

RPM

SCIENTIFIC RESEARCH & APPLICATIONS

FROM EXPERIMENTS TO EVIDENCE.

A curated collection of 49 scientific publications exploring the use of Random Positioning Machines (RPMs), clinostats and related microgravity research across multiple biological disciplines.

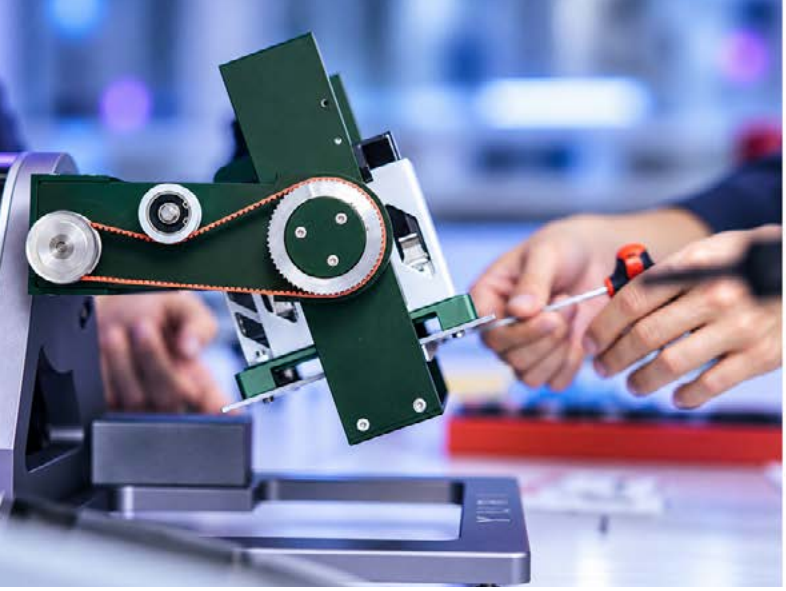
Discover the biological models investigated, experimental approaches applied and key findings reported, with direct links to the original publications.
From cancer research to tissue engineering – scientific evidence made accessible.

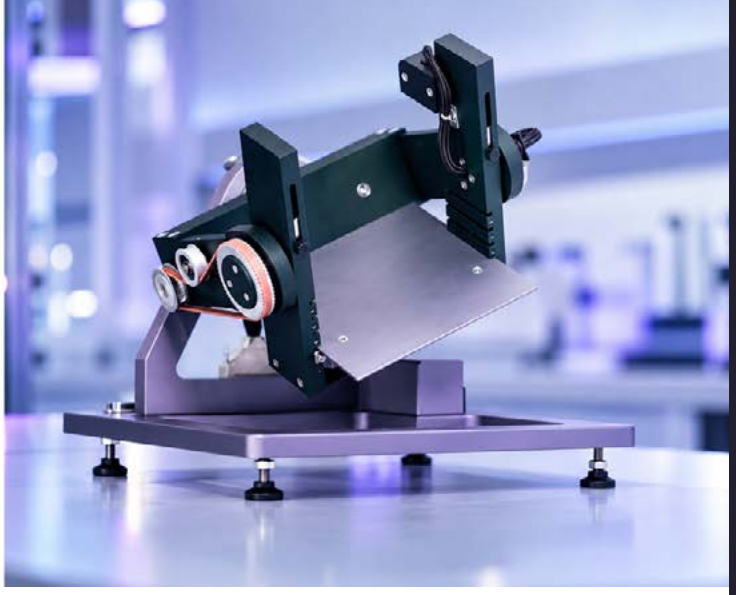
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YURI | RPM – SCIENTIFIC RESEARCH & APPLICATIONS

PUBLISHED STUDIES, EXPERIMENTAL MODELS & KEY FINDINGS

01 – CANCER RESEARCH - BREAST CANCER

01 | From Breast Cancer Cells to Duct-Like 3D Structures

Biological model: Human MCF-7 breast cancer cells.
What was tested: RPM exposure for 2, 4, 16 and 24 hours, and 5 days, to investigate three-dimensional cell growth and gene expression.
Observed results: Small multicellular spheroids formed after 24 hours. After five days, numerous duct-like 3D structures were observed, accompanied by changes in genes associated with cell shape and organization.

