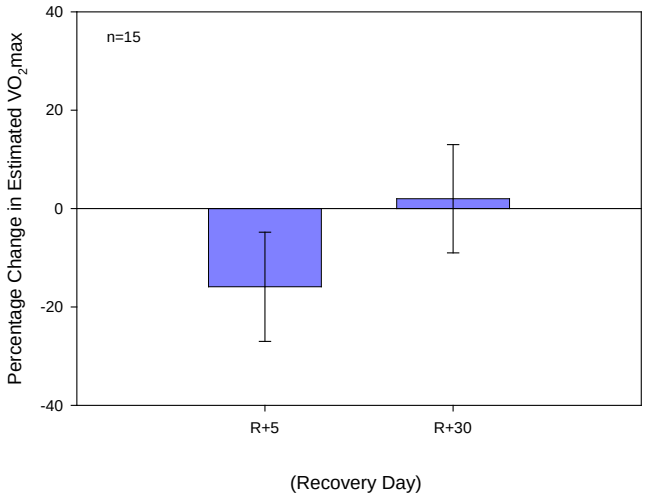


- Currently, VO_2max is estimated using HR response to submaximal exercise
- Assumes VO_2 at each exercise stage during flight same as preflight
- The validity of this technique has not been established during or after flight

VO_2max

Background





- Current data suggests a sharp decline in VO_2max 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 VO_2max reflect true changes?
  - Factors such as cycling efficiency can influence the HR and VO_2 response to exercise
  - Anything affecting exercise HR response also effects the VO_2max estimate

Specific Aims

- To directly measure VO_2max during and following long duration missions
- To assess the validity of the current methods of estimating VO_2max change during and following ISS missions, and;
- To determine if the accuracy of estimating changes in VO_2max during and following ISS missions can be improved (e.g. addition of submaximal VO_2, cardiac output measures)

VO_2max

Experiment Design

Preflight	In-Flight	Postflight
Peak Cycle Exercise Test- Nominal MEDB 4.1 L-270 (3 weeks) 1 hour **VO_2max Cycle Exercise Test – Preflight Trial 1*** L-60 (± 5 days) 1.5 hours **VO_2max Cycle Exercise Test – Preflight Trial 2§** L-30 (± 5 days) 1.5 hours §If L-60 is technically sound, L-30 test will be waived.	**VO_2max Cycle Exercise Tests** FD 14 (± 2 days) 3.0 hours (Repeated every 30 days)	**VO_2max Cycle Exercise Tests** R+1 1 hour R+10 (± 2 days)* 1 hour R+30 (± 2 days) 1 hour

*Represents test session not normally performed for MEDB 4.1

Session Descriptions
Preflight

SESSION: **Peak Cycle Exercise Test** on L-270 (3 weeks)

Scenario: (1 hour)

- Measure VO_2max 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_2max 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_2max using investigation specific protocol
- First 3 exercise stages are 5 min @ work rates eliciting ~ 25, 50 and 75% of L-270 VO_2max, 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: **VO_2max 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

Session Title	Schedule	Duration
MEC OV*	L-1 year	1 hour
CMS Ops 1*	L-1 year	1.5 hours
PPFS Hardware Overview	L-365/180 days	2 hours
VO_2max Integrated Training	L-160/120 days	2 hours
VO_2max Refresher Training	L-90/45 days	1.5 hours

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 CO_2 may cause "air hunger" symptoms
  - Mitigated by elevation of oxygen concentration in rebreathing gas
  - Rebreathing period is short: ≤ 30 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

Experiment Success

Defined by:

- Direct and accurate measures of VO_2max during and following long duration missions accomplished
- Determination of the accuracy of estimating VO_2max using submaximal test results (workload vs. HR; VO_2 vs. HR)
- Determination of added benefit of cardiac output to estimates of VO_2max from submaximal test results

Experiment Benefits

- Direct measures of VO_2max will establish the "space normal" response of VO_2max 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_2max. 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_2max derived from submaximal test results.