USAFSAM Risk Assessment: Maternal and Fetal Health Risks Associated with USAF Flying Operations

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24 MAR 2022

Background & Methods

- In 2019, the U.S. Air Force School of Aerospace Medicine (USAFSAM) was requested to conduct an assessment of the human health risks from USAF flying operations to the pregnant aviator and fetus.
- USAFSAM assessed 21 hazard categories across 3 hazard types (chemical, physical, and aeromedical/physiological). 49 specific hazards were assessed in total.
- For all hazards/exposures, it was assumed that the pregnancy was uncomplicated and singleton (not high-risk).
- Risks to maternal health, fetal health, and mission were evaluated for each specific hazard.
- USAFSAM utilized Air Force Risk Management principles as the basis for determining the human health risk associated with military flight for the pregnant aviator and fetus.
- Data for the risk assessment came from existing literature (>100 sources) and subject matter expert input; no new data were collected for this study.

Specific Methods – Risk Assessment

- USAFSAM Risk Assessment approach based on USAF Instruction 90-802
  - Risk = Severity * Probability/Likelihood
  - Severity and probability determined independent of one another; risk matrix then determines L/M/H/EH risk level.
- There are limited data on pregnancy among aircrew, but none of it proves safety; instead, many areas are based on an absence of evidence that there will be harm to the pilot, fetus, or mission.
- Hazards with “low” risk are not as low as reasonably achievable (ALARA), but instead represent hazards that do not substantially increase risk. Hazards where there is a basis to believe no or ALARA risk are indicated as not applicable (N/A).
- Finally, the risk assessment matrix also includes the category of “Unknown.” In these areas, there is simply not enough information (including expert assessment or opinion) to postulate a risk.

Risk Assessment Matrix			PROBABILITY: Frequency of Occurrence Over Time				
			A Frequent (Continuously experienced)	B Likely (Will occur frequently)	C Occasional (Will occur several times)	D Seldom (Unlikely; can be expected to occur)	E Rarely (Improbable; but possible to occur)
SEVERITY — Effect of Hazard	Catastrophic (Death, Loss of Asset, Mission Capability or Unit Readiness)	I	EH	EH	H	H	M
	Critical (Severe Injury or Damage, Significantly Degraded Mission Capability or Unit Readiness)	II	EH	H	H	M	L
	Moderate (Minor Injury or Damage, Degraded Mission Capability or Unit Readiness)	III	H	M	M	L	L
	Negligible (Minimal Injury or damage, Little or No Mission Capability or Unit Readiness)	IV	M	L	L	L	L

Risk Assessment Levels

EH=Extremely High H=High M=Medium L=Low

Generalized Results

- Chemical Exposures
  - Risk of all specific hazards is either low or unknown
- Physical Hazards
  - Risk of specific hazards ranges from low to high, with many unknown risks
- Aeromedical Exposures
  - Risk of specific hazards ranges from low to high, with many unknown risks

- Specific Exposures with Highest Risk:
  - Cosmic radiation
  - Hazardous noise
  - Vibration
  - Acceleration
  - High thermal burden
  - Impaired G-suit function
  - Impaired egress during an emergency
  - Altered cockpit dynamics
  - Risk of injury with ejection
  - Cognitive/sleep changes due to pregnancy interfering with management of high-cognitive demand tasks.

Hazard Risk Assessment for Maternal and Fetal Risk in USAF Aviation: Chemical Hazards

		MATERNAL			FETAL		MATERNAL RISK			FETAL RISK					
Hazard Type	**Specific Hazard**	**Probability**	**Severity: Health Effect**	**Severity: Effect on Mission**	**Probability**	**Severity: Health Effect**	**1st Trimester**	**2nd Trimester**	**3rd Trimester**	**1st Trimester**	**2nd Trimester**	**3rd Trimester**	**Mission Risk**	Notes	Primary References
Chemical															
Metals	All Heavy Metals	E	IV	IV	E	III	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
Fuels/POL's	JP-8, Jet A+, Kerosene, Oils, Lubricants	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	3
VOCs/SVOCs	Acetone	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
	Ethylbenzene	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
	Methyl Ethyl Ketone	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
	Toluene	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
	Xylene	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
Particulates	Jet Fuel Combustion Emissions	E	IV	IV	U	U	**L**	**L**	**L**	**U**	**U**	**U**	**L**	1,2	3
Toxic Gases	Carbon Monoxide	E	IV	IV	E	III	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2
	NOx/SOx	E	IV	IV	U	U	**L**	**L**	**L**	**U**	**U**	**U**	**L**	1,2	2
	Ozone	E	IV	IV	U	U	**L**	**L**	**L**	**U**	**U**	**U**	**L**	1,2	2
Carcinogens and Mutagens	1,1-dichloroethene	E	IV	IV	E	III	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
	Benzene	E	IV	IV	E	III	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
	Formaldehyde	E	IV	IV	E	III	**L**	**L**	**L**	**L**	**L**	**L**	**L**	1	2, 3
	Polyaromatic Hydrocarbons	E	IV	IV	E	U	**L**	**L**	**L**	**U**	**U**	**U**	**L**	1,2	3

