

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

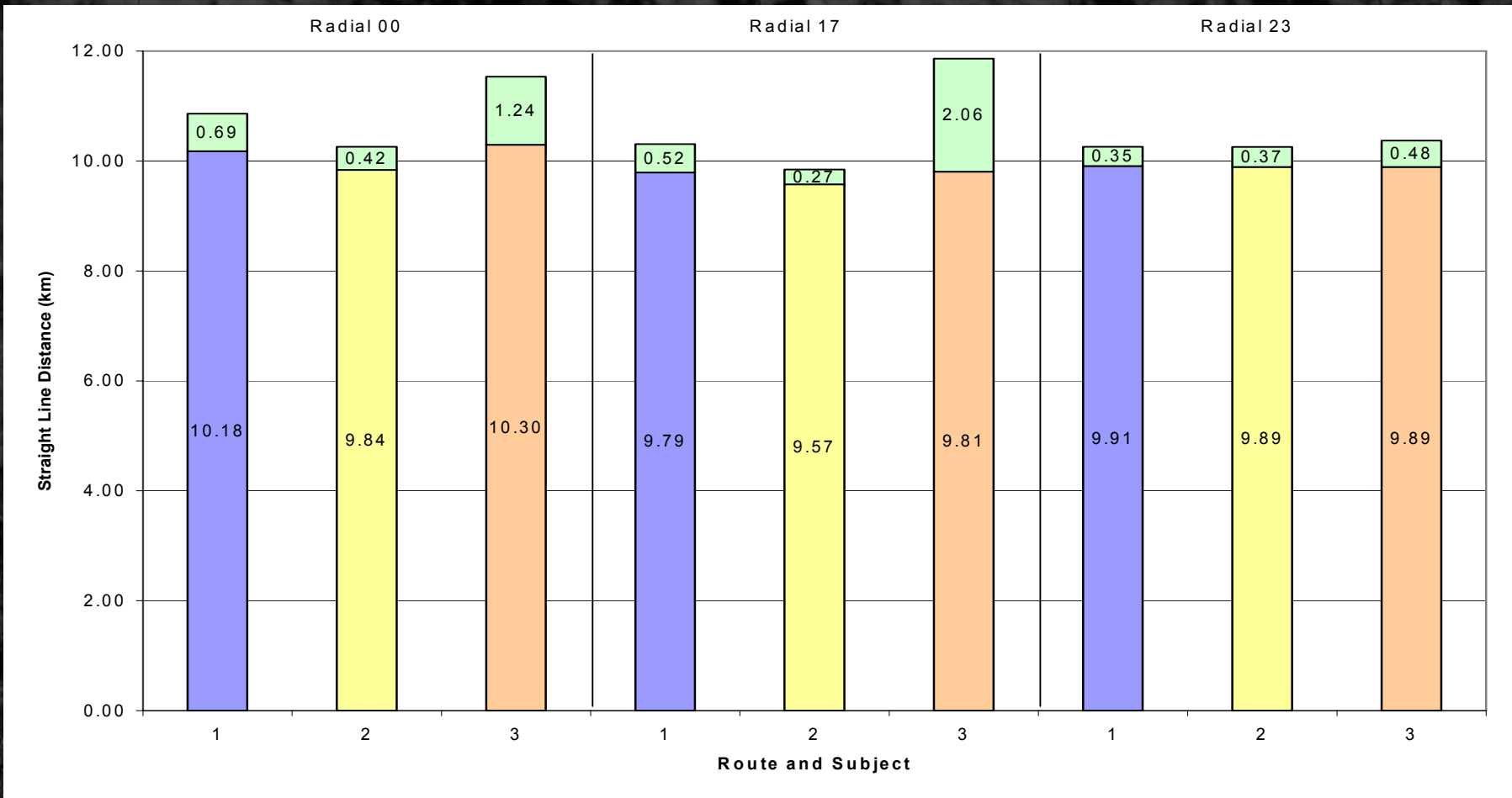
- Test checklist completed: start called
- Formed two return groups:
 - Each group: GPS, maps, >2 radios and batteries, one firearm
 - 1. Roving group: videotaped test
 - 2 ATVs (video & guide/protection)
 - 2. Test group: tracked subject
 - Subject on foot, trailed by guide/others
 - Medical kit, emergency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



