Effect of Changing Weight and Mass on Human Performance in a Lunar Prototype Spacesuit

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ABSTRACT

Physical effort, compensation, and controllability in a spacesuit can be affected by suit mass and gravity level. Because of limitations in certain reduced-gravity simulators and the finite selection of lunar prototype suits, it is difficult to ascertain how a change in suit mass affects suited human performance. One method of simulating a change in mass is to vary the total gravity-adjusted weight (TGAW), which is defined as the sum of the suit mass and subject mass, multiplied by the gravity level. **PURPOSE**: To determine if two methods of changing TGAW during parabolic flight—changing suit mass or gravity level—affect subjective ratings of suited human performance equally. **METHODS**: A custom weight support structure was connected to a lunar prototype spacesuit, allowing the addition of mass to the suit while maintaining a near-constant center of mass. In the varied-weight (VW) series, suit mass (120 kg) was constant at 0.1-g, 0.17-g, and 0.3-g, yielding TGAWs of 196, 333, and 588 N, assuming an 80-kg subject. In the varied-mass (VM) series, gravity level was constant at 0.17-g and suit mass was 89, 120, and 181 kg, yielding TGAWs of 282, 333, and 435 N. The 333 N condition was common to both series. Direct comparison was not possible due to limited adjustability of suit mass and limited options for parabolic profiles. Five astronaut subjects (80.3 11.8 kg) completed 4 different tasks (walk, bag pickup, lunge, and shoveling) in all conditions and provided ratings of perceived exertion (RPE) and the gravity compensation and performance scale (GCPS) upon completion of each task. **RESULTS**: Where VM and VW series overlapped, RPE and GCPS trend lines were similar. Mean RPE and GCPS at 333 N was 8.4 and 3.7. Mean RPE and GCPS for VM was 7.8 and 3.8 for 282 N and 9.8 and 4.1 for 435 N. Extrapolation of the VM trend to match VW TGAWs 196 and 588 N predicts an RPE of 6.5 and 12.3 and GCPS of 4.4 and 5.9, whereas the measured VW values for RPE were 8.1 and 9.8 and GCPS were 4.4 and 3.7. **CONCLUSION**: Modeling a change in suit mass by altering weight alone may be an adequate simulation through a limited range when looking at gross metrics of subjective suited human performance. Whether altering weight alone will be sufficient for more precise metrics of human performance, and across a wider range of activities, still needs further study.

INTRODUCTION

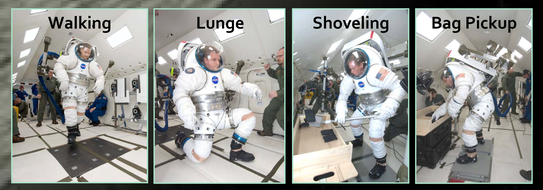
- Spacesuits for exploration missions should be optimized for human performance and health. Depending on gravity level it is possible to build a suit that is too heavy or too light for this optimization.
- Limitations of reduced gravity simulators and available prototype planetary spacesuits affect our ability to evaluate how a change in mass in reduced gravity affects suited human performance.
- Although the ability to vary mass is limited, we can use partial gravity simulators to vary the offload to arrive at the same weight on the ground, or Total Gravity Adjusted Weight (TGAW).
- TGAW is a function of the total system (suit and subject) mass and gravity level.

PURPOSE

To determine if two methods of altering TGAW during parabolic flight—changing suit mass or gravity level—affect subjective ratings of suited human performance equally

METHODS

- Study conducted Dec 2008 through Mar 2010 using the NASA Reduced Gravity Office's C-9 Aircraft for reduced gravity simulation
- Aircraft volumetric restrictions and short (15-30 s) parabola durations limited data to primarily subjective ratings -
  - Ratings of perceived exertion (RPE)
  - Gravity compensation & performance scale (GCPS)
- Five astronaut subjects (80.3±11.8 kg) completed 4 different tasks (walk, bag pickup, lunge, shoveling)

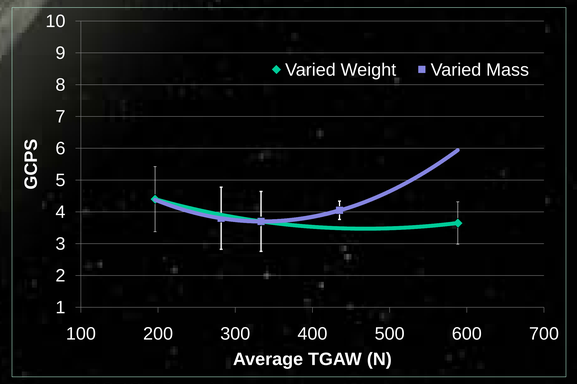


- A custom CG rig was connected to a lunar prototype spacesuit, allowing the addition of mass to the suit while maintaining a near-constant center of mass
- Varied Mass (VM) series altered TGAW by changing the system mass at a constant gravity
- Varied Weight (VW) series altered TGAW by changing the gravity profile at a constant mass

