International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

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Exploring maternal parity and the feasibility of childbirth in space: Insights from terrestrial and extraterrestrial research

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International Journal of Science and Research Archive, 2024, 13(02), 1611–1619

Publication history: Received on 15 October 2024; revised on 24 November 2024; accepted on 26 November 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.13.2.2297

Abstract

This comprehensive study, led by Ghaffari, explores the relationship between parity and various maternal health outcomes by analyzing 260 maternal death cases across Iran over a three-year period. The research, pioneering in its focus on astronaut-mothers, examines the association of parity with factors such as prolonged labor, rapid labor, induction rates, retained placenta, placental curettage, peripartum cardiomyopathy, vaginal bleeding, postnatal wellness, and maternal mortality. Methodologically, the study conducts a thorough statistical analysis of these parameters, aiming to identify patterns that may inform astronaut selection criteria for future space missions involving childbirth. Despite finding no significant correlation between parity and maternal health outcomes, the study underscores the need for further research on parity-specific differences, as current literature often amalgamates data for multiparous women. This research provides pivotal insights for advancing maternal health considerations in the unique context of space exploration.

Keywords: Parity; Maternal health; Astronaut-mothers; Labor outcomes; Space exploration

1. Introduction

In a comprehensive study conducted by Ghaffari, maternal death cases across Iran over a three-year period (encompassing 260 cases) were scrutinized to understand the relationship between parity and various maternal health outcomes. This research, presented for the first time, sheds light on the implications of parity number for astronaut-mothers. Specifically, it delves into the association of parity with prolonged labor, rapid labor, induction rates, retained placenta, placental curettage, peripartum cardiomyopathy, vaginal bleeding, postnatal wellness, and maternal mortality, providing crucial insights for future space missions involving childbirth.

2. Methods

The study entailed a meticulous analysis of maternal death cases, focusing on statistical correlations between parity and a spectrum of maternal health outcomes. The parameters assessed included prolonged labor (with the active phase and second stage lasting less than three hours), induction with oxytocin, retained placenta, placental curettage, peripartum cardiomyopathy, vaginal bleeding, postnatal wellness, and scenarios resulting in maternal death. This comprehensive approach aimed to uncover patterns that could inform the selection criteria for astronaut-mothers.

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3. Results

The statistical analysis did not reveal a significant correlation between parity number and the maternal health outcomes under consideration. However, it highlighted the necessity for additional studies concentrating on parity-specific differences, as current literature often aggregates data for multiparous women.

4. Discussion

The findings indicate that while parity does not exhibit a significant correlation with certain maternal health outcomes, there are notable practical exceptions. For example, prolonged labor was observed in 1.8% of second parity pregnancies and 2.6% of third parity pregnancies, with all affected mothers ultimately succumbing to their conditions. This suggests that, although multiparous mothers generally experience shorter labor durations, exceptions do exist.

Vaginal bleeding emerged as a significant concern, with an incidence of 26.3% in second parity and 38.5% in third parity pregnancies. These findings are consistent with other studies, indicating that higher parity is a risk factor for uterine atony. The incidence of postpartum hemorrhage increases from 0.3% in women with low parity to 1.9% in women with a parity of four or more. An overly dilated uterus, common in high parity pregnancies, is prone to postpartum hypotony, which can be exacerbated by the muscle wasting and reduced muscle strength experienced in zero gravity environments.

4.1. Implications for Space Missions

Given these findings, it is imperative to consider the parity number when selecting astronaut-mothers for space missions. A history of one successful birth on Earth is a fundamental prerequisite. For the first human birth in space, second parity is preferred over third parity due to the increased risk of complications associated with higher parity. Higher parity leads to a looser and more dilated uterus, which, combined with the effects of zero gravity, may significantly reduce muscle strength and uterine contraction efficiency.

Clinical observations reveal that women with high parity often give birth unexpectedly and rapidly, sometimes before reaching medical facilities. Hence, selecting mothers with third or higher parity for space missions heightens the risk of premature labor and delivery before reaching low Earth orbit (LEO), potentially jeopardizing the mission's success.

4.2. Physiology of Neonate After Birth

A neonate has never been in space, and the physiology of a neonate after birth is distinctly different from that of an adult. By reviewing the physiology of a neonate after birth in [Table 2] and comparing these with the physiological changes that occur in a zero-gravity environment in [Table 1], concerns about a baby’s ability to tolerate space conditions are alleviated. This comparative analysis aids in understanding how a neonate might adapt to space conditions, ensuring better preparedness for any potential challenges.