Hazard Risk Assessment for Maternal and Fetal Risk in USAF Aviation: Physical Hazards

		MATERNAL			FETAL		MATERNAL RISK			FETAL RISK					
Hazard Type	**Specific Hazard**	**Probability**	**Severity: Health Effect**	**Severity: Effect on Mission**	**Probability**	**Severity: Health Effect**	**1st Trimester**	**2nd Trimester**	**3rd Trimester**	**1st Trimester**	**2nd Trimester**	**3rd Trimester**	**Mission Risk**	Notes	Primary References
Physical															
Ionizing Radiation, Cosmic	Polar Flights--70,000 ft	VARIABLE (B TO E)	VARIABLE (II TO IV)	IV	VARIABLE (B TO E)	VARIABLE (II TO IV)	**0 hrs**		**250 hrs**	**50 hrs**		**250 hrs**	**L**	3	4-9
	Polar Flights--45,000 ft						**0 hrs**		**500 hrs**	**100 hrs**		**500 hrs**			
	Polar Flights--33,000 ft						**0 hrs**		**830 hrs**	**166 hrs**		**830 hrs**			
	Equatorial Flights--70,000 ft						**0 hrs**		**1670 hrs**	**336 hr**		**1670 hrs**			
	Equatorial Flights--45,000 ft						**0 hrs**		**3300 hrs**	**664 hrs**		**3300 hrs**			
	Equatorial Flights--33,000 ft						**0 hrs**		**4200 hrs**	**800 hrs**		**4200 hrs**			
Electromagnetic Fields (EMF)	< 100 kHz	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**		10, 11
	100 kHz - 3 GHz	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**		10, 11
	> 3 GHz	E	IV	IV	E	IV	**L**	**L**	**L**	**L**	**L**	**L**	**L**		10, 11
Noise	20 Hz - 20 kHz (Audible)	E	IV	IV	B	III	**L (with PPE)**	**L (with PPE)**	**L (with PPE)**	**L**	**M**	**M**	**L**	4	12-15
	Above 20 kHz (Ultrasound)	E	IV	IV	D	1V	**L**	**L**	**L**	**L**	**L**	**L**	**L**		12-16
	Less than 20 Hz (Infrasound)	E	IV	IV	U	U	**L**	**L**	**L**	**U**	**U**	**U**	**L**		12-15
Vibration	A/C operations	D	II	II	D	U	**M**	**M**	**M**	**U**	**U**	**U**	**M**	5	17-19

Hazard Risk Assessment for Maternal and Fetal Risk in USAF Aviation: Aeromedical & Physiological Considerations

Hazard Type	Specific Hazard	MATERNAL Probability	MATERNAL Severity: Health Effect	MATERNAL Severity: Effect on Mission	FETAL Probability	FETAL Severity: Health Effect	MATERNAL RISK 1st Trimester	MATERNAL RISK 2nd Trimester	MATERNAL RISK 3rd Trimester	FETAL RISK 1st Trimester	FETAL RISK 2nd Trimester	FETAL RISK 3rd Trimester	Mission Risk	Notes	Primary References
Aeromedical & Physiological Considerations															
Acceleration	Acceleration in low-G Aircraft (TTB)	D-E	IV	IV	D-E	IV	L	L	L	L	L	L	L	6	20-24
	Acceleration in High-Performance Aircraft & Trainers	B	U	U	B	U	U	U	U	U	U	U	U	6	20-24
Routine Accleration Exposure (+Gz)	Reduced G-Tolerance due to Pregnancy in Low-G Aircraft (TTB)	D-E	IV	IV	D-E	IV	L	L	L	L	L	L	L	7	25-27
	Reduced G-Tolerance due to Pregnancy in High-Performance Aircraft & Trainers	B	U	U	B	U	U	U	U	U	U	U	U	7	25-27
Temperature	Heat Exposure (general)	C	III	III	C	II-III	M	M	M	H	M	M	M	8	28-40
	Heat sufficient to raise core temp >102° F	D	II	II	D	I	M	M	M	H	U	U	M	8	28-40
	Cold	D	IV	IV	E	IV	L	L	L	L	L	L	L	9	41-42
Cabin Altitude (without supplemental O2)	≤FL80	B	IV	IV	B	IV	L	L	L	U	U	U	L	10	43-59
	≤FL100	B	U	IV	B	U	U	U	U	U	U	U	L	10	43-59
	≤FL180	E	I-II	II-I	E	II	L	L	L	U	U	U	L-M	10	43-59
	≤FL220	E	I-II	I-II	E	I	L	L	L	U	U	U	L-M	10	43-59
Cabin Altitude (with supplemental O2)	≤FL220	A-C	IV	IV	A-C	U	L	L	L	U	U	U	L	11	60-63

