cannister (4 or 5 litres) should be used. The trial should last for a period of 5 hours (based on RN Table 62). It would only remain then to test the desiccant granule cannister system while a therapeutic recompression is taking place. The aim should be to develop a system that keeps the relative humidity in the main chamber at less than 75% and does not allow the PCO_2 to reach 10 millibars.

The outer chamber carbon dioxide and humidity control systems are functioning adequately and need no further testing.

The need for air saturation therapy of DCS and/or CAGE is rare. However, the oxygen make-up trial has provided information that will prove useful to the operators of the RCC at AIMS in the event that they need to make-up oxygen in the main chamber. It is important that the oxygen sampler valve be relocated to avoid the problem of a spuriously high oxygen analyser reading when adding oxygen to the main chamber. It could be relocated to an area close to the carbon dioxide scrubber outlet. This would enable the added oxygen to be distributed around the chamber more efficiently and allow a more accurate analysis of the actual chamber PO_2.

REFERENCES

1. Edmonds CW, Lowry CJ, Pennefather JW. Diving and subaquatic medicine. Second Edition. Diving Medical Centre, Sydney, Australia, 1983.

2 Gorman DF. Submarine escape training facility: Recompression chamber performance trials. Unpublished initial report, 1988.

3 Shilling CW, Carlston CB, Mathias RA, eds. The physicians guide to diving medicine. Plenum Press, New York, 1984.

4 Nunn JF. Applied respiratory physiology. Third Edition. Butterworth, London, 1987.

Andrew Peacock is a medical student at Flinders University of South Australia and Ray Palmer was the Hyperbaric Chamber Supervisor for the National Safety Council of Australia (Victorian Division), Townsville.

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WOMEN AND DIVING

Margie Cole

Introduction

Scuba diving today is a rapidly growing sport. The increase in leisure time and leisure money has seen many people take up diving as an addition to their other sporting activities. The growth in the industry in general has created a large financial interest in developing ever newer and more attractive (and more expensive) and safer diving gear. The emphasis in diving has similarly changed from spearing fish and spearfishing competitions to photography, travel and marine biology. Because of these changes women have been more inclined to join their men friends, and venture into the deep.

Although these days women like to consider themselves men's equals, there are some important differences to take into consideration when it comes to safety in diving. These medical aspects have only recently been addressed and as yet there are many unanswered questions.

Historically women have been diving for centuries. The Ama divers of Japan and Korea have been commercially involved in diving for some 2,000 years. They free dive all year round to depths of 10 to 70 feet They are mainly involved in collecting shellfish and seaweed for food and medicinal purposes. Traditionally they have been women although there have been some male divers. The reasons for the female predominance are unclear but one theory is that it was because there was a belief that diving reduced male fertility and hence the women were given the job by default1. These women are fewer in number nowadays and their profession not as highly esteemed as previously. They are obviously extremely proficient divers diving all year round in waters often as cold as 10 degrees. They free dive from small boats, often with an attendant on the surface to help pull up the diver and the catch. Traditionally they wore only cotton cloths wrapped around them or even dived naked. These days many wear wet suits. They make an interesting study when considering the effects of temperature acclimatisation and cold adaptation, as well as the long term effects of repetitive diving in these conditions.

Our society seems to have taken slightly longer to accept females in a divers' role. It only takes a quick look through old diving magazines to realise the changes that have taken place. Luckily times have changed.

With all this put in perspective I would now like to briefly discuss some of the more relevant medical aspects of women in diving.

Menstruation

The effects of menstruation on different women can vary greatly. Symptoms of menstruation can include abdominal cramps, headaches, lethargy, nausea, and backache, and there are many premenstrual symptoms including fluid retention and bloating, irritability, emotional disturbances, and decreased exercise tolerance. Long-term problems of anaemia can be caused by frequent heavy menstrual blood loss. Many women however have few if any of these symptoms and are capable of normal and above normal physical feats as evidenced by Olympic athletes competing at various stages in their menstrual cycle[2].

Just as one should not dive when unwell in any way, women should not dive when experiencing severe menstrual or pre-menstrual symptoms[2,3]. Having taken this into consideration there is still some special concerns about non-symptomatic fluid retention occurring pre-menstrually. The extra fluid may impair blood flow and reduce inert gas elimination from fatty tissue. Thereby increasing susceptibility to decompression sickness (DCS)[3]. There are no studies which show these effects either way, but perhaps a conservative approach to the dive tables around period time would be wise.