Route Selection



HMP Walkback Results



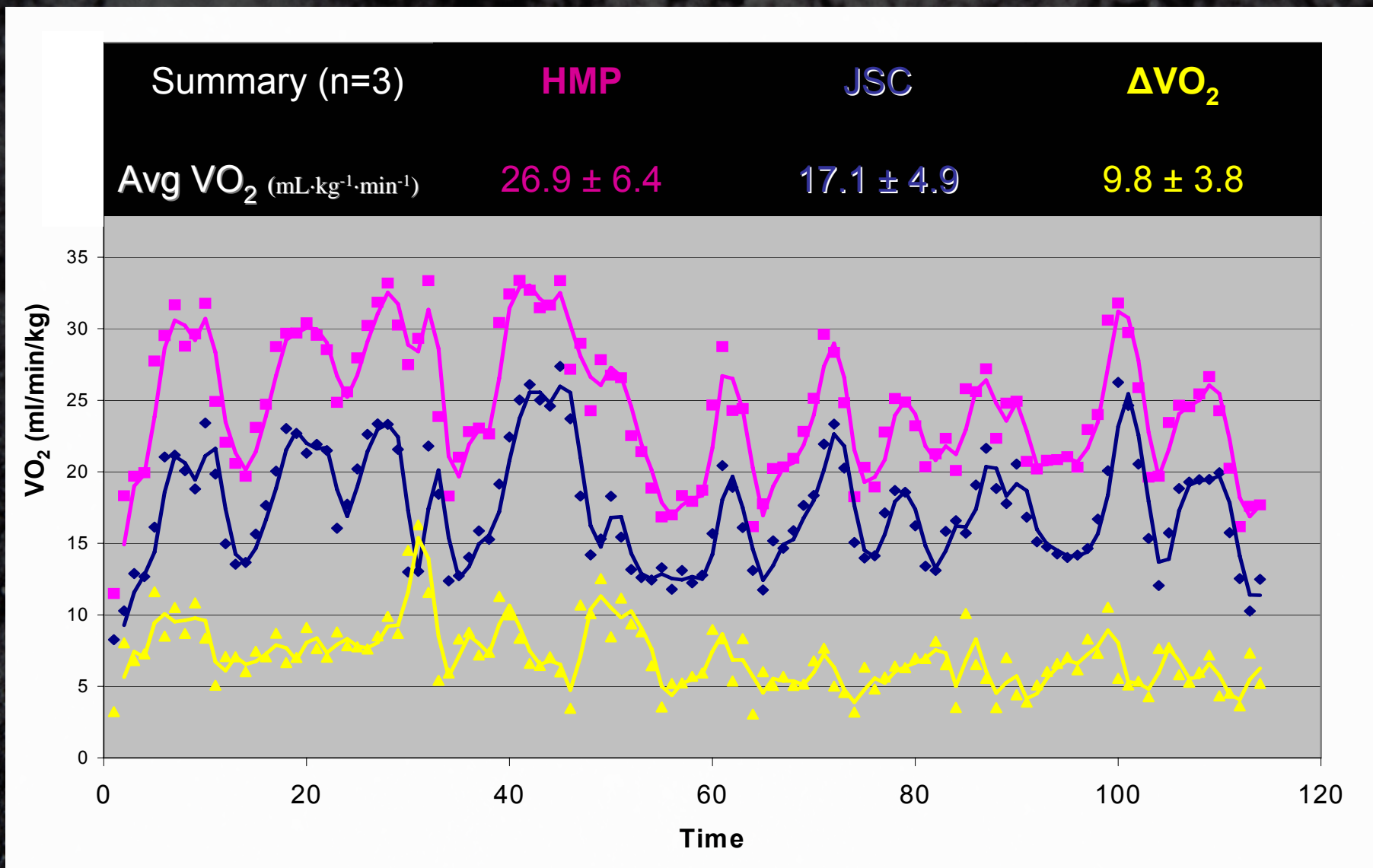
- Average time 126.5 ± 28.7 min (mean \pm SD).....[96 min for EWT]
- Average VO_2 27.8 ± 5.1 mL·kg⁻¹·min⁻¹.....[24.8 for EWT]
- Straight line distance 9.91 ± 0.22 km
- Actual distance was 10.61 ± 0.61 km (7% increase)

