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 altering 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 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, shoveling) for each condition (VW and VM). RESULTS: Where VM and VW series overlapped, RPE and GCPS trend lines were consistent with potential consistency with the VW series. No practically significant differences were noted across the areas of overlap. CONCLUSIONS: Modeling a change in suit mass by altering weight alone will be sufficient for more precisely evaluating human performance, and almost a wider range of activities, suit mass 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


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 operations 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
• In the varied-mass (VM) series, gravity level was constant at 0.17-g and suit mass was 120 kg was constant at 0.1-g, 0.17-g, and 0.3-g, yielding TGAWs of 186, 333, and 588 N, assuming a 90kg subject.

RESULTS

Average TGAW (N)

For RPE:

For GCPS (above):

CONCLUSIONS

• No practically significant differences were noted across the areas of 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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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.

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.

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