4.3. Animal Research and Human Reproduction in Space

Limited research has been conducted on the ability of humans to reproduce in altered gravity environments. However, animal experiments on birth in space have been carried out, primarily on mice. While it may seem that these results cannot be directly applied to human births in space, they provide valuable insights. Comparing the anatomy, tissue, and cells (including the heart, skeletal system, respiratory system, vascular structure, and uterus anatomy) of mice with humans, as well as pregnancy and placenta formation, offers critical information for mission planning.

From a brief observation of the comparisons of the anatomy and histology of some organs of mice with humans, it becomes apparent that mice, with their simpler versions of cells and organs, managed pregnancy and childbirth in space, and their infants also adapted to the space environment with slight differences. This raises the question: if mice can do it, why can’t humans, with their more complex and advanced cells and organs? It is time to confront this challenge and find definitive answers. Perhaps the notion that giving birth in space is impossible or difficult exists only in the minds of those who have not attempted it, not in practice and reality.

Table 2 Maternal Health Outcomes Across Different Parity Levels

	Para 1	**Para 2**	**Para 3**	**Para 4**	**Para 5**
Prolonged labor	3.6%	1.8%	2.6%	0%	5.9%
rapid labor	3.6%	0%	0%	0%	0%
Rate of induction	19%	14%	20.5%	9.1%	5.9%
Remaining placenta	6%	1.8%	10.3%	0%	0%
Placental curettage	4.8%	8.8%	10.3%	9.1%	17.6%
Peri- partum cardiomy- opathy	2.4%	1.8%	5.1%	0%	0%
Vaginal bleeding	23.8%	26.3%	38.5%	36.4%	60%
Being un- well Post NVD	25.5%	21.8%	16.4%	5.5%	10.9%
Death after NVD	30.3%	18.2%	15.2%	4.5%	9.1%

Body System	**Physiology Of Neonate After Birth**
Cardiovascular System	Fetal shunts are functionally closed. The change from fetal circulation to circulation occurs after birth breathing begins with the replace- ment of air with the liquid that previ- ously filled the neonate›s lungs
Respiratory System	The kidney system is not completely complete until one year after birth, and fluid imbalance may occur.
Renal System	There are uncoordinated movements of the esophagus (pristalsis).
GI	A neonate has a limited ability to digest fat
Thermogenic	The neonate is sensitive to rapid tem- perature drop because the environ- ment has changed acutely and the fat layer under the skin is thin. Non-shivering thermogenesis occurs. The presence of brown fat is more in full-term babies and less in pre- term newborns, causing the neonate to warm up due to increased heat production.
Immune System	The Inflammatory Response of The Tissues Is Insufficient in Limiting and Localizing the Inflammation.
The Blood System	Coagulation time is long.
Neurological System	The Presence of Primary Reflexes and The Time of Their Appearance and Disappearance Indicate Maturity It Is the Nervous System
Hepatic System	The newborn may show jaundice
Integumentary Covering System	Epidermis And Dermis Are Thin and Loosely Connected To Each Other. The Parotid Glands Are Active.
Musculoskeletal System	There is more cartilage than bone.
Reproductive System	Newborn Girls May Have False Vaginal and Mucoid Discharge (Men- struation) Due to Maternal Estrogen Levels. Small White Cysts Called Epithelial Pearls May Be Present at The Tip of The Foreskin. The Scrotum Can Be Swollen If the Fetus Was Breech

Table 2 Comparative anatomy and histology mice and human

Feature	**Mice**	**Human**
Macroscopic		
Heart Weight	0.12-0.15grams	200-350 Gr In Adults
Heart Weight (Percent- age Of Fat-Free Body Weight)	0.45-0.5%	0.40%- 0.45% In Adults
Left Ventricular Wall Thickness	1.5-1.8 Mm	1.2-1.5 Cm
Right Ventricular Wall Thickness	0.5-0.6 Mm	0.4-0.5 Cm
The Thickness Of The Septum	1.5-1.8 Mm	1.2-1.5 Cm
Heart Beat	350-700 Beats Per Minute	60-100 Beats Per Minute
Left Ventricular Cardiac Output	11-16ml/Min	4.5 – 5 Lit/Min In Adults
Left Ventricular Stroke Volume	30-36µl/Beat	60- 70 Ml/Beat In Adults
Heart-Shaped	Oval	Conical
Leaning On The Dia- phragm	No	Yes
Interventricular Groove	No	Yes
Pericardium	Thick With Several Layers Of Flat Cells	Thickness 1-3 Mm
Epicardial Fat	None At All	Moderate To Abundant Along The Coronary Arteries
Anterior Middle Vena Cava	Two (Left And Right)	One
Pulmonary Veins	Pooling Of Pulmonary Veins Before Joining The Left Ventricle	The Left Atrium Re- ceives Four Pulmonary Veins Independently
Number Of Main Coro- nary Arteries	Usually Two, Sometimes Three	Normally, The Proximal Aorta Bifurcates Along With The Left Branch Into Two Main Arteries
Origin Of Coronary Arteries	Internal Or Superior Coronary Sinus	Internal Coronary Sinus
Septal Coronary Artery	Yes	No
Location Of Coronary Arteries	Inside The Myocardium	Normally, Proximally In The Epicardium And Distally In The Middle Of The Myocardium