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° to 30° available
 - Within this band $> 98\%$ of time



Results: Field vs. Matched Control



Level, Self-selected Speed Control Trial

Total VO ₂ (L)	JSC Level Control	JSC Matched Control	HMP
Sub 1	208	173	243
Sub 2	208	171	279
Sub 3	174	149	249
Avg	197	164	257

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



Putting in All Together

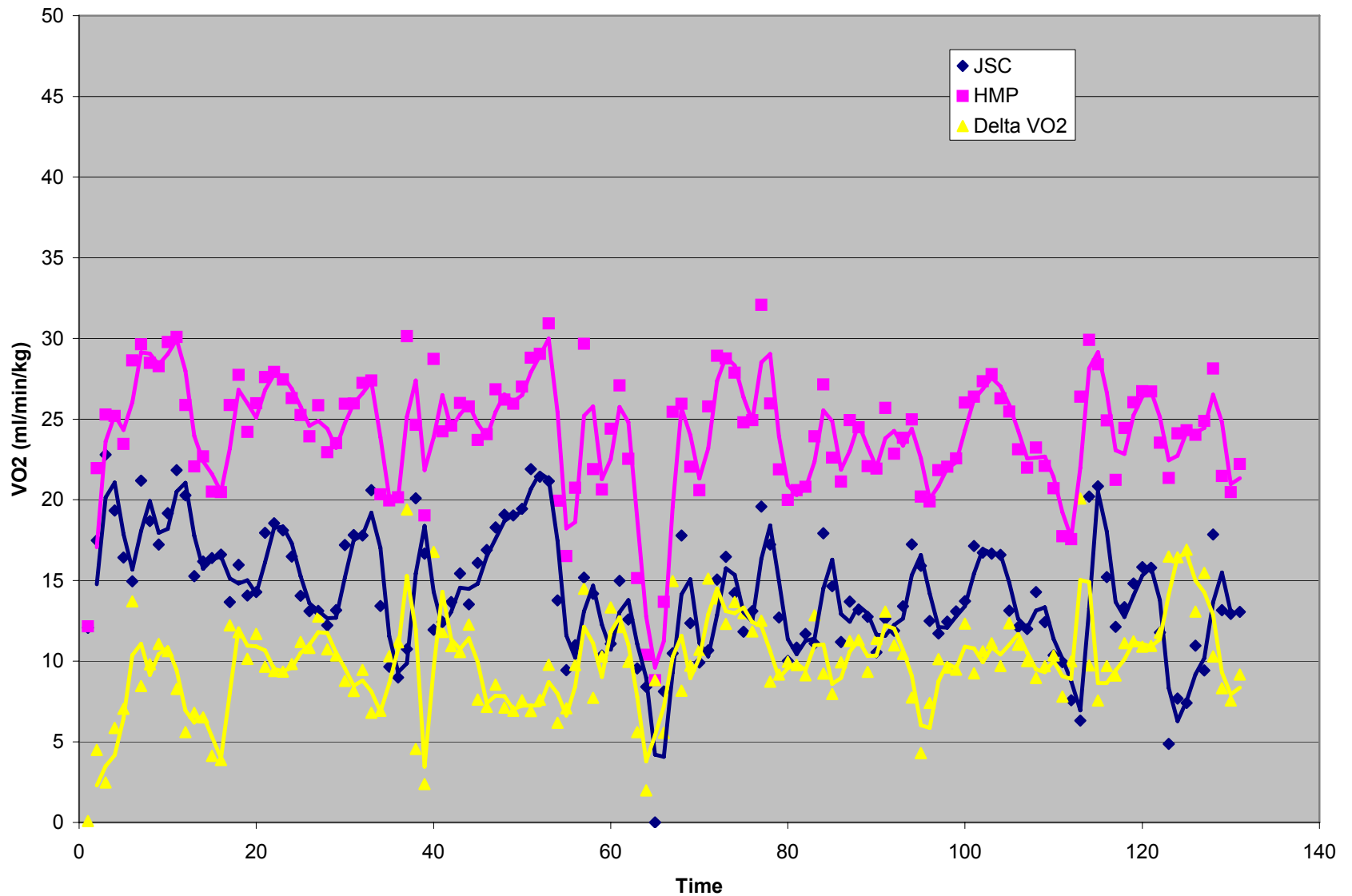
- EWT results need re-evaluation
- Terrain and navigation:
 - ↑ VO_2 by 56% avg (range 41-67%)
 - ↑ distance by 7% (up to 21%)
- Incline/decline:
 - Story is unclear
 - 1-g transport cost u-shaped
 - Suited 1/6-g incline metabolic cost shows energy recovery



