Human Thermal Assessment of Traverse and Geology Task Iterations During Simulated Lunar Extravehicular Activity

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Spacewalks or extravehicular activities (EVA) in microgravity are mentally and physically demanding. Current microgravity EVAs are predominantly focused on upper body tasks on engineered surfaces; however, the introduction of gravity means that crew members during future lunar EVAs will be required to perform tasks that generate full body workloads such as navigating natural lunar terrain while conducting geological sampling. To date, only 12 people have walked on the surface of the Moon resulting in limited knowledge of suited thermal regulation under lunar-relevant physical workloads. To address this gap, a study is underway to focus on spacesuit operations with simulated lunar EVA workloads. This study presents methodology for collecting standard thermal measures during suit testing.

In this pilot study, two suited subjects underwent simulated lunar EVAs using the NASA Active Response Gravity Offload System (ARGOS) to simulate the effects of partial gravity. Each lunar EVA, lasting three to five hours, included various metabolically demanding EVA tasks. Subjects donned the NASA Mark III (MK III) space suit and were offloaded to 1/6th G (lunar gravity). A subset task circuit from one of these simulations replicated an EVA traverse to a lunar crater, taking a geological sample, and returning to base. The suited subject walked one 1500 m (0% grade) and three 500 m traverses at three different grades (10, 20, 30%). Between each traverse, subjects performed geology sampling tasks (0 and 10% grade). Thermal measurements included core and skin temperature, liquid cooling garment (LCG) inlet and outlet temperature, and spacesuit gas inlet and outlet temperature and humidity.

Compared to baseline core temperature (S1 = 37.07±0.32 °C, S2 = 37.27±0.01 °C) and mean skin temperature (S1 = 32.38±0.34 °C, S2 = 33.62±0.03 °C), after a 1500 m traverse, each suited subject showed an increased core temperature (S1 = 37.23±0.12 °C, S2 = 37.41±0.11°C) and decreased mean skin temperature (S1 = 32.16±0.17 °C, S2 = 31.53±1.15 °C) at a delta LCG temperature (S1 = 1.86±0.24 °C, S2 = 2.20±0.76 °C) and delta suit humidity (S1 = 9.66±1.49 %, S2 = 11.50±1.58 %). Core temperature continued to increase from compounding traverse and geology tasks (S1 = 38.04±0.03 °C, S2 = 38.1±0.02 °C) accompanied by an increase in delta LCG temperature (S1 = 2.24±0.13 °C, S2 = 2.67±0.12 °C) and delta suit humidity (S1 = 28±2.42 %, S2 = 31±2.13 %). Conversely, as the circuit progressed, mean skin temperature continued to decrease due to sustained LCG heat rejection (S1 = 30.08±0.15 °C, S2 = 30.28±0.07 °C). During the simulated EVA circuit core temperature increased to elevated values and remained elevated as heat was retained while mean skin temperature decreased due to peripheral heat offloaded to the LCG. The thermal measures collected during this study provided critical heat loading dynamics during lunar EVA tasks. Including core and skin temperatures along with suited thermal measures provides a standard data collection scheme for human thermal metrics during EVA task management. Data collected in this configuration can be used to build future lunar EVA task circuits and human thermal predictions.