Scientific source: https://www.nature.com/articles/srep26887

02 | The Role of NF-κB in Breast Cancer Spheroid Formation

Biological model: Human MCF-7 breast cancer cells.
What was tested: 24-hour RPM exposure to investigate the role of NF-κB signaling in multicellular spheroid formation.
Observed results: Cells formed adherent and three-dimensional spheroid populations. NF-κB p65 showed different intracellular localization patterns, accompanied by changes in selected gene expression.

Scientific source: https://doi.org/10.1038/s41598-017-18556-8

03 | How Simulated Microgravity Affects Breast Cancer Cell Adhesion and Migration

Biological model: Human MCF-7 and MDA-MB-231 breast cancer cells.
What was tested: Breast cancer cells were exposed to an RPM for 24 hours to assess three-dimensional growth, focal adhesion-related gene expression and subsequent spheroid reattachment and migration.
Observed results: Both cell lines developed adherent and spheroid populations. Focal adhesion-associated gene responses differed between cell lines. Following RPM exposure, MDA-MB-231 spheroids showed pronounced cell migration after reattachment, whereas MCF-7 cells displayed a different growth pattern.

Scientific source: https://doi.org/10.3389/fcell.2021.672098

04 | Long-Term RPM Exposure Alters Gene Expression in Breast Cancer Cells

Biological model: Human MCF-7 and MDA-MB-231 breast cancer cells.
What was tested: 14-day RPM exposure to investigate gene expression related to the cytoskeleton, extracellular matrix, focal adhesion and cellular signaling pathways.
Observed results: Both cell lines developed three-dimensional spheroids alongside adherent cells. Alterations in gene expression were identified, including genes associated with structural organization and signaling.

Scientific source: https://doi.org/10.3390/ijms24021181

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05 | Increased Extracellular Vesicle Release in Breast Cancer Cells

Biological model: Human MCF-7 breast cancer cells.
What was tested: Five and ten days of RPM exposure to investigate the release and surface-protein characteristics of small extracellular vesicles.
Observed results: RPM exposure substantially increased extracellular vesicle release. Changes in the distribution of vesicle subpopulations were also observed.

Scientific source: https://doi.org/10.3390/ijms232416095

06 | Early Cell Adhesion Responses in Triple-Negative Breast Cancer

Biological model: Human MDA-MB-231 triple-negative breast cancer cells.
What was tested: Early cellular responses under RPM-simulated microgravity, parabolic-flight microgravity, hypergravity and vibration conditions.
Observed results: The study identified condition-dependent changes in adhesion-related genes and cellular signaling. Responses to real microgravity, simulated microgravity and accompanying mechanical conditions were investigated separately.

Scientific source: https://doi.org/10.3390/ijms20225730

THYROID CANCER

07 | Three-Dimensional Growth of Human Thyroid Cancer Cells

Biological model: Human ML-1 thyroid carcinoma cells.
What was tested: The effects of simulated weightlessness on three-dimensional thyroid cancer cell growth.
Observed results: Within 12 hours of clinorotation, ML-1 thyroid carcinoma cells formed three-dimensional multicellular tumour spheroids. The study reported increased extracellular matrix proteins and TGF-β1, alongside reduced secretion of selected thyroid-related factors.

Scientific source: https://pubmed.ncbi.nlm.nih.gov/15002569/

08 | Normal vs. Cancerous Thyroid Cells: Different Responses to RPM Exposure

Biological model: Human FTC-133 thyroid cancer cells and normal Nthy-ori 3-1 thyroid cells.
What was tested: Seven and fourteen days of RPM cultivation to compare three-dimensional growth and molecular responses in normal and malignant thyroid cells.
Observed results: Both cell types formed multicellular spheroids. FTC-133 cancer cells produced larger and more numerous spheroids, accompanied by differences in growth- and angiogenesis-associated factors.