Today many of the nuisance symptoms of pre-menstrual tension (PMT) and menstruation can be effectively controlled with appropriate medical management. Certainly general measures including maintenance of general fitness and good health, weight control and a balanced diet go a long way minimising these problems.

It seems from my reading that there is a big concern among women about shark attacks if they dive during their periods[3]. It is reassuring to find that there is absolutely no evidence to suggest that there is any increased danger whatsoever and therefore should not deter any keen female diver who is otherwise well.

The Oral Contraceptive Pill

"The Pill" is by far the most popular form of contraception in Australia. Australia in fact has the highest proportionate use of the oral contraceptive pill over all other forms of contraception world-wide. Australians seem to be a nation of pill poppers! So far there is no data on the effects of the contraceptive pill and diving, in particular the effects on susceptibility to DCS. There certainly are some fairly valid theoretical concerns, however.

It is known that women who take the pill have an increased clotting tendency in their blood, particularly if they are also smokers. It is now well documented that many dives within the no-decompression limits of the dive tables can produce 'silent bubbles'. These are bubbles which form in the circulation which cause no demonstrable symptoms but which can be detected using an ultra-sound echo device called a Doppler monitor. These bubbles are found in the venous circulation and are thought not to produce any symptoms because they are quickly filtered out in the lungs or the liver. The surfaces of bubbles are known to stimulate clotting mechanisms in the blood. A significant feature of decompression sickness is the effects of blockages in the vessels caused by a combination of bubbles and clots. Hence an initially small and decreasing obstruction can be transformed into a more significant one[1].

If the effects of the pill increase this clotting tendency then one can assume that the end result of silent or symtomatic bubbles would be that much more serious. This effect would b e even more pronounced in the female pill taking diver who smokes and who dives closer to the 'safe' no-decompression limits[4].

Other theoretical risk factors from the pill include other side effects, namely fluid retention, nausea, headaches and cramping. All of these are amenable to treatment[5].

Diving and Pregnancy

Having stopped our contraceptive pill because of the worry of DCS, we then may face the problems of diving in pregnancy. These risks must be viewed from two aspects. Firstly the risk to the pregnant mother, risks of DCS, trauma, fatigue, hypothermia because of poor wet-suit fit and drowning. Secondly the risks to the developing fetus from DCS, the toxic effects of increased partial pressures of gases, hypothermia, hyperthermia, and hypoxia from near drowning.

Statistical data for humans is very much lacking. Studies done have been in the form of retrospective questionnaires where females who dived during pregnancy wrote in detailing obstetric complications and fetal abnormalities.

Susan Bangassar in 1977[4] looked at a group of women of which 72 dived during pregnancy out of a total of 680 respondents. These dives included 5 decompression dives. All the babies born were normal, but there was a small incidence of complications of pregnancy; 1 premature birth; 1 septic abortion; 2 miscarriages and 2 caesarian sections. Overall not a significant increase over the general pregnant population.

In 1980 Margie Bolton[5] looked at 208 female respondents and a subgroup of 178, 109 of whom had dived during pregnancy, compared to 69 who did not. The average depth of the dives was 42 feet 20 women dived to 99 feet during the first trimester. There was a significantly higher incidence of spontaneous abortion, low birth weight, birth defects and respiratory difficulty. However the overall percentages again were still within the normal limits for the population at large.

One must accept the problems and limitations of questionnaire type surveys in that one is relying on individuals responding with accurate information.

The other source of data is from experimental studies on animals. As it is unlikely that there will ever be similar studies on humans, we must accept the limitations of species differences in both susceptibility to DCS and in differences in fetal and placental function.

In 1968 McIver[6] experienced with pregnant dogs, subjecting them to 165 foot chamber dives for 30 minutes. This produced marked intravascular bubbling in all the mothers but only 2 of the 94 fetuses showed bubbling. Interestingly the amniotic fluid surrounding the fetuses contained numerous large bubbles.

In 1974 Chen (quoted by Fife[7]) repeated the study using pregnant rats exposing them to 247 foot dives for 30 minutes. No fetuses had any bubbles despite the mothers dying of massive bubbling.

In 1978 Fife et al.[8] experimented with 7 pregnant sheep. Using an implanted ultrasonic flow meter around the umbilical artery of the fetus and another around the maternal jugular vein he exposed them to 140 foot dives. All the fetuses had DCS but no bubbles were detected in the mothers, the opposite of previous observations.

