The Use of Microgravity Simulators for Space Research

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ABSTRACT

The spaceflight environment is known to influence biological processes ranging from stimulation of cellular metabolism to possible impacts on cellular damage repair, suppression of immune functions, and bone and muscle loss in astronauts. Microgravity is one of the most significant stress factors experienced by living organisms during spaceflight, and therefore, understanding cellular responses to altered gravity at the physiological and molecular level is critical for expanding our knowledge of life in space.

Since opportunities to conduct experiments in space are scarce, various microgravity simulators and analogues have been widely used in space biology ground studies. Even though simulated microgravity conditions only produced some, but not all of the biological effects observed in the true microgravity environment, they provide test beds that are effective, affordable, and readily available to facilitate microgravity research.

Kennedy Space Center (KSC) provides ground microgravity simulator support by offering a variety of microgravity simulators and platforms for Space Biology investigators. Assistance will be provided by KSC experts in molecular biology, microgravity simulation, and engineering. Comparisons between the physical differences in microgravity simulators, examples of experiments using the simulators, and scientific questions regarding the use of microgravity simulators will be discussed.

KSC Microgravity Simulation Support

Ground Microgravity Simulation Support at KSC is being established for short duration studies utilizing a variety of microgravity simulator devices that negate the directional influence of the “g” vector for Space Biology investigators. Experiments using ground microgravity simulations can serve as secondary ground controls to ISS studies.

The simulators include, but are not limited to: 2D Clinostats, 3D Clinostats, Random Positioning Machines, and Rotating Wall Vessels. Assistance will be provided by KSC experts in molecular biology, microgravity simulation, and engineering.

These gravity simulators can be accommodated within controlled environment chambers allowing investigators to customize and monitor environmental conditions such as temperature, humidity, CO₂, and light exposure.

Ground Microgravity Simulation Devices

Rotating Wall Vessels

2D Rotating Clinostats

3D Clinostats

Examples of Biological Studies Using Microgravity Simulators

Research Gaps

Simulated microgravity conditions have produced some, but not all of the biological effects observed in the true microgravity environment. Research topics of interest using ground-based microgravity simulators include, but are not limited to:

• Comparing and validating the effectiveness of micro-g to hyper-g simulations using various ground simulation models.
• Analyzing the differences between true microgravity and simulated microgravity and between existing micro-g simulators using theoretic mathematical models.
• Developing new micro-g simulators or modifying existing designs.
• Investigating the biological effectiveness of modeled micro-g and partial-g in different cell types at different developmental stages.
• Evaluating the biological effectiveness of modeled micro-g and partial-g in cells at different cell cycle stages.
• Determining the biological effectiveness of simulated micro-g and partial-g using 2-D vs 3-D cell models.
• Investigating the biological effectiveness of simulated micro-g and partial-g on subcellular component formation, conformation, and interaction.
• Evaluating synergistic biological effects of simulated microgravity in combination with other space environmental factors.

Conclusions

Even though simulated microgravity conditions only produced some, but not all of the biological effects observed in the true microgravity environment, they provide test beds that are effective, affordable, and readily available to facilitate microgravity research.

Analyzing similarities and differences between biological responses in living organisms to true microgravity and simulated microgravity is critical for understanding the effects of Gravity as a Continuum. In addition, the comparison and validation of the effectiveness of micro-g to hyper-g simulations using various ground simulation models is important for species specific data interpretation.