Scientific source: https://www.nature.com/articles/srep16691

09 | Comparing Thyroid Cancer Cell Responses on an RPM and a 2D Clinostat

Biological model: Human ML-1 and RO82-W-1 thyroid cancer cells.
What was tested: Three and seven days of exposure to a Random Positioning Machine or a 2D clinostat, compared with static 1 g controls, to investigate three-dimensional growth, cytoskeletal organization and cytokine secretion.
Observed results: Both simulation systems induced multicellular spheroid formation. Cytokine responses depended on the cell line and experimental conditions. MCP-1 release increased in ML-1 cultures but was suppressed in RO82-W-1 cells under simulated microgravity. IL-6 responses also differed between the investigated conditions.

Scientific source: https://doi.org/10.1371/journal.pone.0135157

10 | How Long-Term RPM Exposure Affects Thyroid Cancer Cell Proteins

Biological model: Human ML-1 thyroid cancer cells.
What was tested: Seven and eleven days of RPM exposure to investigate cellular protein profiles using electrophoretic separation, mass spectrometry and Western blot analysis.
Observed results: Proteomic analyses identified differences between RPM-exposed cells and 1 g controls. Selected proteins were investigated further using Western blotting.

Scientific source: https://doi.org/10.1007/s12217-011-9258-5

11 | Proteomic Differences Between Thyroid Cancer Spheroids and Adherent Cells

Biological model: Human FTC-133 follicular thyroid cancer cells.
What was tested: Proteomic analysis of RPM-exposed thyroid cancer cells grown under conditions promoting or inhibiting multicellular spheroid formation.
Observed results: More than 5,900 proteins were identified. Differences in focal adhesion-associated proteins, including vinculin, paxillin and focal adhesion kinase, were identified between cell populations.

Scientific source: https://doi.org/10.3390/ijms18030546

12 | Molecular Pathways Behind Thyroid Cancer Spheroid Formation

Biological model: Human follicular thyroid cancer cells (UCLA RO82-W-1).
What was tested: 24-hour RPM exposure to investigate molecular pathways involved in three-dimensional spheroid formation, focusing on gene expression, cytoskeletal organization and extracellular matrix regulation.
Observed results: Multicellular spheroids formed within 24 hours, accompanied by changes in F-actin organization and the expression of genes associated with cell structure, extracellular matrix and angiogenesis.

Scientific source: https://www.mdpi.com/1422-0067/17/4/528

13 | Dexamethasone Suppresses Thyroid Cancer Spheroid Formation

Biological model: Human FTC-133 follicular thyroid cancer cells.
What was tested: RPM cultivation with different concentrations of dexamethasone to investigate tumour spheroid formation and cancer-associated molecular pathways.
Observed results: Dexamethasone inhibited spheroid formation in a dose-dependent manner and altered the expression of genes involved in cell growth, adhesion and signaling.

Scientific source: https://doi.org/10.3390/cells9020367

14 | Dexamethasone Inhibits the Detachment of Metastatic Thyroid Cancer Cells

Biological model: FTC-133, WRO, ML-1 and Nthy-ori 3-1 human thyroid cell models.
What was tested: Random positioning with dexamethasone treatment to investigate cancer cell detachment, adhesion and stress signaling.
Observed results: Dexamethasone inhibited cell detachment in FTC-133 and WRO thyroid cancer cells, but not in ML-1 or Nthy-ori 3-1 cells. In FTC-133 cells, treatment interfered with p38 stress signaling and promoted cell adhesion, including restoration of tight junction formation. The findings demonstrate cell-model-dependent responses to dexamethasone during random positioning.

Scientific source: https://doi.org/10.3390/cancers15061641

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PROSTATE CANCER

15 | Altered VEGF, MAPK and PI3K/AKT/mTOR Signaling in Prostate Cancer Cells

Biological model: Human PC-3 prostate cancer cells.
What was tested: Three and five days of RPM exposure to investigate the cytoskeleton, extracellular matrix, cell adhesion and VEGF, MAPK and PI3K/AKT/mTOR signaling pathways.
Observed results: RPM exposure was associated with three-dimensional cell growth and changes in molecular factors involved in cell adhesion, growth and signaling.

