Effect of space environment on mammalian reproduction

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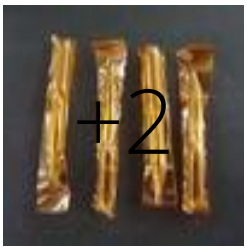

Space Pup Sample Case. Image courtesy of JAXA....

Experiment Description | Applications | Operations | Decadal Survey Recommendations | Publications | Related Websites | Related Experiments

ISS Science for Everyone

SCIENCE OBJECTIVES FOR EVERYONE

Space Pup represents the first step towards studying the effects of space radiation on mammalian reproduction, which must be understood to sustain life beyond Earth. This starts by holding freeze-dried mouse sperm aboard the International Space Station for one, 12, and 24 months, and then fertilizing mouse eggs on Earth to produce mouse pups to study the effects of space radiation.

CATEGORY

Biology and Biotechnology

ALSO KNOWN AS INFO

Space Pup; Effect of space environment on mammalian reproduction; Space Pup; Space Pup;

OPNOM:

Space Pup

PRINCIPAL INVESTIGATOR(S)

Teruhiko Wakayama

SCIENCE RESULTS FOR EVERYONE

Where do babies come from? Someday they may come from space! Freeze-dried mouse sperm flown aboard the space station showed no overall difference in structure and only slightly increased DNA damage compared to controls kept on the ground. In-vitro fertilization with space-flown and control sperm resulted in similar birthrates and, when some of the resulting pups were mated after reaching adulthood, this second generation showed normal gene expression profiles. These findings demonstrate that damage to DNA from space radiation did not affect production of viable offspring, suggesting that sperm DNA damage was decreased or repaired after fertilization; at least after 9 months of preservation on the International Space Station.

The following content was provided by Teruhiko Wakayama, and is maintained in a database by the ISS Program Science Office.

Experiment Description

RESEARCH OVERVIEW

- Sustaining life beyond Earth orbit will require a clear understanding of how the environment in space affects key phases of mammalian reproduction. Recently, a study was done on mammalian fertilization and preimplantation development under simulated microgravity (simulated μG) using three-dimensional (3D) clinostat conditions. Although fertilization occurred normally in vitro under simulated μG, the offspring birth rate was significantly lower than the 1G controls due to the poor development of placental cells. This suggests that mammalian species may have difficulty reproducing in space, and highlights the importance of performing experiments in

Riken Center for Developmental Biology, Japan

CO-INVESTIGATOR(S)/COLLABORATOR(S)

Sayaka Wakayama
Riken Center for Developmental Biology, Japan

Rui Yuge
Hiroshima University, Japan

Hiromi Kawahara
Hiroshima University Hospital, Japan

Eiji Mizutani
Riken Center for Development Biology, Japan

DEVELOPER(S)

Data is either unavailable, restricted, or under review.

SPONSORING SPACE AGENCY

Japan Aerospace Exploration Agency (JAXA)

SPONSORING ORGANIZATION

Japan Aerospace Exploration Agency

ISS EXPEDITION DURATION

March 2013 — October 2019

EXPEDITIONS ASSIGNED

35/36	37/38	39/40	41/42
43/44	45/46	47/48	49/50

actual, rather than simulated, space conditions in order to verify these results.

- Because of the difficulty of conducting such experiments in live animals, most studies on reproduction in space have thus far been carried out in species such as fish or amphibians. Mammalian embryos can only be cultured for a few days, meaning that such experiments may require difficult in vivo procedures that could pose technical challenges for the astronauts. In a previous study, it was found that freeze-dried spermatozoa can be preserved at room temperature without losing their fertilization capacity. This is advantageous for space experiments because the samples have lower mass and do not require a freezer for storage during launch or landing. These freeze-dried spermatozoa will be kept on board the ISS in the Japanese Experiment Module "Kibo" and exposed to cosmic radiation for several months. After this sample returns to the ground, we will try to make offspring from them and examine the effects of cosmic radiation on sperm DNA.

- This research will be the first step for studying mammalian reproduction in space. We hope to expand on this study by developing an automatic culturing system for frozen embryos, as well as animal cages to maintain live animals in space, and ultimately to attempt to produce live offspring under space conditions.