Hazard Risk Assessment for Maternal and Fetal Risk in USAF Aviation: Aeromedical & Physiological Considerations (cont'd)

		MATERNAL			FETAL		MATERNAL RISK			FETAL RISK					
Hazard Type	Specific Hazard	Probability	Severity: Health Effect	Severity: Effect on Mission	Probability	Severity: Health Effect	1st Trimester	2nd Trimester	3rd Trimester	1st Trimester	2nd Trimester	3rd Trimester	Mission Risk	Notes	Primary References
Restrictive Breathing & Positive Pressure Breathing Systems (HPA and Trainers)	Elastic and Resitive Breathing Limitations due to Life Support Systems and Pregnancy Physiological Changes	A	IV	IV	A	U	L	L	L	U	U	U	M	11	60-63
Hypobaria	Decompression Sickness	E	II-III	II-III	U	U	L	L	L	U	U	U	L	12	64-71
Ergonomics	VTE Related to Limited Mobility (TTB)	E	I-III	II-III	U	U	L-M	L-M	L-M	U	U	U	L	13	72-75
	VTE Related to Limited Mobility (HPA and Trainers)	U	I-III	II-III	U	U	U	U	U	U	U	U	U	13	72-75
	Impaired G-Suit Function	A-D	IV	I-IV	U	U	L	L	L	U	U	U	L-EH	14	76-77
	Impaired Egress in an Emergency	E	I-II	N/A	E	I-II	L	L-M	H	L	M	H	N/A	15	78-83
	Altered Cockpit Dynamics	A-D	IV	II-III	N/A	N/A	L	L-M	M-H	N/A	N/A	N/A	L-EH	16	84-87
	Risk of Injury with Ejection	E	I-III	N/A	E	I-III	L	L-M	M	L	L-M	M	N/A	17	88-93
Management of High-Cognitive Demand Tasks	Sleep Disturbance	B	III-IV	I-IV	B	N/A	L-H	L-H	L-H	N/A*	N/A*	N/A*	L-EH	18 (*see note)	94-104
	Neurocognitive Impact of Pregnancy	C	III-IV	I-IV	N/A	N/A	L-H	L-H	L-H	N/A	N/A	N/A	L-H	19	105-109
Impaired Vision	Impaired Visual Acuity	C-D	IV	III	N/A	N/A	L-M	L-M	L-M	N/A	N/A	N/A	L-M	20	110-114

Assumptions:

1. Uncomplicated, singleton pregnancy

2. Risk = Probability * Severity (see AFI 90-802)

3. U = Unknown

4. N/A = Not applicable

Discussion – Chemical and Physical Hazards

- The Occupational and Environmental Health (OEH) risk assessment is based upon Table One where an increase in risk to the aviator is compared to the risk of a non-aviator worker. Therefore, exposures below an established maximum exposure limit such as a Permissible Exposure Level (OSHA PEL) or Occupational Exposure Limit (AICGH OEL) is considered low.
- Unknown Fetal risk: The basic premise taken is that if a given exposure is acceptable to pregnant non-flyer (and her fetus), the same exposure would be acceptable for a pregnant flyer (and fetus) until otherwise shown. For many exposures, Airmen are allowed to work on flight lines while pregnant; this would extend to aircrew as well.
- Ionizing Radiation:
  - The International Commission on Radiation Protection (9) recommends a pregnant woman should not receive greater than 100 mrem of ionizing radiation exposure during the entire pregnancy
  - Nuclear Regulatory Commission (NRC), 10 Code of Federal Regulations (CFR) 20.1208 “Dose equivalent to an embryo/fetus” requires licensees to maintain exposure to the fetus of an occupationally exposed mother to 500 mrem or less over the entire length of the pregnancy
  - The health risks presented in the Risk Assessment Matrix regarding ionizing radiation takes into account the average variance of cosmic radiation in terms of altitude and latitude. Using the average cosmic radiation exposure levels at differing altitudes and latitudes, the maximum time, in hours, to reach 100 mrem (medium risk) and 500 mrem (high risk) is provided.