Scientific source: https://doi.org/10.3390/ijms21041263

16 | Prostate Cancer Cells Form 3D Spheroids Within 24 Hours of RPM Exposure

Biological model: Human PC-3 prostate cancer cells.
What was tested: RPM exposure for 30 minutes, 2 hours, 4 hours and 24 hours to investigate spheroid formation and cancer-associated gene expression.
Observed results: After 24 hours, cells formed both adherent populations and multicellular spheroids. Changes in genes associated with extracellular matrix, cytokines, adhesion and cellular signaling were observed.

Scientific source: https://doi.org/10.3389/fcell.2022.841017

02 – BONE, CARTILAGE & MUSCLE RESEARCH

BONE RESEARCH

17 | Simulated Microgravity Inhibits Preosteoblast Differentiation

Biological model: Mouse 2T3 preosteoblast cells.
What was tested: RPM exposure for up to nine days to investigate osteoblast differentiation, alkaline phosphatase activity and gene-expression profiles.
Observed results: RPM exposure significantly inhibited alkaline phosphatase activity and altered differentiation-related gene expression without substantially affecting cell proliferation or shape.

Scientific source: https://doi.org/10.1152/ajpcell.00222.2004

18 | Bone Cell Mineralization Depends on Culture Conditions During RPM Exposure

Biological model: Human SAOS-2 osteoblast-like cells.
What was tested: RPM exposure under osteogenic and non-osteogenic culture conditions to investigate mineral deposition and PTX3 expression.
Observed results: Mineralization-associated responses increased in cultures without osteogenic supplements. Under osteogenic conditions, mineral deposits and PTX3 expression decreased.

Scientific source: https://doi.org/10.3390/life12050610

19 | Recombinant Irisin Reduces RPM-Induced Osteoblast Damage

Biological model: Primary human osteoblasts from healthy and osteoporotic donors.
What was tested: Three and six days of RPM exposure, with and without recombinant irisin treatment, to investigate cell survival and mineralization.
Observed results: RPM exposure increased oxidative stress and apoptosis-associated responses and impaired mineralization in primary human osteoblast cultures. Recombinant irisin attenuated several adverse effects, particularly after three days of exposure. However, protective effects on mineralization-associated markers were not maintained consistently after six days.

Scientific source: https://doi.org/10.3389/fphys.2023.1107933

CARTILAGE RESEARCH

20 | Human Chondrocytes Form 3D Aggregates Under Simulated Microgravity

Biological model: Human chondrocytes.
What was tested: RPM cultivation to investigate three-dimensional growth, apoptosis and extracellular matrix composition.
Observed results: Chondrocytes developed three-dimensional cell aggregates. Changes in apoptosis and cartilage-associated extracellular matrix components, including collagen and aggrecan, were reported.

Scientific source: https://doi.org/10.1159/000303059

21 | Human Cartilage Cells Show Molecular Changes Within 30 Minutes

Biological model: Human chondrocytes from six donors
What was tested: RPM exposure for 30 minutes, 2 hours, 4 hours, 16 hours and 24 hours to investigate morphology, gene expression and protein content.
Observed results: Early changes in gene expression occurred after 30 minutes. Alterations in the vimentin cytoskeleton were observed after four hours, while TGF-β1-related responses increased during longer exposure.

Scientific source: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0079057

22 | Scaffold-Free Cartilage-Like Tissue Formation on an RPM

Biological model: Human articular chondrocytes.
What was tested: RPM cultivation for up to 28 days using different culture media to investigate scaffold-free cartilage-like tissue formation.
Observed results: Human chondrocytes formed scaffold-free 3D spheroids under RPM exposure. Spheroid growth depended on the culture medium. After 28 days, constructs reached approximately 1 mm in DMEM/F-12 and up to 2 mm in chondrocyte growth medium (CGM). The spheroids exhibited cartilage-associated characteristics, including aggrecan positivity and collagen II structures.

