THE EFFECTS OF TERRAIN AND NAVIGATION ON HUMAN EXTRAVEHICULAR ACTIVITY WALKBACK PERFORMANCE ON THE MOON

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Background and Primary Objective

- Results of the EVA Walkback Test showed that 6 male astronauts were able to ambulate 10 km on a level treadmill while wearing a prototype EVA suit in simulated lunar gravity.

- However, the effects of lunar terrain, topography, and real-time navigation on ambulation performance are unknown.

- Primary objective: To characterize the effect of lunar-like terrain and navigation on VO$_2$ and distance traveled during an unsuited 10 km (straight-line distance) ambulatory return in earth gravity.
Test Protocols

- Haughton Mars Project (HMP) Walkback
  - 10 km “as the crow flies”
  - GPS navigation
  - Rapid but sustainable pace
    • <85% predicted max HR
  - No time limit or route limitations
  - 3 separate routes
- Matched Treadmill Control
  - Speed/grade/distance matched to HMP Walkback
  - 1 minute average (speed/grade)
  - Matched to SW Highland Route
- Level Treadmill Control
  - Distance matched
  - Rapid but sustainable pace
    • <85% predicted max HR
  - No time limit
  - Subjects blinded to speed
**HMP Walkback Protocol**

**Out**
- Synchronize GPS with base
- Calibrate Cosmed
- Traverse departs
- Test subject wears backpack (Cosmed, GPS, water) on ATV1
- Two people double up on ATV
- 5-6 ATVs together

**In**
- Test checklist completed: start called
- Formed two return groups:
  - Each group: GPS, maps, >2 radios and batteries, one firearm
  1. Roving group: videotaped test
     - 2 ATVs (video & guide/protection)
  2. Test group: tracked subject
     - Subject on foot, trailed by guide/others
     - Medical kit, emergency food and water
Route Selection

Haughton Mars Project
EVA 10 Km Walkback
2007

- Subject Number 1
- Subject Number 2
- Subject Number 3

Southwest Route
“Lunar Highlands”

South Route
“Crater Climb Out”

North Route
“Mare”

Haughton Crater, Devon Island, Nunavut, Canada

Landsat 7 ETM+
UTM Projection
Zone 16N
WGS 84
Scene Acquired Aug 3, 1999

“The Effect of Terrain and Navigation on Human EVA Walkback Performance on the Moon” - Jason Norcross
**HMP Walkback Results**

- Average time $126.5 \pm 28.7$ min (mean ± SD).........[96 min for EWT]
- Average $\text{VO}_2$ $27.8 \pm 5.1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$.................................[24.8 for EWT]
- Straight line distance $9.91 \pm 0.22$ km
- Actual distance was $10.61 \pm 0.61$ km (7% increase)

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**The Effect of Terrain and Navigation on Human EVA Walkback Performance on the Moon** - Jason Norcross
HMP Walkback Speed/Grade Matched Control Trial

- Speed/grade matched to the best 1-min average from field
- Speed/grade adjusted manually every minute
- Clothing and boots similar to field trials
- Weighted vest used to account for weight differences
- \(-10^\circ\) to \(30^\circ\) available
  - Within this band > 98% of time
### Results: Field vs. Matched Control

<table>
<thead>
<tr>
<th>Summary (n=3)</th>
<th>HMP</th>
<th>JSC</th>
<th>ΔVO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg VO₂ (mL·kg⁻¹·min⁻¹)</td>
<td>26.9 ± 6.4</td>
<td>17.1 ± 4.9</td>
<td>9.8 ± 3.8</td>
</tr>
</tbody>
</table>

![VO₂ Graph](image-url)
### Level, Self-selected Speed Control Trial

<table>
<thead>
<tr>
<th>Total VO$_2$ (L)</th>
<th>JSC Level Control</th>
<th>JSC Matched Control</th>
<th>HMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub 1</td>
<td>208</td>
<td>173</td>
<td>243</td>
</tr>
<tr>
<td>Sub 2</td>
<td>208</td>
<td>171</td>
<td>279</td>
</tr>
<tr>
<td>Sub 3</td>
<td>174</td>
<td>149</td>
<td>249</td>
</tr>
<tr>
<td>Avg</td>
<td>197</td>
<td>164</td>
<td>257</td>
</tr>
</tbody>
</table>

- Level treadmill
- Distance matched
  - Noted 10 km stats also
- No time limit
- Speed blinded to subject
  - Can change at any time
- Similar clothing/boots to field trials
- Weighted vest used to account for weight differences
Putting in All Together

• EWT results need re-evaluation

• Terrain and navigation:
  \( \uparrow \text{VO}_2 \) by 56% avg (range 41-67%)
  \( \uparrow \) distance by 7% (up to 21%)

• Incline/decline:
  - Story is unclear
  - 1-g transport cost u-shaped
  - Suited 1/6-g incline metabolic cost shows energy recovery
Forward Work

• Increase data pool
  – Complete remaining 6 control trials
  – Increase # of walkbacks

• Does this carry over to 1/6 g?
  – Gait differences (contact time, ground reaction force, stride length, cadence)
  – Slope and soil characterization
  – HMP subjects complete 10-km suited walkback
  – Speed/grade matched 10-km walkback profile
  – Speed matched only 10-km walkback profile
  – Portable Pogo
Back-up slides – Sub 3

VO2 (ml/min/kg)

JSC
HMP
Delta VO2

Time

0 20 40 60 80 100 120 140
Suited Metabolic Cost of Incline

- Lunar Shirt Sleeve
- Lunar SS Weight-Matched
- Lunar Suited
- 1g Shirt Sleeve