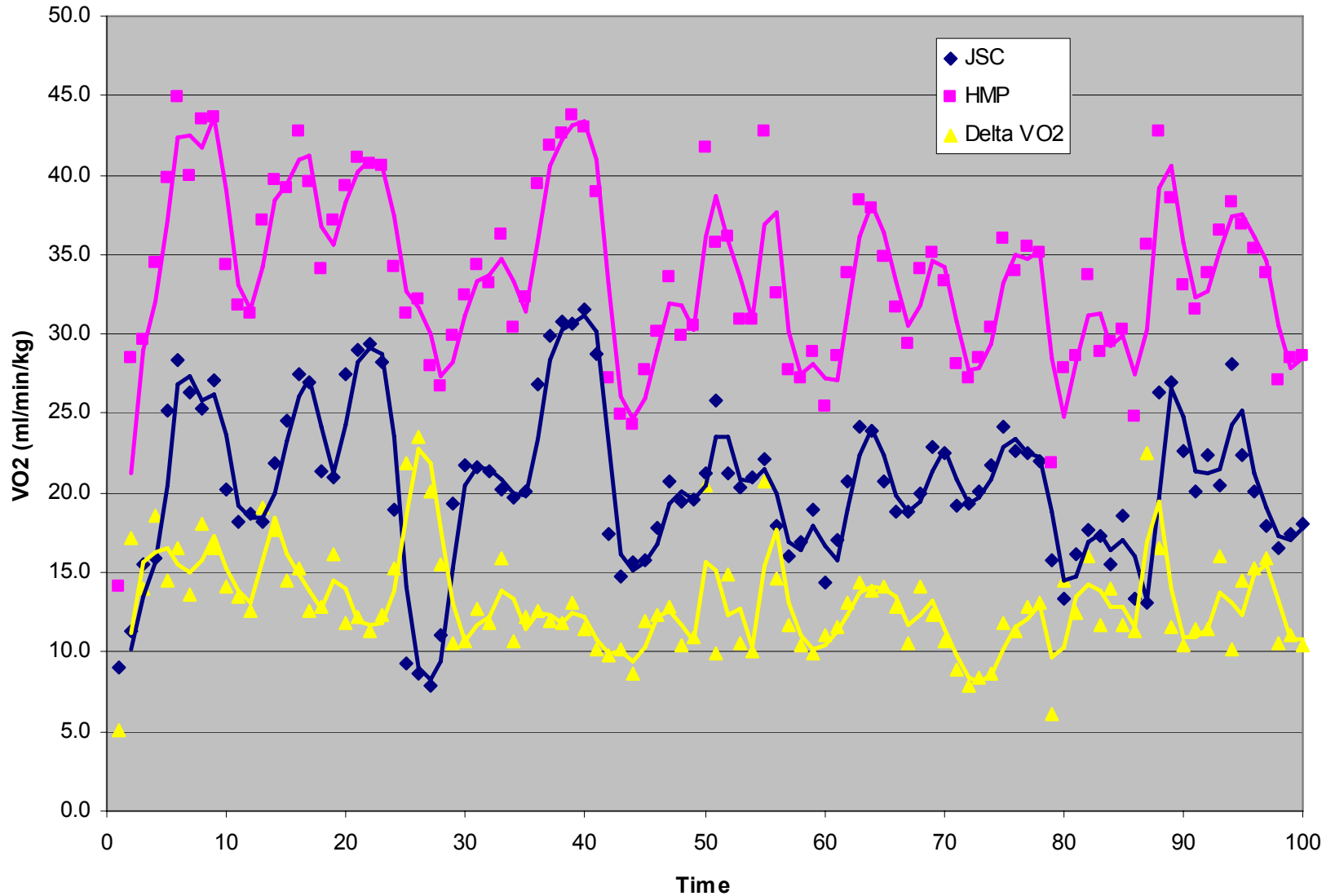
Forward Work

- **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**