Scientific source: https://doi.org/10.3390/ijms21249596

MUSCLE RESEARCH

23 | Myostatin Inhibition Supports Muscle Cell Survival Under RPM Exposure

Biological model: Primary human muscle satellite cells obtained from patients undergoing hip arthroplasty.
What was tested: 72-hour RPM exposure with and without anti-myostatin antibodies to investigate muscle satellite cell survival and myostatin-associated responses.
Observed results: RPM exposure reduced cell survival and altered myostatin expression. Anti-myostatin treatment showed protective effects in the investigated cell model.

Scientific source: https://doi.org/10.3389/fphys.2022.782000

03 – IMMUNOLOGY

24 | Macrophage Responses Reveal Limitations of Random Positioning Modes

Biological model: Macrophage model system.
What was tested: ROS production during the oxidative burst response of NR8383 macrophages was compared under 2D clinorotation at 60 rpm and two RPM random positioning modes operating at 2–10 rpm.
Observed results: Clinorotation reduced ROS production by approximately 75% compared with the 1 g control. Both random positioning modes produced more variable ROS responses that differed substantially from clinorotation. The authors concluded that these random positioning modes were not suitable for simulating microgravity in the investigated macrophage model.

Scientific source: https://link.springer.com/article/10.1007/s12217-019-9687-0

25 | Simulated Microgravity Impairs Dendritic Cell Maturation and Function

Biological model: Murine splenic and bone-marrow-derived dendritic cells.
What was tested: RPM exposure to investigate dendritic cell maturation, cytokine production, NF-κB signaling and the ability to support T-cell responses.
Observed results: RPM exposure reduced selected maturation markers and pro-inflammatory cytokine production, altered NF-κB signaling and impaired dendritic-cell-mediated naïve CD4 T-cell responses.

Scientific source: https://doi.org/10.3390/ijms24021720

26 | 3D Collagen Cultures Reduce Microgravity-Associated Changes in T Cells

Biological model: Resting and activated T lymphocytes cultured in 2D conditions and 3D collagen matrices.
What was tested: RPM exposure to investigate changes in the T-cell transcriptome and nuclear morphology in different culture environments.
Observed results: RPM exposure altered gene expression and nuclear morphology. The effects were less pronounced in 3D collagen cultures than in 2D cultures and were attenuated in activated compared with resting T cells

Scientific source: https://doi.org/10.1007/s00018-022-04531-8

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04 – TISSUE ENGINEERING & CELL BIOLOGY

VASCULAR BIOLOGY

27 | Endothelial Cells Form 3D Structures While VEGF Reduces Apoptosis

Biological model: Human EA.hy926 endothelial cells
What was tested: Human EA.hy926 endothelial cells were exposed to simulated microgravity using a three-dimensional Random Positioning Machine (clinostat) for 4, 12, 24, 48 and 72 hours, with and without VEGF treatment (10 ng/ml).
Observed results: Simulated microgravity increased extracellular matrix protein expression and induced apoptosis-associated changes. VEGF significantly attenuated apoptosis, including reductions in caspase-3-associated responses. After 72 hours, most surviving endothelial cells had assembled into three-dimensional tubular structures.

Scientific source: https://doi.org/10.1007/s10495-006-5697-7

28 | Human Endothelial Cells Develop Tube-Like Structures Under RPM Exposure

Biological model: Human endothelial cells.
What was tested: Long-term RPM cultivation for up to 28 days to investigate three-dimensional cell growth and the formation of vascular-like structures.
Observed results: Endothelial cells developed three-dimensional, tube-like structures. Changes in adhesion- and extracellular-matrix-associated proteins were identified.

Scientific source: https://doi.org/10.1089/ten.tea.2008.0576

29 | Long-Term RPM Cultivation Promotes Complex Endothelial Cell Structures

Biological model: Human EA.hy926 endothelial cells.
What was tested: 35-day RPM exposure to investigate multicellular spheroids, tubular structures and proteins associated with angiogenesis and endothelial function.
Observed results: Cells developed adherent populations, multicellular spheroids and tubular structures. Changes in extracellular matrix proteins, cytokines and angiogenesis-associated factors were observed.

