The Risks of Diving While Pregnant

Reviewing the Research

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Should a pregnant woman scuba dive?

Whether expectant women should dive is a question that affects not only female divers but also their partners, dive buddies and dive professionals. Most divers can recall from their open water training that women are encouraged to stop diving during pregnancy, but few classes go into further detail.

What are the risks of diving while pregnant? What is it about scuba diving that is dangerous for a developing fetus? The published literature provides a foundation for the discussion.

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As with all research, there are limitations on how much the available studies can tell us. For ethical reasons, experiments with pregnant women are very limited. Most studies conducted with humans are surveys, and surveys have weaknesses, most importantly that they are not as easily controlled as laboratory research and that they can easily be biased.

A survey of female divers who had recently given birth included 69 women who had not dived during their pregnancies and 109 women who had. The nondiving women reported no birth defects, while the diving women reported an incidence of 5.5 percent.[7] To provide perspective, the survey author stated that the latter rate was within the normal range for the national population. The small sample size and the likelihood of selection bias in those responding to the survey make the results even more difficult to interpret.

While surveys can establish correlations, they cannot confirm causal relationships. In this case, they cannot confirm that diving caused a defect. To obtain such data, scientists rely on more highly controlled animal studies.

'Diving' in chambers

Hyperbaric chambers, which can simulate the increased pressure of diving, have been used to test different species of animals. Those results must then be translated to the human experience.

Many complex processes occur during pregnancy, and insults (disruptions of normal events) can lead to varied complications. Most diving-related studies have addressed the first and third trimesters of pregnancy. First trimester research has concentrated on the teratogenic, or birth-defect-causing, effects of hyperbaric oxygen (HBO). Third trimester research has examined the effects of decompression sickness (DCS) on the fetus and how diving and the fetal circulatory system interact.

TABLE 1. Depth at oxygen partial pressure limits for humans.

Breathing Gas	PO_2 Limit			
	1.4 ATA Depth		1.6 ATA Depth	
	(fsw)	(msw)	(fsw)	(msw)
100% O_2	13	4	20	6
36% Nitrox	95	29	114	35
32% Nitrox	111	34	132	40
Air (21% O_2)	187	57	218	66

A range of developmental abnormalities have been associated with hyperbaric exposure. These include low birth weights among the offspring of diving mothers[14,15,26]; fetal abortion[28]; bubbles in the amniotic fluid[13,25]; premature delivery[14]; abnormal skull development[11,15,16]; malformed limbs[11,15,16]; abnormal development of the heart[16,20]; changes in the fetal circulation[2]; limb weakness associated with decompression sickness[21]; and blindness[14].

We expose ourselves to hyperbaric oxygen – that is, oxygen concentrated by pressure – during almost all dives. A safe limit for the partial pressure of oxygen (PO_2) is frequently accepted as 1.4 to 1.6 atmospheres of absolute pressure (ATA)[19]. Table 1 shows the depth (in fsw and msw) where these PO2 levels are achieved with different breathing gas mixtures.

Rodents, which have large litters and relatively short gestational periods[12], have been used to study the effects of HBO on developing fetuses. Female hamsters experiencing untreated DCS had offspring with severe limb and skull abnormalities.[15,16] Pregnant hamsters experiencing HBO-treated decompression sickness also bore offspring with defects, though with less frequency than the untreated group[15]. Neither study reported noticeable differences in anatomical development between offspring from the nondiving control group and the group that dived without developing signs of DCS[15,16].

Fetal rat hearts have proven sensitive to multihour HBO exposure (3.0 ATA for eight hours), albeit of a magnitude in excess of what humans could tolerate. In almost half the cases, the septum, which divides the right and left sides of the heart, failed to form properly[20]. Major blood vessels were positioned incorrectly just as often, compromising normal circulatory patterns[20].

Another study of HBO-exposed rats found no significant differences between offspring from mothers that had dived and offspring from mothers that had not dived[6]. The PO_2 in this study (1.3 ATA for 70 minutes) was significantly less than that used in the previous study. The treatment difference may explain the dissimilar results.

Table 2 shows a summary of the timeline for human fetal development. It appears that hyperbaric exposure can alter the signals fetal tissues rely on to correctly orchestrate developmental processes. The nature of the abnormality is influenced by the timing of the insult. It is important to note, however, that exposure will not affect development in all instances.