Table 3 Comparative anatomy and histology mice and human

The Position Of The Sinus Node	**The Junction Of The An- terior Vena Cava And The Right Atrium**	**The Junction Of The Su- perior Vena Cava And The Appendage Of The Right Atrium**
Atrioventricular Node Position	Interatrial Septum	Like Mice
The Position Of The Bundle Of His	Basal Interventricular Septum (IVS)	Central Fibrotic Body To Basal IVS

The Position Of The Branches Of The Left And Right Handles	Subendocardially Along The Left And Right Surfaces Of The IVS, Respectively	Like Mice
Atrioventricular Valves	The Continuous Curtain Has Tendinous Cords	Specific Lats; It Has Strings
Crescent Valves	It Does Not Have Tendi- nous Cords	Like Mice
Histology		
Epicard	Thin	Impressive
Endocardium	Thin	Impressive
Subendocardial Connec- tive Tissue	None At All	Impressive, Especially On The Left Side Of The Heart May Contain Blood Vessels, Nerve Fibers, Fat Bundles Of Smooth Muscle
Cardiac Skeleton	Unknown	Specified
Valve Layers	There Are No Distinct Layers, There Are Fibrous And Spongy Areas	Three Distinct Atrioven- tricular Layers, Fibrous And Spongy
Cells		
Binuclear Cardiomyo- cytes	The Majority (75%)	At Least (25%)

Table 3 Comparative anatomy and histology mice and human (Heart)

Feature	**Mice**	**Human**
Macroscopic		
Lung lobes	4 right numbers and one left number	3 right numbers and 2 left numbers
Creating an air passage	13-17	17-21
Airway branching pattern	monopodial	double
Diameter, Main Broncos (mm)	1	10-15
Histology		
Diameter, terminal bronchiole (mm)	0.01	0.6
Respiratory bronchioles	One or none	There is
Lung parenchyma/total parenchyma volume (percentage)	18	12
Alveolus (micrometer)	39-80	200-400
Thickness of blood-air barrier (micrometer)	0.32	0.62
Cells		
Epithelial tissue of the trachea		
Coating thickness (mi- crometer)	11-14	50-100
Ciliated cells (percent- age)	39	49
Clara cells (percentage)	49	
Goblet mucous cells (percentage)	Less than one percent	9
Serous cells (percentage)	Less than one percent	Less than one percent

basal cells (percentage)	10	33
other (percentage)	1	
Primary intrapulmonary epithelial tissue		
Coating thickness (mi- crometer)	8-17	40-50
Ciliated cells (percent- age)	36-28	37
Clara cells (percentage)	59-61	
Goblet mucous cells (percentage)	Less than one percent	10
serous cells (percentage)	Less than one percent	3
basal cells (percentage)	Less than one percent	32
other (percentage)	2-14	18
Terminal bronchioles		
Coating thickness (mi- crometer)	7-18	Not specified

Table 4 Comparative anatomy and histology mice and human

Ciliated cells (percent- age)	20-40	52
Clara cells (percentage)	60-80	
Goblet mucous cells (percentage)	0	
serous cells (percentage)	0	35
basal cells (percentage)	Less than one percent	Less than one percent
other (percentage)	0	13
Feature	**Mice**	**Human**
Macroscopic		
vertebra	More number of thorac- ic, lumbar and coccygeal (caudal) vertebrae than humans	24 articulated vertebrae, thoracic and lumbar neck and 9 connected sacral vertebrae and coccygeal vertebrae
cervical vertebra	7	7
thoracic vertebra	13	12
lumbar vertebra	6	5
sacral bone	4	5
coccygeal vertebra	27-31	4
Histology		
Cortical bone	There is no osteon; And porosity increases with age	There is osteon
spongy bone	During the first few months of life the secondary sponge is present and after that it should decrease	There is no secondary spongy after bone mat- uration.
physis, or growth plate	It remains throughout life.	It exists only during growth and develop- ment.