Scientific source: https://doi.org/10.1159/000486920

FIBROBLAST & CARDIOVASCULAR RESEARCH

30 | Human Skin Fibroblasts Form 3D Spheroids Under Simulated Microgravity

Biological model: Normal human dermal fibroblasts.
What was tested: RPM cultivation to investigate changes in cell morphology, cytoskeleton, extracellular matrix, focal adhesion and growth-related factors.
Observed results: Fibroblasts formed compact multicellular spheroids alongside adherent cell populations. Molecular changes were identified in components associated with extracellular matrix organization, adhesion and three-dimensional growth.

Scientific source: https://doi.org/10.1038/s41598-019-48378-9

31 | Cardiac Fibroblasts Form Spheroids and Respond to Growth Factors

Biological model: Cardiac fibroblasts derived from porcine hearts
What was tested: RPM cultivation with and without VEGF and bFGF treatment to investigate three-dimensional growth, extracellular matrix synthesis and apoptosis.
Observed results: Three-dimensional spheroids developed within 24 hours. RPM exposure increased extracellular matrix protein synthesis and apoptosis, while growth factor treatment reduced several of these effects.

Scientific source: https://karger.com/cpb/article-abstract/26/6/1011/318640/The-Impact-of-Vascular-Endothelial-Growth-Factor?redirectedFrom=fulltext

32 | Investigating Wound Healing Under Combined Spaceflight-Related Stressors

Biological model: Human dermal fibroblasts.
What was tested: Human dermal fibroblasts were exposed to cortisol, different types of ionizing radiation and 24 hours of RPM-simulated microgravity. Wound closure was investigated using an in vitro scratch assay, alongside analyses of inflammatory mediators, growth factors, cytoskeletal organization and extracellular matrix proteins.
Observed results: The investigated stressors affected different phases of the wound-healing process, including inflammatory signaling, cell migration and extracellular matrix remodeling. Interactions between simulated microgravity, radiation and cortisol were observed, demonstrating that the biological responses depended on the specific combination of experimental conditions.

Scientific source: https://doi.org/10.3390/cells12020246

EYE RESEARCH

33 | RPM Exposure Alters Cytoskeletal and Extracellular Matrix Gene Expression in Retinal Cells

Biological model: Human ARPE-19 retinal pigment epithelial cells.
What was tested: Five and ten days of RPM exposure, followed by morphological, gene-expression and protein analyses.
Observed results: Changes in the expression of cytoskeletal and extracellular matrix genes were observed under simulated microgravity.

Scientific source: https://doi.org/10.1159/000452520

NON-MALIGNANT THYROID CELL RESEARCH

34 | Normal Thyroid Cells Form Spheroids and Alter Cytokine Release

Biological model: Normal human thyroid epithelial cells (Nthy-ori 3-1).
What was tested: RPM exposure for up to 72 hours to investigate multicellular spheroid formation, cytokine release and focal adhesion-related gene expression.
Observed results: Early changes in cytokine-associated genes were identified after four hours. Multicellular spheroids appeared after 24 hours, while IL-6, IL-8 and TIMP-1 secretion increased after 72 hours.

Scientific source: https://doi.org/10.1159/000480368

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05 – MICROBIOLOGY

BACTERIAL RESEARCH

35 | Comparing Bacterial Biofilm Responses Using the Yuri RPM 2.0
Biological model: Mycobacterium marinum.
What was tested: Bacterial biofilm formation, planktonic growth, gene expression and rifampicin survival were investigated using the Yuri RPM 2.0, a custom-built 3D clinostat and a commercial 2D clinostat under different operating conditions.
Observed results: The Yuri RPM 2.0 and a custom-built 3D clinostat operated at selected frame velocities produced comparable attached biofilm structures and bacterial transcriptomic responses. A different operating configuration of the 3D clinostat reproduced reduced planktonic growth and increased rifampicin survival observed under the tested 2D clinostat conditions. These findings highlight the importance of simulator configuration and experimental conditions when interpreting bacterial responses.

