



INTRODUCTION

- Astronauts need to display a high degree of mental aptitude, problem solving, critical thinking, and risk-benefit analysis. This is perhaps most aptly exemplified during EVA missions when astronauts need to perform at their very best.
- The degree to which we can understand their limitations as the complexity of internal and external stressors that separately and collectively adversely affect astronauts from performing at their best has yet to be determined. We are examining the application of HRV as a simple, intuitive measure to indirectly assess an astronaut's functional state prior to performing complicated or rigorous missions such as EVA activities. Additionally, we are determining if HRV can be used to monitor astronauts in real time and provide immediate feedback that can be used to mitigate potential injuries or accidents in space.



Figure 1. NASA regolith bin at NASA-Ames simulating the difference in illumination during the night on the surface of the moon. A similar experimental setup will be used in Phase I of our study to replicate the moon's surface during EVA-simulated activities.



Figure 2. An example of regolith excavation performed in a similar environment that phase 2 of our study will be performed in.
Picture. RASSOR 2.0 In Swamp Works Regolith Bin, <https://technology.nasa.gov/patent/KSC-TOPS-7>

MATERIAL AND METHODS

- EVA-simulated activities will be performed in partnership with Kennedy Space Center's Swamp Work Laboratory. **Lunar surface will be simulated**, and **regolith** will be brought in to sufficiently recreate Lunar surface and to enhance the efficacy of our research design. On the experimental visits, HRV will be determined before and after inducing physiological and psychological stress.
- Participants will then perform a series of EVA-simulated activities and their performance during these activities (**time to complete task, errors made, perceived difficulty, gate analysis**) will be quantified.
- EVA-simulated activities dependent variables will include performance measures such as maximal rate of force development, maximal strength, balance, gait analysis, neuromuscular function, muscle oxygenation, and heart rate responses.
- EVA-simulated activities will include carrying rocks/specimens, climbing ladders, getting into and out of lunar-type vehicles, opening latches, solving puzzles, maximal strength testing and endurance. All of these activities will be performed using the simulated Lunar surface.
- As a follow-up to this initial design within the 1-year grant timeline, we will apply this concept in year 2 (**Phase 2**) during the **Lunar Robotics Challenge (Ex. Figures 2 and 3)**.



Figure 3. An example of regolith excavation performed in a similar environment that phase 2 of our study will be performed in.
Picture. <https://technology.nasa.gov/patent/KSC-TOPS-7>

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RESULTS

We have recently demonstrated the robustness of subjective- versus objective-based exercise prescription (Figure 4). Specifically, utilizing ratings of perceived exertion (RPE) opposed to absolute loads resulted in more potential physiological adaptations while mitigating muscle fatigue **both above and below critical force**. Collectively, our previous and preliminary findings have indicated that previous fatigue thresholds such as physical working capacity at the fatigue threshold (**PWC_{FT}**) **may not be sensitive to fluctuations in physiological stress that is captured by HRV**. Additionally, PWC_{FT} was dissociated from ratings of perceived exertion and PWC_{FT} was not reflective of physiological stress. Furthermore, we have found that HRV is an early indicator of physiological stress and may be used to preemptively identify performance limitations.

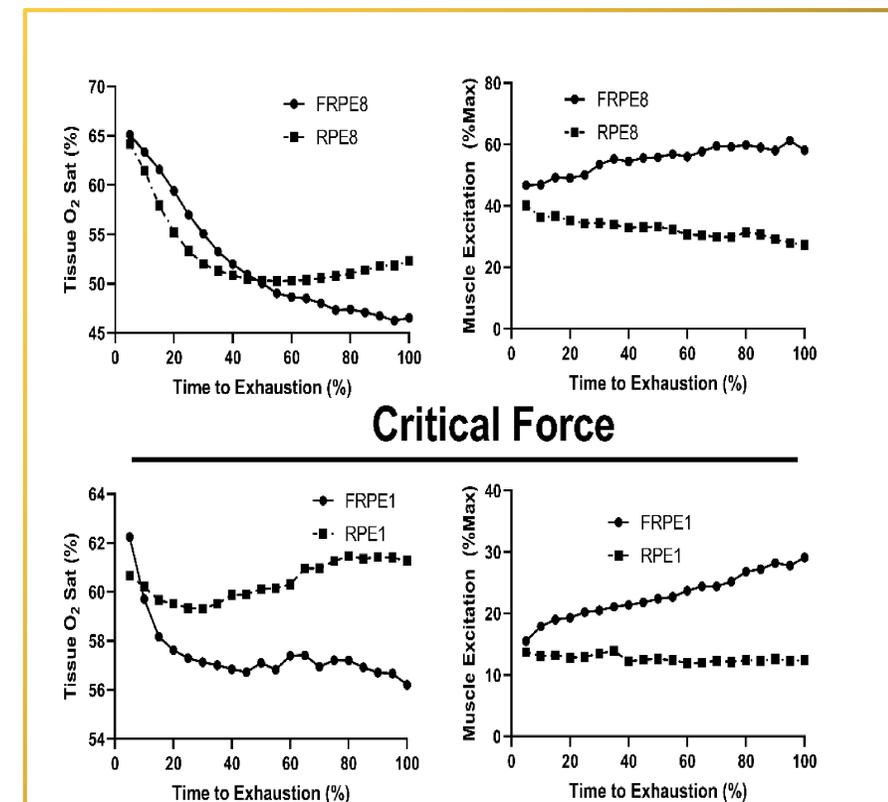


Figure 4. Mean data of tissue O₂ saturation index as well as muscle excitation during the force rating of perceived exertion (FRPE; •) trials and rating of perceived exertion (RPE; ■) trials above and below critical force. During the FRPE trials, force was not free to vary and the participants maintained their self-selected force value that corresponded to the force value during the first 5% of the respective RPE trial. As seen in each panel, there are unique physiological responses to fatiguing tasks pending objective vs. subjective intensity parameters. Qualitatively, subjective measures prevented the onset of fatigue-induced changes in muscle excitation above and below critical force as well as less pronounced changes in tissue oxygen saturation.