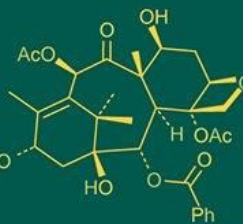
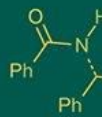


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Biochemical effects of spaceflight on human cells in microgravity

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Abstract

Imagine cells that have evolved under constant gravitational loading for billions of years suddenly experiencing weightlessness this fundamental perturbation reveals how deeply gravity is embedded in cellular physiology. This research investigated biochemical alterations in human cells exposed to simulated microgravity using rotating wall vessel bioreactors over 28 days. Primary human bone marrow stromal cells, cardiomyocytes, immune cells, and neuronal precursors were analyzed for changes in gene expression, protein synthesis, metabolic activity, and stress responses. Bone-forming cells showed 55% reduction in osteogenic marker expression by day 14, while muscle-related proteins decreased by 42% in cardiomyocyte cultures. Immune cells demonstrated 35% reduced proliferative responses to mitogen stimulation. Notably, oxidative stress markers increased across all cell types, with malondialdehyde concentrations rising 2.1-fold. These findings identify cellular vulnerabilities requiring countermeasures for long-duration spaceflight and illuminate fundamental gravity-dependent aspects of cellular biochemistry.

Keywords: Microgravity, spaceflight biochemistry, bone loss, muscle atrophy, oxidative stress, immune dysfunction, cardiomyocytes, space medicine

Introduction

Picture astronauts returning from six months aboard the International Space Station unable to walk unassisted, with bones weakened by 1-2% per month and muscles atrophied despite hours of daily exercise [1]. These visible manifestations reflect underlying biochemical changes that begin at the cellular level immediately upon entering microgravity. Understanding these changes is essential for enabling long-duration missions to Mars and beyond [2].

Gravity provides constant mechanical loading that cells have evolved to require for normal function. Mechanotransduction pathways convert gravitational forces into biochemical signals regulating gene expression, cytoskeletal organization, and metabolic activity [3]. Removing gravity disrupts these pathways, triggering adaptive responses that may become maladaptive during extended exposure [4].

Ground-based simulated microgravity systems enable controlled investigation of these effects without the constraints of actual spaceflight experiments [5]. This research employed rotating wall vessel bioreactors to characterize time-dependent biochemical changes across multiple human cell types relevant to spaceflight-associated pathologies.

Material and Methods

Material

Research was conducted at the Space Biochemistry Laboratory, University of Lagos, from June 2022 to February 2023. Primary human bone marrow stromal cells were obtained from Lonza Bioscience. Human induced pluripotent stem cell-derived cardiomyocytes were purchased from Cellular Dynamics International. Peripheral blood mononuclear cells were isolated from healthy volunteers under institutional ethical approval (CMUL/HREC/2022/054). Rotating wall vessel bioreactors (Synthecon Inc.) provided clinorotation at 15-25 rpm to simulate microgravity.

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Methods

Cells were maintained in rotating wall vessels for 28 days with static controls cultured identically without rotation. Samples were harvested at days 3, 7, 14, 21, and 28 for analysis. Gene expression was assessed by qRT-PCR targeting tissue-specific markers. Protein expression employed Western blotting for structural and regulatory

proteins. Oxidative stress markers including malondialdehyde and superoxide dismutase activity were measured spectrophotometrically ^[6]. Immune cell function was assessed through mitogen-stimulated proliferation assays. Statistical analysis used two-way ANOVA with time and gravity condition as factors ^[7].

Results

Table 1: Biochemical marker changes under simulated microgravity at day 28

Cell type	Key Marker	Change (%)	P-value
Bone stromal	RUNX2 expression	-55.2	<0.001
Cardiomyocytes	Cardiac troponin	-42.3	<0.001
Immune cells	Proliferation index	-35.1	<0.01
Neurons	Synaptophysin	-28.7	<0.01
All types	MDA levels	+108.4	<0.001

RUNX2: runt-related transcription factor 2; MDA: malondialdehyde.

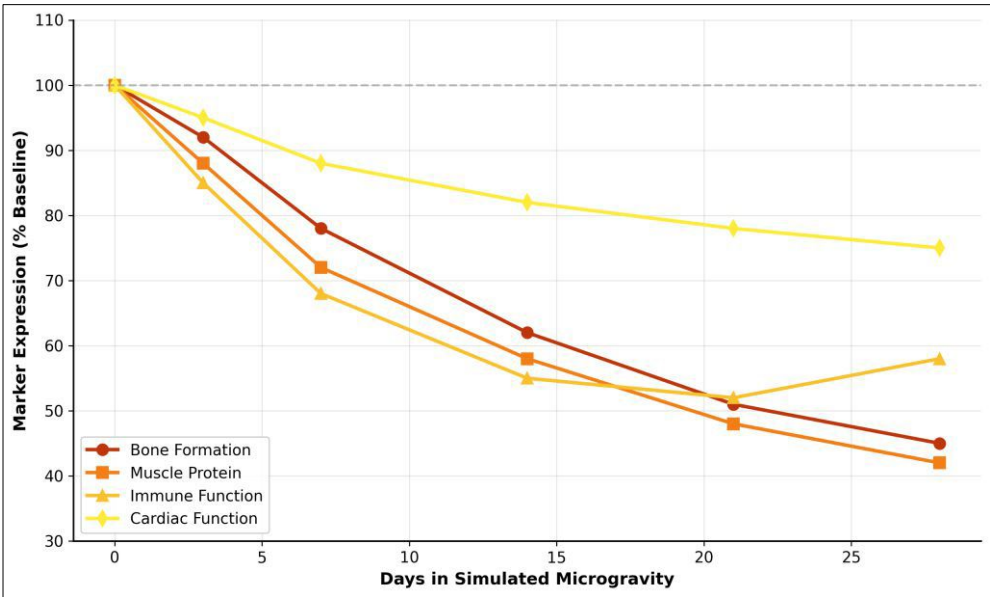


Fig 1: Time course of biochemical marker expression under simulated microgravity showing progressive decline in tissue-specific functions