Scientific source: https://doi.org/10.3389/frspt.2022.1032610

FUNGAL RESEARCH

36 | RPM Exposure Increases Fungal Growth but Reduces Biofilm Formation
Biological model: Fusarium solani species complex.
What was tested: RPM exposure to investigate fungal growth, spore production, germination and biofilm formation.
Observed results: RPM exposure increased fungal growth, sporulation and germination, while biofilm production decreased under the investigated conditions.

Scientific source: https://doi.org/10.3390/microorganisms10112270

06 – METHOD VALIDATION & RPM TECHNOLOGY

These publications investigate or describe the operation, experimental capabilities and methodological limitations of RPMs and clinostats. They provide supporting evidence for experimental design and interpretation but do not necessarily report new biological effects.

37 | Measuring RPM-Induced Shear Forces Using Bioluminescent Microorganisms
Biological model: Bioluminescent dinoflagellate Pyrocystis noctiluca.
What was tested: Comparison of shear forces induced by RPM random positioning modes and constant clinorotation, using bioluminescence as an indicator of mechanical stress.
Observed results: The investigated random positioning modes generated higher mechanical stress than constant one-axis clinorotation. The study demonstrated the importance of accounting for simulator-induced shear forces.

Scientific source: https://doi.org/10.1038/s41526-017-0016-x

38 | The Development of the Desktop Random Positioning Machine

Biological model: No biological model investigated in an independent outcome experiment.
What was tested: Development and technical characterization of a compact desktop RPM for biological laboratory applications.
Observed results: The publication describes a two-axis rotation system, software-controlled random positioning and technical features designed for operation within laboratory incubators.

Scientific source: https://www.descsite.nl/Publications/Other/RPM-FS-MG-R00-017.pdf

39 | Validating a Modified RPM for Experimental Research with Rats

Biological model: Male Wistar rats in a device-related stress assessment.
What was tested: Technical validation of a modified RPM designed to accommodate up to four experimental animals, including gravity-vector distribution and stress-related responses.
Observed results: The modified RPM showed gravity-dispersion characteristics comparable to the reference system. The behavioral assessment did not indicate increased anxiety in the exposed animals.

Scientific source: https://doi.org/10.3390/inventions7030085

40 | Using Reduced-Gravity Simulators in Plant Biological Research

Biological model: Plant biological systems discussed in a methodological context.
What was tested: The publication describes methods and experimental considerations for using reduced-gravity simulators, including Random Positioning Machines, in plant biology.
Observed results: The methodological chapter provides guidance on experimental approaches and limitations. It does not independently establish a new biological RPM outcome.

Scientific source: https://doi.org/10.1007/978-1-0716-1677-2_16

41 | Ground-Based Microgravity Simulation Technologies at NASA

Biological model: Biological research systems discussed in the context of ground-based microgravity simulation.
What was tested: Description of simulation equipment, experimental capabilities and methodological considerations at NASA's ground-based microgravity simulation facility.
Observed results: The publication documents simulation technologies and their applications. It does not constitute an additional original biological RPM outcome study.

Scientific source: https://link.springer.com/protocol/10.1007/978-1-0716-1677-2_18

07 – SCIENTIFIC REVIEWS & SUPPORTING RESEARCH

SCIENTIFIC REVIEWS

The following scientific reviews evaluate previously published research involving RPMs, clinostats and other altered-gravity platforms. They provide scientific context, comparisons and methodological insights but should not be counted as additional original RPM or clinostat experiments.

42 | Multicellular Tumour Spheroids as Models for Cancer Research

Biological model: Various cancer cell models discussed in the context of three-dimensional spheroid formation.
What was tested: No new RPM experiment. The review evaluates published research on multicellular tumour spheroids under real and simulated microgravity.
Observed results: The review summarizes experimental findings on three-dimensional tumour cell growth, molecular regulation and the use of spheroids as models for cancer-associated processes.

Scientific source: https://doi.org/10.3390/ijms23063073

43 | Three-Dimensional Tissue Growth in Real and Simulated Microgravity

Biological model: Various tissue-related cell models, including endothelial cells, chondrocytes and cancer cells, discussed in previously published research.
What was tested: No new RPM experiment. The review evaluates published tissue engineering research under real and simulated microgravity using different experimental platforms.
Observed results: The review describes three-dimensional cell organization, multicellular spheroid formation and tissue-like structures reported in earlier studies.