Table 2. Fetal development during pregnancy (modified from WebMD[21] and The March of Dimes[16] websites)

Time Period		Fetal Development
1st Trimester	1st Month	Limb buds (arms and legs), heart, lungs, neural tube (spinal cord and brain), placenta, jaw, throat, blood cells form; heart starts beating by day [22]
	2nd Month	Ears, arms, legs, eyelids, fingers and toes grow; bone begins to replace cartilage; major organ systems are formed but still developing
	3rd Month	Fingernails, toenails, buds in mouth (future teeth), hair, ears, reproductive organs grow; circulatory and urinary systems begin to function
2nd Trimester	4th Month	Eyelids, eyebrows, eyelashes form; nervous system starts to function
	5th Month	Fingerprints and toe prints formed; muscles develop; period of rapid growth
	6th Month	Eyelids part and eyes open
3rd Trimester	7th Month	Fat deposition; fetus responds to light, sound, and pain
	8th Month	Fat deposition; rapid brain growth; lungs still maturing
	9th Month	Lungs mature, reflexes become coordinated

Decompression stress

The relative risk of decompression stress on mother and fetus is another question for consideration. Given sufficient decompression stress, blood returning to the heart from the body may contain venous gas emboli (VGE or bubbles)[23]. Sheep have been studied frequently because of the similarity between sheep- and human placentae. Fetal sheep whose mothers underwent decompression dives (following U.S. Navy dive tables) sometimes formed bubbles even when the mothers showed no signs of DCS[13,21].

When the ewes did develop signs of DCS, the fetuses demonstrated even more dramatic evidence of affliction. Researchers reported being able to tell that a fetus had bubbles by detecting early cardiac arrhythmias[21]. For the fetus, these abnormal heartbeats could be life-threatening. The offspring of some sheep that were dived late in pregnancy showed limb weakness and spinal defects associated with DCS, even when the mother had remained symptom-free[21].

Scientists have long known that so-called 'silent bubbles' – those not associated with symptoms – can develop after diving (note: Dr. Albert Behnke, a pioneer in modern diving medicine and physiology research, is credited for coining this term[4]). Fully functional lungs are extremely effective in filtering bubbles from the circulation. In the fetus, however, most blood bypasses the lungs (via the foramen ovale and ductus arteriosus shunts), and gas exchange occurs through the placenta. Thus, pulmonary filtration of bubbles does not occur within the fetus. This may increase the risk of arterial gas embolism (AGE), with potentially devastating consequences.

Fetal circulation requires further consideration. During a series of dives that exposed ewes to 100 percent oxygen at 3.0 ATA for approximately 50 minutes, researchers noticed that the circulatory shunts began to close while at depth. Flow through the foramen ovale dropped by 50 percent, and the ductus arteriosus flow fell to zero or even reversed direction[2].

Once the dives were completed, the circulation reverted to its usual form, and the researchers did not notice any negative effects from the temporary change. Whether the fetus suffered consequences that were not obvious to the researchers was unclear.

The animal study data can be compared with human experience. Premature closure of the ductus arteriosus during human pregnancy has been associated with congestive heart failure[1,3,18] and neonatal death[3,5,18]. Such closure can unintentionally be induced by prolonged use of indomethacin, a drug commonly used to halt premature labor[9]. Whether scuba diving could induce problematic closure is uncertain, but the possibility should be considered.

Practical considerations

In addition to possible risk to the fetus, changes in a woman's body during pregnancy might make diving more problematic. Swelling of the mucous membranes in the sinuses could make ear clearing difficult[8,10], and nausea may increase discomfort[10,27].

The physical aspects must also be appreciated. A woman's growing abdomen could pose a problem in fitting suits, buoyancy compensation devices, weight belts and other equipment. In addition to the hazards inherent in poorly fitted gear, diving simply may not be enjoyable.

Decisions

Sifting through the published literature reveals why there is debate over the topic. Data are limited and, in many cases, apparently inconsistent. While this makes drawing conclusions more difficult, it should not be surprising.

Science is very rarely as clear-cut as might be desired. It is difficult to design an ethical experiment that tests only the variable of interest and controls for all others. It is the researcher's job to design the best experiments possible, and it is the individual's or advocate's responsibility to examine the results and decide how to best respond to them.

The question of diving and pregnancy is a difficult one to study since the trend is for women to refrain from diving while pregnant[24]. Most physicians treat diving as they would any drug for which the evidence with respect to pregnancy is incomplete: If there is not a good reason to take it, avoid it.

Anyone who inadvertently dives while pregnant, however, may take solace in the anecdotal evidence from women reporting repeated diving during pregnancy without complication. There is certainly insufficient evidence to warrant termination of a pregnancy. Moreover, if emergency hyperbaric oxygen is required during pregnancy, for example to treat carbon monoxide poisoning, the evidence suggests that the risk to the fetus with treatment is lower than without.

The overall picture of the literature indicates that, while the effect may be small, diving during pregnancy does increase the risk to the fetus, and the consequences could be devastating to all involved. Appreciating these essential factors, the prudent course is to avoid diving while pregnant. While it is possible that some diving could be completed without impact, the absolute risk of any given exposure cannot be determined from the available data. Given the ethical challenges of research on diving during pregnancy and the fact that diving represents a completely avoidable risk for most women, it is unlikely that studies will be conducted to establish the absolute risk in the foreseeable future.

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