Discussion – Chemical and Physical Hazards

- Noise:
  - Selander et. al. concluded an association between occupational noise exposure during pregnancy and hearing dysfunction in children.
  - USAFSAM Epidemiology Consult Service conducted a case-control study to compare the odds of sensorineural hearing loss and tinnitus in offspring of U.S. Air Force women who flew during pregnancy and those who did not fly; sample size was relatively low (i.e. underpowered) but was of borderline statistical significance. Study cannot comfortably rule in or rule out an auditory risk to the fetus.

- Vibration:
  - The literature regarding the adverse effects of whole body vibration (WBV) is somewhat mixed.
  - Summarizing the available data, increased risks of abortions, menstrual disturbances, and anomalies of positions can be assumed to be associated with long-term exposures to WBV.
  - A safe limit to avoid a higher risk cannot be derived from literature.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Acceleration (Unknown)
  - No studies related to human pregnancy and fetus safety while flying military aircraft, performing unique military flight maneuvers were found, nor were animal studies found.
  - Data that are readily available relate to motor vehicle accidents (MVAs), and maternofetal injury patterns in these scenarios are well-described. Of note, MVAs provide an analogue for mishap, i.e., impact acceleration in the –Gx direction, rather than sustained acceleration. Not surprisingly, placental abruption is a common complication of MVA trauma.
  - Exposure to G-forces on roller coasters is more analogous to the military aviation environment (sustained acceleration). As expected, there are no studies addressing the safety of roller coasters during pregnancy. While roller coasters are not formally addressed in obstetrics guidelines, they are generally understood to be contraindicated in pregnancy. Significantly, the G-forces experienced with roller coasters (2-2.5 G) are much lower than in the high-performance flying environment.
  - G-tolerance: It seems probable that G-tolerance would be reduced at some point in pregnancy, but more accurately stated, the synergistic effect of the substantial cardiovascular and hemodynamic changes on G-tolerance in the operational flying environment during pregnancy is unknown.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Temperature (Heat)
  - **Probability: Seldom** (heat exposures that may raise maternal core temperature to 102^{o}F or greater). **Occasional** (heat exposures that may raise maternal core temperature or provoke symptoms).
  - **Severity of Maternal Health Effect: Moderate.**
    - “Tactical” (voluntary) dehydration prior to flight is of increased concern in pregnant women; women may be more likely to intentionally dehydrate due to the unique challenges in their disposing of urine while in flight, which would be exacerbated by the urinary symptoms associated with pregnancy. Studies demonstrate that well over half of women experience urinary frequency and/or urgency at 12 weeks of pregnancy, and this finding remains stable through term., Secondly, the consequences of such dehydration may be especially dire. All factors combined, the severity of the maternal effect of heat exposure in the operational flying environment is graded at moderate.
  - **Severity of Fetal Health Effect: Moderate to Catastrophic** (fetal death, fetal developmental abnormalities).
  - Maternal core temperature is the critical factor with respect to the fetal health effect of heat stress.
  - Maternal hyperthermia is a known teratogen affecting CNS development and other structures if the exposure coincides with a developmental event in the fetus, such as neural tube closure.
  - An elevated risk of neural tube defects with maternal hyperthermia in the first trimester has been observed in both animals and humans.
  - Several other abnormalities with maternal heat exposure have also been demonstrated in animal models, including death, spontaneous abortion, microencephaly, cataract, hypoplasia of digits and oral clefts.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Cabin Altitude (without supplemental O2)
  - **Probability: Likely exposure to FL80 and FL100** (will occur frequently during flight). **Rare exposure to FL180 and FL220 without supplemental O_2** (improbable but can occur).
  - **Severity of Maternal Health Effect (FL180 and FL220): Critical to Catastrophic**
    - A study performed in women intubated for elective Caesarean section demonstrated that pregnant women become more hypoxemic with one minute of apnea than non-pregnant women, experiencing a 30% reduction in arterial oxygen tension compared to only 11% in the controls.
  - **Severity of Fetal Health Effect: Unknown.** Data are limited with regard to flight exposures.
    - Adequate fetal oxygenation requires a maternal SaO2 of > 95% [PaO2 of > 70 mmHg]. There are fetal compensatory mechanisms that allow the fetus to tolerate periods of maternal hypoxia, but the timeframe is limited.
- Cabin Altitude (with supplemental O2)
  - **Probability: Varies** by aircraft but can be expected to be **frequent** in high-performance aircraft and trainers and likely/occasional for bombers.
  - **Severity of Fetal Health Effect: Unknown.**