In 1980 Stocke et al.[9] repeated these last experiments and found that in fact the bubbles in the fetus were probably artifactual, caused by the surgical implants. They chamber dived both surgically monitored and non-monitored fetuses and found that fetuses which had not been operated upon did not have detectable DCS.

More recent studies on pregnant hampsters (Gilman et al.[10,11]) subjected to decompression and non-decompression dives in early pregnancy, revealed low birth weights in those subjected to decompression dives. Marked teratogenic effects were seen in the fetuses born to mothers who suffered DCS and survived to term. Fetuses born to mothers who suffered DCS and who were treated showed no statistical difference in fetal outcome from controls.

Thus it may seem from these experimental studies that the fetus is less likely than the mother to develop bubbles. However we must consider the effects of even very small bubbles on the fetus. Firstly size is important. The dimensions of important fetal vessels, for example the main arteries to the brain, kidneys, etc. could be obstructed by a bubble so small that in the mother would cause no detectable problem. The fetal circulation largely bypasses the lungs which would venous bubbles to bypass the lung filter and become an arterial embolus[12]. Again causing a much more serious problem than a similar bubble presenting in the mother.

The developing fetus is dependent on a regular supply of oxygen for normal growth and development. It may therefore suffer if the mother suffers hypoxic episodes from near drowning or aspiration.

As well as the risk of DCS, the toxic effects of raised partial pressures of gases on the fetus must be considered. We know that premature babies breathing 100% O_2 can suffer from retinal damage and blindness. Hence it is likely that the unborn fetus may suffer the same consequences of raised O_2 tensions caused by deep dives. High oxygen tensions are also thought to predispose to birth defects and fetal death in early gestation, and cause problems in late gestation of closure of the ductus arteriosus and possible prematurity[13].

These high partial pressures of oxygen are a consideration in normal deep air diving as well as in the recompression chamber if the mother needs therapeutic recompression.

The pregnant woman herself may be more at risk of developing DCS by virtue of the changes that occur with pregnancy. Increased fluid retention and increased body fat stores will allow for more nitrogen retention. Other problems such as nausea, vomiting, backache, headache, fatigue clumsiness and physical discomfort due to size, make diving more uncomfortable as well as more dangerous, increasing the risk of drowning or near drowning and subsequent hypoxia to herself and her baby.

So what then is the recommended safe diving limits for the pregnant diver? There are many different opinions on this, varying from limiting the dive to 9 m, to 18 m, to 27 m. Diving only in warm, calm, protected waters and avoidance of decompression dives have all been advised. I feel that until more is known for sure, the best solution is no diving at all. It is really a small price to pay for a healthy mother and baby at the end of the 9 months.

Susceptibility to Decompression Sickness

There is very little comparative data comparing the rate of DCS between the sexes. Men predominate on a numerical count but this is biased as there are more men actively diving. Most of the studies done have been from Air Force statistics looking at exposure to reduced barometric pressure in their trainees and some small studies from naval divers of which there is a very small percentage of females. Other statistics come from questionnaire type studies of active sport divers.

Before looking at the statistical data, we should examine the physiological and anatomical differences between the sexes which would theoretically place women at an increased risk of developing DCS. These factors are firstly an increased proportion of and different distribution of body fat, fluid shifts and fluid retention related to hormonal changes with menstruation and the contraceptive pill. Other perhaps more hypothetical differences may be an increased female tendency to vasospastic phenomena such as migraine and Raynaud's phenomenon. There may be an increased clotting tendency irrespective of the contraceptive pill as well as differences in blood flow through adipose tissue which may impede inert gas transfer. All of these create a theoretical increase in the likelihood of developing DCS. So far no statistical analysis has been made of divers requiring recompression for DCS which would help to answer these questions[3,4].

Data that is available does suggest that women are more susceptible. During the 12 year period from 1966 to 1977 a study from the US Air Force's altitude chamber indoctrination program recorded 104 individuals treated by recompression for altitude DCS. Although DCS from diving is not exactly the same the problems are similar enough to warrant looking at the data. It was found that the incidence of DCS for men was 0.09% and for women was 0.36%, that is a four fold increase in incidence. Comparing individual factors it was found (not surprisingly) that women were smaller in height, weight, and body build. One would expect these factors to be advantageous. Significantly there were a larger number of women who reported a history of vascular or migraine headaches and previous altitude reaction. Women in this study had actually attained a lower maximum exposure altitude. This also supports a finding of greater susceptibility to DCS. Case data showed that significantly more women had the onset of bends pains at altitude, i.e. earlier than men, and had more skin manifestations. Other differences noted, though not statistically significant, were that during treatment women had more relapses and required retreatment more often[3,4].