DESCRIPTION

Sustaining life beyond Earth orbit will require a clear understanding of how the environment in space affects key phases of mammalian reproduction. Recently, a study was done on mammalian fertilization and preimplantation development under simulated microgravity (simulated μG) conditions using a three-dimensional (3D) clinostat. Although fertilization occurred normally in vitro under simulated μG, the offspring birth rate was significantly lower than the 1G controls due to the poor development of placental cells. This suggests that mammalian

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PREVIOUS MISSIONS

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MEDIA LINKS

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species may have difficulty reproducing in space, and highlights the importance of performing experiments in actual, rather than simulated, space conditions in order to verify these results.

However, because of the difficulty of conducting such experiments in live animals, most studies on reproduction in space have thus far been carried out in species such as fish or amphibians. The gametes and embryos of these species are comparatively easy to manipulate for use in reproduction experiments, reducing the need to maintain live animals. Mammalian embryos, on the other hand, can only be cultured for a few days, meaning that such experiments may require difficult in vivo procedures that could pose technical challenges for crew members. For this reason experiments on mammalian reproduction in live animals or gamete cells was considered unfeasible using present-day technology.

In a previous study, we found that freeze-dried spermatozoa can be preserved at room temperature without losing their fertilization capacity. This is advantageous for space experiments because the samples have lower mass and do not require a freezer for storage during launch or landing. These freeze-dried spermatozoa will be kept on board the ISS in the Japanese Experiment Module "Kibo" and exposed to cosmic radiation for several months. After this sample returns to the ground, we will try to make offspring from them and examine the effects of cosmic radiation on sperm DNA.

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Applications

SPACE APPLICATIONS

Sustaining life beyond Earth either on space stations or other planets requires a clear understanding of how the space environment affects key phases of mammalian reproduction. So far only non-mammals have been used in reproductive studies in space. Studies using simulated microgravity on Earth showed birth rates due to poor placental development, indicating that microgravity has an adverse but unknown role in fertilization and gestation. Space Pup will help isolate radiation as a factor in long-term studies.

EARTH APPLICATIONS

The gestational period is highly sensitive to environmental factors, including radiation and potentially the effects of gravity. Results from this experiment should provide valuable information for the collection and preservation of mammalian reproductive tissue for a range of uses.

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Operations

OPERATIONAL REQUIREMENTS AND PROTOCOLS

Space Pup Sample Cases (containing freeze-dried samples) will be launched at ambient. Space Pup Sample Cases should be kept at -95^{o}C in MELFI on board for several months (about (1) one month, (2) 12 months, (3) 24 months). On board operation is only to keep these samples at-95^{o}C in MELFI. Space Pup Sample Cases will be returned one by one at ambient. Return plan: (1) SpX-4, (2) SpX-7 (TBD), (3) SpX-10 (TBD).

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Decadal Survey Recommendations

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Publications

Preserved freeze-dry mouse spermatozoa were exposed to cosmic radiation on the ISS for 9 months and then brought back to Earth for in-vitro fertilization. The overall morphology of space sperm did not differ from ground controls and DNA damage was only slightly increased. During fertilization, most oocytes (female germ cells) formed normal pronuclei similar to ground controls. The offspring derived from space sperm and control sperm showed similar birth rates. After pups grew to adulthood, some pairs were mated with each other. The second generation of pups showed normal gene expression profiles. These findings demonstrated that damage to the DNA due to space radiation did not affect the production of viable offspring and it suggested that sperm DNA

damage was decreased or repaired after fertilization.

RESULTS PUBLICATIONS

Wakayama S, Kamada Y, Yamanaka K, Kohda T, Suzuki H, Shimazu T, Tada MN, Osada I, Nagamatsu A, Kamimura S, Nagatomo H, Mizutani E, Ishino F, Yano S, Wakayama T. Healthy offspring from freeze-dried mouse spermatozoa held on the International Space Station for 9 months. Proceedings of the National Academy of Sciences of the United States of America. 2017 May 22; epub201701425. DOI: 10.1073/pnas.1701425114. (http://dx.doi.org//10.1073/pnas.1701425114)PMID: 28533361. DOI: 10.1073/pnas.1701425114 (http://dx.doi.org/10.1073/pnas.1701425114) | Abstract

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