    - Even in the absence of maternal hypoxia, positive pressure breathing may exert an effect on the fetus. In the clinical setting, one concern with mechanical ventilation management in pregnant women is that high levels of PEEP (typically defined as >30 cmH_20) reduce venous return and can compromise uteroplacental blood flow and in turn, fetal oxygenation.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Hypobaria
  - **Severity of Fetal Health Effect: Unknown**
    - Limited data available derives from animal experiments. How these studies extrapolate to hypobaric decompression or to humans is unclear. The risk appears to be elevated, but based on the lack of human data and the differing exposures (hyper- vs hypobaria) no severity was assigned.
- Ergonomics (Risk of VTE with Limited Mobility)
  - **Probability:** The probability of VTE related to limited mobility and the flying environment in TTB aircraft (tankers, transport, bombers) is considered **rare**. The probability of VTE related to limited mobility and the flying environment in high-performance aircraft and trainers is **unknown.**
  - **Severity of Maternal Health Effect: Moderate to Catastrophic.** Most pregnancy-related VTE presents as deep vein thrombosis (DVT, which would be moderate in severity). Venous thromboembolism is one of the leading causes of maternal deaths, but this is primarily attributable to pulmonary embolism (PE) rather than DVT. PE is regarded as critical to catastrophic in severity; one study showed a case fatality rate of 2.4%. Maternal complications of anticoagulation in pregnancy include major bleeding events.
  - **Severity of Fetal Health Effect: Unknown.** High-quality data regarding antithrombotic therapy in pregnancy is limited. Known complications include fetal hemorrhage, pregnancy loss, congenital malformations, and developmental delay.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Ergonomics (Impaired G-suit Fit and Function)
  - **Probability: Increases from Seldom to Frequent as pregnancy progresses**. Both abdominal girth and weight gain would be expected to affect the fit of the G-suit, and would require resizing at regular intervals. The effectiveness of the abdominal bladder in the G-suit at later stages in pregnancy (against the gravid uterus) is unclear.
  - **Severity of Maternal Health Effect: Negligible** unless GLOC occurs due to poor G-suit function, which could be catastrophic in the event of a mishap (loss of life). Otherwise, reduced G-tolerance is unlikely to cause lasting maternal injury, nor is the discomfort of a poorly fitting G-suit.
  - **Severity of Fetal Health Effect: Varies.** The health effect on the fetus of a G-suit is potentially catastrophic if maternal GLOC occurs. This risk assessment addresses impaired G-suit fit and function. In the setting of a functioning G-suit, it is unclear if compression from the abdominal bladder poses a risk to the fetus.
  - **Severity of Mission Effect: Negligible to Catastrophic** (GLOC with loss of aircraft). Note that the health impacts to the aviator would likely only occur in the case of GLOC/ALOC.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Ergonomics (Impaired Egress in an Emergency)
  - **Probability: Rarely to Frequently.**
    - Pregnancy increases the risk of falls with even routine activity due to weight gain, joint laxity and postural instability, and 25% of women experience at least one fall at some point in pregnancy (most commonly third trimester).
  - **Severity of Maternal Health Effect: Critical** (if injury occurs) **to Catastrophic** (if timely exit is impeded leading to loss of life).
  - **Severity of Fetal Health Effect: Critical** (trauma) **to Catastrophic** (due to trauma or maternal death).
- Ergonomics (Altered Cockpit Dynamics)
  - **Probability: Negligible to Frequent**
  - **Severity of Mission Effect: Moderate to Critical** if ergonomics impact safe operation of controls, the ability to “check six,” etc.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Ergonomics (Risk of Injury with Ejection)
  - **Probability: Rarely** (ejection is improbable but possible).
  - **Severity of Maternal Health Effect: Moderate to Catastrophic.** Ejection from an aircraft is associated with a risk of trauma, even in the absence of pregnancy. In the event of injury, trauma may lead to placental abruption, uterine rupture, preterm labor, and other complications. *There are no studies on the safety of ejection in pregnancy.*
  - **Severity of Fetal Health Effect: Moderate to Catastrophic.** Same considerations as above, with the addition that trauma may also lead to fetal growth restriction and fetal death. From Rayman's *Clinical Aviation Medicine* at this point in the risk assessment: "High-performance aircraft, mainly military, routinely impose accelerative forces on aircrew. Although the physiology of acceleration and its effects on pilots is well understood, we know practically nothing about the possible effects on a fetus. Military flight surgeons would agree that such forces are often sudden, violent and frequent enough in military operations to pose an unacceptable risk to a fetus. Even though we have no empirical data to support this, and we may never have such data, such violent accelerative forces should never intentionally be imposed on a pregnant woman."