Scientific source: https://pmc.ncbi.nlm.nih.gov/articles/PMC4241976

44 | How Altered Gravity Influences Bone Cells and Mesenchymal Stem Cells

Biological model: Bone cells and mesenchymal stem cells discussed across published experimental studies.
What was tested: No new RPM experiment. The review summarizes research using RPMs, clinostats, rotating-wall-vessel bioreactors and real microgravity platforms.
Observed results: Previously published findings concerning cellular differentiation, three-dimensional growth, extracellular matrix organization and responses to altered gravity are evaluated.

Scientific source: https://doi.org/10.1155/2014/928507

45 | Evaluating the Capabilities and Limitations of RPM-Based Cell Culture

Biological model: Mammalian cell culture models discussed in previously published RPM research.
What was tested: No new biological RPM experiment. The review evaluates RPM operation, gravity-vector averaging, rotation speed, residual acceleration and comparisons with real microgravity.
Observed results: The authors identify important methodological limitations and experimental requirements, while supporting the use of appropriately configured RPMs for ground-based gravitational biology research.

Scientific source: https://doi.org/10.1155/2015/971474

SUPPORTING RESEARCH – REAL MICROGRAVITY & OTHER SIMULATORS

The following publications provide additional evidence from real microgravity experiments, comparative studies and other relevant research. Studies involving RPMs or clinostats are included where their use or scientific relevance is documented in the original publication. Findings from real microgravity, RPMs and clinostats are distinguished to ensure accurate interpretation of the reported results.

46 | Comparing Endothelial Cell Responses in Space and Simulated Microgravity

Biological model: Human EA.hy926 endothelial cells.
What was tested: Endothelial cell growth and secretory responses during a 12-day spaceflight experiment were investigated and compared with findings obtained under simulated microgravity using ground-based research platforms.
Observed results: Endothelial cells grown in space developed three-dimensional structures and exhibited changes in secreted factors. Comparison with simulated microgravity research provided insights into similarities and differences between the experimental environments.

Scientific source: https://doi.org/10.33594/000000071

47 | Caveolin-1 and the Regulation of Thyroid Cancer Spheroid Formation

Biological model: Human FTC-133 thyroid cancer cells.
What was tested: The involvement of caveolin-1 (CAV1) in three-dimensional thyroid cancer cell growth was investigated using findings from simulated microgravity and the NanoRacks-CellBox-Thyroid Cancer spaceflight experiment.
Observed results: Changes in caveolin-1 expression were associated with spheroid formation and alterations in adhesion-related molecular pathways. The study identified CAV1 as a potential regulator of three-dimensional thyroid cancer cell growth under altered-gravity conditions.

Scientific source: https://doi.org/10.3390/ijms161226108

48 | Rapid Gene Expression Changes in Thyroid Cancer Cells During Parabolic Flight

Biological model: Human ML-1 follicular thyroid cancer cells.
What was tested: Short periods of real microgravity during parabolic flight, compared with hypergravity and vibration conditions.
Observed results: Changes in cytoskeletal and extracellular matrix-associated gene expression were observed, including responses involving ACTB, KRT80 and COL4A5.

Scientific source: https://doi.org/10.1159/000331730

49 | Basic Fibroblast Growth Factor Modifies Endothelial Cell Responses to Simulated Microgravity

Biological model: Human EA.hy926 endothelial cells.
What was tested: Cultivation under simulated microgravity using a 3D clinostat, with and without basic fibroblast growth factor (bFGF), to investigate apoptosis, inflammatory cytokines, gene expression and intracellular signaling.
Observed results: Simulated microgravity increased apoptosis and IL-6 and IL-8 secretion while altering several signaling pathways. Under simulated microgravity, bFGF reduced IL-6 and IL-8 release and attenuated apoptosis-associated responses. Its effects differed from those observed under normal gravity.

Scientific source: https://doi.org/10.1002/jcb.21710