Development and Validation of a Synchronous Model to Simulate Skeletal Muscle Damage due to Spaceflight Ionizing Radiation and Microgravity | Biological Engineering

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Abstract: A major challenge for astronauts in long-duration space travel is overcoming the hazardous spaceflight environment caused by microgravity and high levels of ionizing radiation. Microgravity damages cellular DNA by increasing the production of reactive oxygen species and ionizing radiation damages DNA by creating double-stranded DNA breaks. Cellular damage due to microgravity and radiation has been investigated using ground-based models, but most models consider microgravity and ionizing radiation alone, or asynchronously. Synchronous modeling is important to better mimic actual spaceflight conditions and understand the combined effects of microgravity and ionizing radiation. However, these devices are rare, requiring both a rotary cell culture system and beam time at a national lab or an independent radiation source.

An adaptable cell culture system was developed for studying the role of synchronous ionizing radiation and microgravity in pathophysiology during spaceflight conditions. Using this model, C2C12 mouse myoblast cells were exposed to ionizing radiation at levels approximating one- and ten-year spaceflight missions while in microgravity conditions. DNA damage to cells was quantified using g-H2AX (a fluorescent marker for double-stranded breaks), while reactive oxygen species production was visualized using CellROX green. Cells exposed to long-term mission doses had significantly more DNA damage and ROS production than both the short-term and control conditions. Experimental results showed that the mini-RCCS was capable of mimicking the complex spaceflight radiation environment while microgravity was simulated at a gravitational force similar to commercial systems.