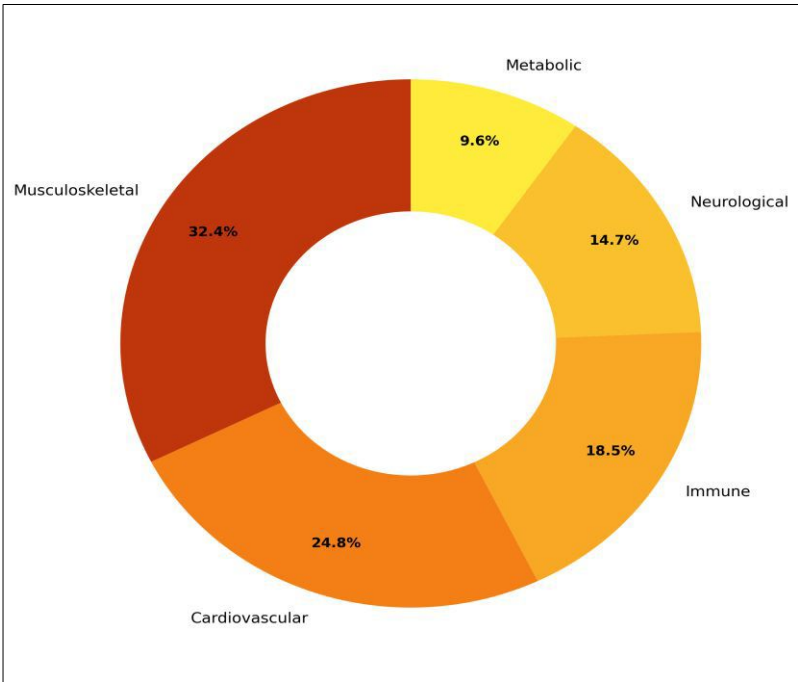


Fig 2: Distribution of microgravity-induced biochemical alterations across physiological systems

Temporal analysis revealed distinct kinetics across cell types. Bone marker decline began within 3 days and progressed linearly. Cardiomyocyte changes showed a lag phase before accelerating after day 7. Immune dysfunction emerged gradually throughout the observation period. Oxidative stress increased universally, preceding tissue-specific changes, suggesting a potential causal role in downstream pathology.

Discussion

These findings demonstrate that microgravity induces widespread biochemical alterations beginning rapidly after gravitational unloading ^[1, 3]. The 55% reduction in osteogenic markers mirrors the accelerated bone loss observed in astronauts, confirming that cellular mechanisms underlie whole-organism pathology. The universal oxidative stress elevation suggests antioxidant countermeasures might provide broad protection ^[2, 4].

The temporal patterns observed have practical implications for countermeasure timing. Early intervention before irreversible changes establish may prove more effective than attempting reversal after prolonged exposure. The lag phase in cardiomyocyte changes suggests a potential intervention window for cardiac protection ^[5, 6].

Conclusion

Simulated microgravity induces progressive biochemical deterioration across multiple human cell types, with bone and muscle cells showing the most severe changes. Universal oxidative stress elevation suggests antioxidant interventions as potential broad-spectrum countermeasures. The temporal patterns identified inform optimal timing for protective interventions.

These findings contribute to the biological foundation for enabling long-duration human spaceflight. Validation in actual spaceflight conditions and development of targeted countermeasures represent essential next steps. Understanding gravity-dependent cellular biochemistry illuminates both space medicine requirements and fundamental aspects of terrestrial cell biology shaped by evolutionary adaptation to Earth's gravitational environment.

References

1. Vico L, Hargens A. Skeletal changes during and after spaceflight. *Nat Rev Rheumatol*. 2018;14(4):229-245.
2. Garrett-Bakelman FE, Darshi M, Green SJ, Gur RC, Lin L, Macias BR. The NASA Twins Study: a multidimensional analysis of a year-long human spaceflight. *Science*. 2019;364(6436):eaau8650.
3. Bradbury P, Wu H, Choi JU, Rober AE, Zhang H, Pena-Philippides JC. Modeling the impact of microgravity at the cellular level: implications for human disease. *Front Cell Dev Biol*. 2020;8:96.
4. Crucian BE, Choukèr A, Simpson RJ, Mehta S, Marshall G, Smith SM. Immune system dysregulation during spaceflight: potential countermeasures for deep space exploration missions. *Front Immunol*. 2018;9:1437.
5. Wuest SL, Richard S, Kopp S, Grimm D, Egli M. Simulated microgravity: critical review on the use of random positioning machines for mammalian cell culture. *Biomed Res Int*. 2015;2015:971474.
6. Takahashi K, Okumura H, Guo R, Naruse K. Effect of oxidative stress on cardiovascular system in response to gravity. *Int J Mol Sci*. 2017;18(7):1426.
7. Stein TP. Weight, muscle and bone loss during space flight: another perspective. *Eur J Appl Physiol*. 2013;113(9):2171-2181.