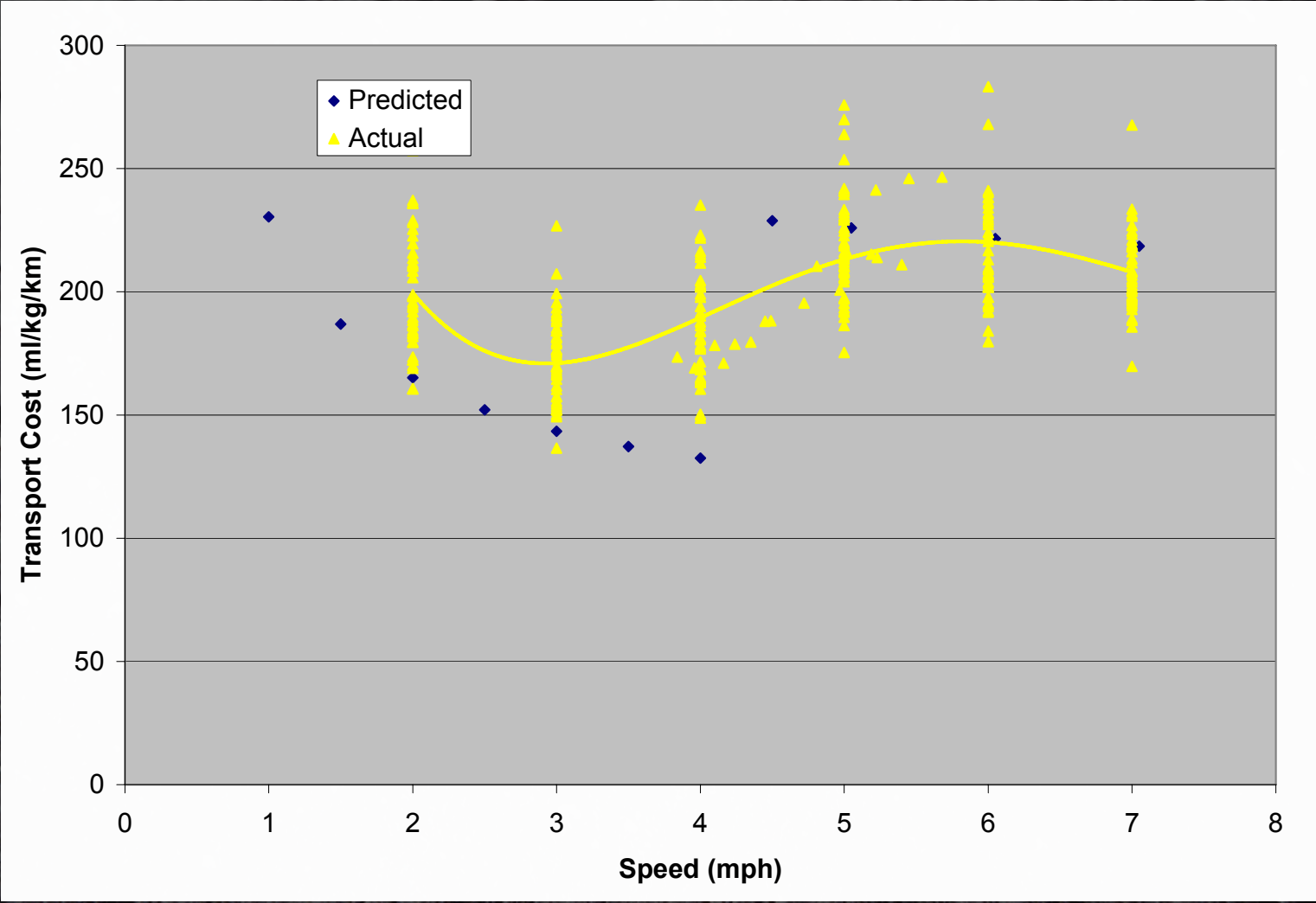
Back-up slides – Sub 3



Back-up Slides – Sub 2



1-g Transport Cost



Suited Metabolic Cost of Incline