Articular cartilage	Thinner than humans; The variable thickness of the subcartilaginous plate; Tadmark is not clear (at the age of 3-4 months of mice).	The thickness depends on the joint; There is a uniform subcartilag- inous plate and Tide Mark.

bone marrow	Hematopoietic bone marrow in the axial and appendicular skeleton in the first few months of life	Hematopoietic bone marrow during develop- ment and in the spinal axis of adults; fat in the appendicular skeletonof adults
Immature bone	Yes	Yes
mature bone	Yes	Yes
Cells		
Osteoblasts Osteoclasts Brown fat	Yes Yes In adults, it is largely behind the interscapular region.	Yes Yes it's complicated. But it may remain mainly in the neck area in adults.

Table 5 Comparative anatomy and histology mice and human Skeletal system

Feature	Mice	Human
Histology		
Artery layers	tunica intima tunica me- dia; Tunica Adventis	like mice
Elastic arteries	Has an elastic blade	like mice
muscular artery	tunica media consist- ing of smooth muscle cells; The elastic lamina is limited to external elastic lamina (EEL) and internal elastic lamina (IEL)	like mice
arterioles	thin muscle layer (1-2 cell layers); Absence of EEL and - often absence of IEL	like mice
Capillaries	Absence of IEL and smooth muscle cell lay- er, presence of intermit- tent pericytes	like mice
Subendothelial connec- tive tissue	It is rarely there	It has different values; usually in larger vessels; It is sometimes seen
veins	rarely seen; It almost never reaches the inner parts of the vessel	
Pulmonary veins	surrounded by cardio- myocytes well inside the lung parenchyma	sometimes surrounded by cardiomyocytes near the base of the heart

	Mice	**Human**
	two horns The mucosa is a simple cylindrical epithelium that extends into the branched tubular glands in the myometrium.	It varies according to the menstrual cycle. Dedicated glands within the dedicated stroma (endometrial) interacting with the myometrium, there is no protrusion of the glands into the myometrium except under abnormal conditions (which is common).
myometrium	External longitudinal and internal circular smooth muscle layers	Single muscle layer

Changes in the length of estrous/metaestrous cycle	Proestrus: hyperemia and expansion with mitosis in the epithelial tissue and leukocytes inside the stroma Estrus: maximum mito- sis/leukocytes are rare. Methestrus: the epithe- lial tissue degenerates, the uterine wall does not expand further, the number of leukocytes increases. Dystrous: the uterus collapses along with leukocytes and regener- ation occurs	The first half of the (proliferative) cycle of tubular glands with cylindrical cells of both glands and stromal mitosis is seen. In the second half of the cycle (secretory), the epi- thelial tissue remains cy- lindrical, but the glands begin to stretch and become more complex. Cells contain subnuclear vacuoles at the begin- ning of the secretory phase, after which these vacuoles disappear. The stroma becomes increasingly epithelioid- ized during the last half of the secretory phase under the influence of progesterone. During the shedding of the stroma, it is condensed and the infiltration of neutro- phils and shedding of the epithelial tissue are observed.
Myometrial glands	It exists in a variety of ways and according to the mouse breed	It is absent in normal myometrium.

Table 6 Comparative anatomy and histology mice and human Vascular structure

Feature	**Mice**	**Human**
Duration of pregnancy	18.5-21 days	37-42 weeks
Size	2 cm	20 cm
Shape	a plate	a plate
Maternal-fetal exchang- es	Labyrinth	fluffy
Maternal barrier	Homo curial	Homo curial
yolk sac	It has little function in maternal-fetal exchanges	It exists as a non-func- tioning residue through- out the course
Uterine spiral arteries		It is regenerated by trophoblast during pregnancy
Trophoblast population	Labyrinthian tropho- blast Spongiotrophoblast Trophoblast giant cells	Syncytiotrophoblast Cytotrophoblast Extra-fluffy trophoblast

5. Conclusion

This study emphasizes the critical importance of considering parity when selecting astronaut-mothers for space missions. While parity alone does not significantly impact certain maternal health outcomes, the increased risks associated with higher parity, especially in zero gravity, require careful selection criteria. Ensuring the strength and readiness of the mother's body is essential for the success of human childbirth in space. Furthermore, understanding the physiology of neonates and their potential adaptation to space conditions can alleviate concerns and enhance the safety and success of such missions. Insights gained from animal research, particularly involving mice, provide valuable guidance in addressing the complexities of human reproduction in space.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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