EVALUATION OF AEROBIC STANDARDS FOR LUNAR SURFACE EXTRAVEHICULAR ACTIVITIES

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INTRODUCTION

As NASA prepares to return to the Moon, astronauts will need to be physically primed to successfully execute Extravehicular Activities (EVA) on the Lunar surface. Compared to past Apollo missions, Artemis missions will include EVAs of increased physical demand, frequency, intensity, and duration, thus requiring adequate fitness to successfully and safely complete mission objectives. The physical demand associated with partial gravity (g) EVAs on the Moon is expected to be greater compared to microgravity EVAs based on initial workload estimation. Currently, aerobic fitness standards for partial g EVAs are not well supported by high-fidelity data and require further research for establishing standards to protect crew health and performance during Lunar surface missions. Therefore, the aim of this investigation is to characterize metabolic data from Lunar analog simulations and in-flight crew population aerobic capacity data to validate the current NASA 3001 standard for celestial partial g aerobic fitness (aerobic capacity (VO_2pk) ≥36.5ml/kg/min).

METHODS

In order to evaluate aerobic fitness requirements for Lunar EVAs, the following were performed: 1) preliminary analysis of long-duration (6 hr) EVA analog simulations in the Neutral Buoyancy Laboratory (NBL) and the Active Response Gravity Offload System (ARGOS) to evaluate expected metabolic rates for 1/6 g EVAs (NBL: n=1 female; ARGOS: n=1 male) and 2) assessment of the current NASA 3001 celestial surface EVA aerobic standard (aerobic capacity (VO_2pk) ≥36.5ml/kg/min) with data from an ISS astronaut population (n=30 male + 13 female) captured before and during space flight (flight day 15).

PRELIMINARY RESULTS

Average fractional aerobic capacity during simulated EVAs were 33%±7% VO_2pk and 23.3±7% VO_2pk in the NBL and ARGOS, respectively. This was within a previously predicted 30–40% sustainable work rate. Average metabolic rates for some tasks performed in the NBL, such as traverse (40.4% VO_2pk) and ingress (47.1% VO_2pk) were higher than the predicted sustainable work range. In ARGOS, the tasks with the greatest metabolic rates were object relocation (34.2% VO_2pk) and incapacitated crew rescue (27.0% VO_2pk). Characterization of ISS crewmember aerobic capacity determined that the average preflight VO_2pk was 42.1±5.4 ml/kg/min for females and 37.5±5.4 ml/kg/min for males. At preflight, 21.5% of crewmembers were below the 36.5 ml/kg/min in-mission aerobic standard for celestial surface EVA as outlined in NASA-STD-3001. In-flight, both female and male crewmembers experienced reductions in VO_2pk (11.7% and 10.9%, respectively), such that, during the mission, 62% of crewmembers were below the standard aerobic capacity level for celestial surface EVAs.

CONCLUSIONS

Our preliminary data suggest that while average metabolic rates for simulated Lunar EVA fall within the 30–40% sustainable work range, task specific metabolic rates exceed this range and may indicate that greater fitness is necessary for more strenuous tasks expected to be performed on the Lunar surface. Additionally, deconditioning due to space flight results in most crewmembers falling below the current celestial partial g EVA standard, which may increase risk to crew health and performance and completing mission objectives for surface missions. Further research is necessary in Artemis-specific analog environments to validate the current NASA-3001 aerobic standard for celestial EVAs. Additionally, work is ongoing to validate the current NASA-3001 strength standard for celestial EVAs.