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Management of High-Demand Cognitive Tasks – Sleep Disturbance
  - **Probability: Likely**
  - **Severity of Maternal Health Effect: Varies from Negligible to Moderate.** In a 1991 study involving women in their first trimester, 90% reported fatigue, which was correlated with unrefreshed sleep. Another study found that women in the first trimester had significantly higher scores on the Numerical Rating Scale for Fatigue (NRS-F) than women who were not pregnant. During the last trimester, approximately 60% of women report being fatigued.
  - **Severity of Mission Effect: Varies from Negligible to Catastrophic.** Pilot fatigue is implicated in at least 4-8% of mishaps.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Management of High-Demand Cognitive Tasks – Neurocognitive Impact of Pregnancy
  - **Probability: Occasional.**
  - **Severity of Maternal Health Effect: Varies from Negligible to Moderate.**
    - Clinically significant but subtle changes in cognition have been found in pregnancy, particularly the third trimester. However, the aviation environment presents a high cognitive demand; subtle cognitive changes that would not otherwise be noticeable may translate to performance decrements.
    - A meta-analysis noted several significant findings: 1) general cognitive functioning, memory and executive functioning were all lower in pregnant women in their third trimester than in non-pregnant controls, 2) general cognitive functioning was lower overall, with the greatest change in the third trimester, and 3) memory performance declined between the first and second trimesters.
  - **Severity of Mission Effect: Varies from Negligible to Catastrophic.**
    - Several studies suggest that neurocognitive impacts would be most significant during the third trimester; this would imply that mission effects would be more probable in the third trimester. As noted above, this timeframe is also more likely to be complicated by sleep disturbances, significant ergonomic changes leading to discomfort and other causes of distraction.
    - However, a large population cohort study (507,262) followed women 4 years prior to pregnancy and 1 year beyond delivery. This study found that pregnant drivers had a 42% increase in rate of MVAs during the second trimester compared to baseline; specifically, the rate was highest in the early second trimester. The MVA rate returned to near-baseline by the third trimester, though it does not appear that the study controlled for frequency of driving.

Discussion – Aeromedical and Physiologic Exposures/Considerations

- Impaired Vision – Reduced Visual Acuity
  - **Probability: Seldom to Occasional.** Pregnancy is associated with a change in visual acuity in some women.
  - **Severity of Mission Effect: Moderate (degraded mission capability).** Currently, the Air Force requires that aviators who fly during pregnancy must undergo visual acuity assessment every four weeks to mitigate the risk of flying with substandard visual acuity. Some women will develop visual acuity changes between the assessments and will fly with substandard vision unless they note and report blurred vision.

Conclusions

- Limitations:
  - The literature regarding clinical findings in pregnancy and pregnancy outcomes is limited by the ethics of research involving pregnant women and the potential effects on the fetus. Much of the evidence is based on retrospective, observational, epidemiologic data rather than rigorous prospective, randomized controlled trials (the gold standard). For exposures where research to answer questions of safety is not feasible or ethical, USAFSAM recommends being very cautious about accepting the health risk of that exposure in military flying. Ejection seat efficacy and safety immediately comes to mind.
  - This analysis did not consider the clinical significance of various pregnancy complications to provide context; this could potentially be an area of future study that might better capture the magnitude of risk in some scenarios. Another limitation is that there is a substantial amount of variation between pregnancies and within an individual pregnancy over time; many of these differences will have a direct impact on whether it is safe for a specific pregnant aviator to fly.

- Conclusion:
  - This study was not intended to create a recommendation, but rather to provide an evidence-based review of available knowledge to inform policy. As such, no specific recommendation officially accompanied the review.

BACKUPS

References

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