Eve of Mars colonization: Moon as test base for pregnancy in fractional gravity

Would you want to become the first mother in a human Mars colony?

Recently, a British candidate for the Dutch Mars One mission announced that she'd like to do just that.

"I want to have the first baby on Mars," 24 year-old Maggie Lieu told the British newspaper, The Daily Mail.

Lieu is an astrophysics PhD student and one of five British finalists for Mars One. This is a Dutch company taking a reality TV show approach to selecting astronauts for a one-way mission to plant a human colony on the Red Planet in 2025.

But before anyone attempts pregnancy on Mars, we need to be sure if that would work, and recently NASA announced plans for a base on the Moon. That's much closer and could be a useful environment for testing pregnancy, where astronauts are not weightless as they are on the International Space Station (ISS), but where gravity is significantly less than what it is on the surface of Earth.

Reality TV needs to be more in touch with reality

If you think that an arrival date on Mars nine years from now seems seems overly ambitious, you're not alone. Recently, I found a Washington DC Metro pass that I've been carrying around for nine years and it's still valid. And while NASA did achieve President Kennedy's moonshot goal in less time in the 1960s, Mars One has been criticized for having no space hardware, such as engines and life support systems that are generally considered prerequisites for building spaceships. As stated on the Mars One website:

> Mars One is not an aerospace company. Therefore, the required systems are to be designed and built by established aerospace companies with relevant experience. Launch services and integration of the different systems will also be outsourced to experienced parties. Mars One will focus mainly on the funding, management of the mission, and finding the right teams to go to Mars. The plan that Mars One has established and the progress that has been made is only part of the overall plan. Mars One would not be able to complete this mission without the support and enthusiasm from the global community.

Contemplation of the first Martian birth thus looks premature. Hopefully this adjective won't also apply to the birth itself, but how could we be sure? How can we be confident that the first Martian fetus won't be at high risk for premature delivery, or worse, congenital malformations, or weak bones, or other serious health issues? Even if NASA, or another organization with spaceflight capability were to announce now that they'll be sending, not mere astronauts, but settlers to establish the human seed on Mars in 2025, we'd be hard pressed to move fast enough on research needed to understand reproduction in off-Earth colony environments.

Effects of space radiation on human reproductive cells (gametes) and embryos would not be a prime concern, because Mars colonists will be living underground to keep radiation exposure low. But the low gravity is an issue that needs to be addressed. From studies of various animal species in weightless environments, such as on the International Space Station (ISS), we know that the direction of gravity is an important signal, both during early pregnancy and throughout the course of development up to birth. We have learned that gravity plays an important role in gene expression and embryology from the stage of the blastocyst, the entity that must implant in the uterus. As genesis of an embryo continues, cells continue taking on different and increasingly more specialized roles, depending on their location and gravity is important to the process.

Various biological species make use of the gravitational vector as a cue to positioning during early embryogenesis. Non-mammalian animal models studied in space to understand development have included *Drosophila melanogaster* (fruitflies), fertilized *Xenopus* eggs, quail embryos, and rodents. To fertilize an egg, sperm must undergo a process called capacitation, which affects sperm motility and other properties. Researchers have looked at the effects of gravity on individual cells, including human spermatozoa, and results have been complex. For example, some evidence suggests that weightlessness may reduce the sperm count, yet there also is some evidence of increased sperm motility.

Medical studies of humans on ISS have gotten very advanced, and recently American astronaut Scott Kelly returned to Earth, healthy after almost a year on the station. But based on the gravitational embryology research in space and on Earth, we wouldn't want to put a female astronaut in ISS for the duration of a pregnancy. There are no plans for a weightless human colony, but the gravitational pull at the surface of Mars is only 0.38 that at the surface of Earth (your Mars weight is 38 percent of your Earth weight). Would this level of gravity be enough for human pregnancy on Mars?

To learn the answer to this question and many others connected with gravity and health, as far back as the early 1990s, there were plans to include a centrifuge on ISS to provide artificial gravity of varying strength with volume enough to house small animals. The faster the centrifuge spins, the more artificial gravity it provides, so on the ISS one could produce Martian gravity, lunar gravity (0.16 Earth gravity), half-Earth G, or any other amount, whereas as centrifuges on Earth can only provide gravity higher than a full G. The ISS small animal centrifuge was canceled, however, so there remains a lot of uncertainty when it comes to pregnancy in fractional G environments, like that on the Moon and Mars.

There is a rationale—a very good rationale—that initiation and continuation of pregnancy in a rodent, monkey, or human, would be essentially normal in fractional gravity, that we'd need some level of pull, but not the full force of Earth. But how much gravity would be enough? Lunar gravity? Mars gravity? Or would we need something more? Surely, that's something that potential Mars colonists would want to know before putting their Earth-bound homes up for sale –especially given the Mars One approach of not providing a round-trip ticket.

Benefits of a lunar base

NASA's idea calls for building the lunar settlement in the early 2020s. That's a short timeline for a major space program, but it's far more plausible than the Mars One goal of getting people to Mars nine years hence, and there's a potential driving factor not related to the goal of sending humans to Mars. It's called lunar solar power (LSP). It involves building enormous farms of solar arrays to generate power that could beamed to Earth as microwave radiation, which then can be converted to electricity. LSP requires a large lunar base, possibly housing hundreds of people, a half trillion dollar undertaking, yet it’s been calculated that it would cost one fifth the price of building Earth-based solar energy at a scale large enough for complete replacement of fossil fuels.

As opposed to a little basket that would have housed a few rodents on the ISS centrifuge, any laboratory built on the Moon would provide test space at lunar gravity (0.16 G). Additionally, a rotating facility on the Moon could provide artificial gravity at Mars levels (0.38 G), or higher. We could learn whether there’s a minimum gravitational force for reproduction to work normally. If it works at lunar gravity, that would be wonderful, because then it would also work at Mars gravity and anywhere up to the gravitational force felt at the Earth’s surface. If it does not work at lunar gravity, we’d still have more homework to do, but then we would have a rational for building the rotating facilities to test Mars gravity. And what the 0.38 G of Mars turned out not to be enough? Then, it would depend on the specific effects of the low gravity. If the only problem were slightly reduced human fertility, Martian colonists could deal with that. They could use reproductive technologies, maybe come up with other interventions, and, depending on research findings, Martian colonists might take up parenting at a younger age than is typical in industrial societies today where people are in school and getting career training well into their 30s. A pioneering society could develop in which young couples reproduce in their early 20s, during or prior to going to college. This, in turn, might bring grandparents, or the community as a whole, to play major role in child rearing to enable the young parents to get their education, which would be vital, since technological progress would be even more important on Mars than it is on Earth.

If the problem were a high rate of birth defects, or fertility reduced to levels orders of magnitude below what is normal on Earth, that would not be not be a good way seed a new world with a new breed of humans, so we’d still have a lot of research ahead of us. We might look into genetic modification to enhance the embryonic response to the low gravity of Mars, and maybe the process would work better in an artificial womb. Or, we might reconsider the idea of Mars colonization and look somewhere else to build a second home for humankind.

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