	Subject Mass (kg)	Suit/CG Rig Mass (kg)	Gravity Level	TGAW
Varied Weight Series	80	120	0.1	196 N (44 lb)
	80	120	0.17	333 N (75 lb)
	80	120	0.3	588 N (132 lb)
Varied Mass Series	80	89	0.17	282 N (63 lb)
	80	120	0.17	333 N (75 lb)
	80	181	0.17	435 N (98 lb)

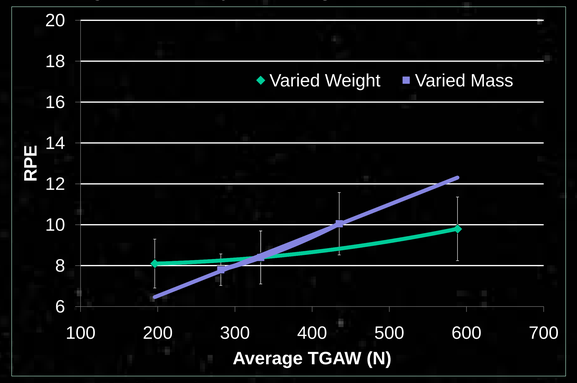
- 333 N condition was common to both series
- Direct point-by-point comparisons were not possible due to limited adjustability of suit mass and limited options for parabolic profiles

RESULTS



For GCPS (above):

- No practically significant differences were noted across the areas of TGAW overlap
- Extrapolating the VM fit to lower TGAW implies potential consistency with the VW series
- Extrapolating the VM fit to greater TGAW implies higher mass may lead to significant differences



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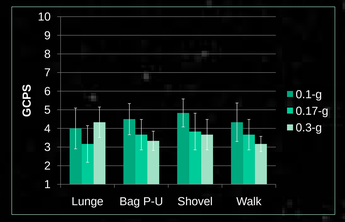
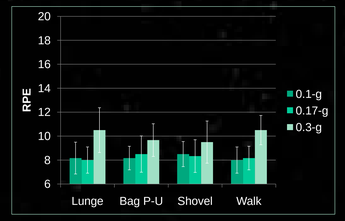
Varied Weight

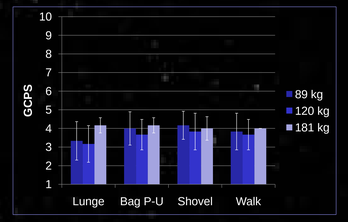


- GCPS ↓ for all tasks except kneel/recover with ↑ gravity

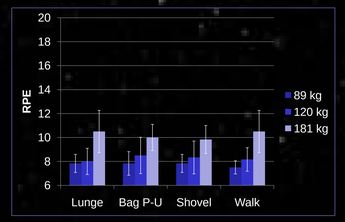


- RPE ↑ for all tasks with ↑ gravity

Varied Mass



- GCPS lowest with 120 kg mass but with large amount of variability



- RPE ↑ for all tasks with ↑ mass

CONCLUSIONS

- Modeling a change in suit mass by altering weight (i.e. offload) alone may be an adequate simulation, within a limited TGAW range, when looking at gross metrics of subjective suited human performance
- Further study is required to determine whether altering weight alone will be sufficient for more precisely evaluating human performance in these and other anticipated exploration activities.

REFERENCES

[1] Norcross JR, Lee LR, Clowers KG, Morency RM, Desantis L, De Witt JK, et al. Feasibility of Performing a Suited 10-km Ambulation - Final Report of the EVA Walkback Test (EWT). NASA/TP–2009–214796. Washington D.C.:; 2009.

[2] Norcross JR, Clowers KG, Clark T, Harvill L, Morency RM, Stroud LC, et al. Metabolic Costs and Biomechanics of Level Ambulation in a Planetary Suit. NASA/TP-2010-216115. Washington D.C.:; 2010.

[3] Chappell SP, Norcross JR, Gernhardt ML, Clowers KG, Cowley MS, Clark T, et al. Final Report of the Integrated Parabolic Flight Test: Effects of Varying Gravity, Center of Gravity, and Mass on the Movement Biomechanics and Operator Compensation of Ambulation and Exploration Tasks. NASA/TP – In Publication. Washington, D.C., 2010.