In contrast a recent study of naval divers demonstrated no increased risk compared to their male counterparts. This study from the Naval Diving and Salvage Training Centre in Florida reported in 1987 statistics comparing 28 female student divers with 487 male counterparts on 878 air and helium-oxygen dives between 120 and 300 feet with bottom times of less than 20 minutes. None of the women developed DCS while 8 men did[14].

There have, however, been naval women who have sustained diving related DCS on long-duration, experimental or saturation dive profiles. It may be that long-duration, saturation or multiple repetitive dives pose an increased risk for women whereas shorter, more typical sport dives increased risk for women whereas shorter, more typical sport dives are no more dangerous than for men[14]. Possibly this is due to the extra adipose tissue which women have, on average about 10% more, creating a capability of absorbing more inert gas. Fat tissue being capable of holding 5 times the amount of nitrogen compared to blood.

The only study in sports diving women to data was one published in 1979 by Sussan Bangassar[4]. She performed a retrospective questionnaire type survey of 649 female divers and looked at a sub-group of women instructors comparing them to a group of male instructors, all having performed a similar number of dives. She found a 0.023% incidence of DCS in the female group compared to 0.007% incidence for the males. That is it showed a 3.3 times greater incidence of DCS in women diver instructors than in men. These results however need to be looked at objectively as they are based on reported incidents rather than medically documented sickness, as well as the fact that any diver who was very seriously injured and left the sport or who actually died, did not answer the questionnaire. There is certainly room for someone to repeat this type of survey with better controls and perspective.

Physical Differences

The obvious differences in size, stature and strength in practical terms often cause no difficulties for the female diver. A fit female may in fact be better equipped to handle strenuous swimming and carrying of heavy dive gear than an unfit male. Pure physical strength and size however could play an important role when attempting to perform a rescue which involves hauling a drowning body from the water, either over the rocks or over the side of the boat.

Small size has advantages of small lung volumes and hence lesser air consumption, allowing a smaller tank size for the same dive. Women also tend to be more flexible and agile and often have an increased natural buoyancy.

There are differences in thermal balance. Firstly women have on average about 10% more body fat, most of this distributed just under the skin. This acts to retain body heat by creating more insulation. A second important factor in heat regulation is the ratio of surface area to body mass. Women who are lean, i.e. having less than 27% body fat, tend to lose heat more quickly than men of comparable fatness. This is due to the larger surface area to mass ratio. Body fatness levels above 30% body fat give men and women an equal heat loss[1,14,15].

Acclimatisation seems to be a third important factor. It seems that exposure to cold environments frequently may cause changes to the body's metabolism. The female Ama divers of Japan have been studied with regard to this and it has been found that their metabolic rates increase by up to 30% to compensate for the extra heat loss during long days of diving during the winter. In our community, men may therefore have an advantage since they tend to participate in water sports all year round and may well develop this adaptation.

For the average sports diver today, however, a well fitting wet-suit or dry suit can compensate for many physical differences and the problem of thermal regulation variations is not so great.

At the other end of the scale it should be noted that there are sex differences with regard to hyperthermia. Women are more susceptible to overheating due to a few factors. Firstly on average women begin to sweat at 2 to 3 degrees higher temperature than men. Also they have a smaller number of functional sweat glands in total. Thus females may tend to overheat when exercising or gearing up in the sun on a hot day and should perhaps take measures to cool off when sitting geared up in a wet suit[1].

Conclusions

In summary it would seem that although women can and do participate in the sport of scuba diving to the same extent as men, there are a few areas in which women need to exercise thought, commonsense and caution in order to maintain an acceptable degree of diving safety.

REFERENCES

1 Edmonds C, Lowry C.J and Pennefather J. Diving and subaquatic medicine. Sydney: Diving Medical Centre, 1983.

2 Bangassar S. Physiological concerns of women scuba divers. Proceedings of the tenth annual international conference on underwater education. NAUI, 1978.

3 Bassett B. Safe diving equals fun diving: Prescriptions for diving women. *SPUMS J* 1979; 9: (Jan-March) 9-14.

4 Bangassar S. Incidence of decompression sickness in women scuba divers. *Undersea Biomed Res* 1979; 6: (2)(Supplement).

5 Bolton M.E. Scuba diving and fetal well being. A survey of 208 women. *Undersea Biomed Res* 1980; 7: (3) 183-189.

6 McIver R.G. Bends resistance in the fetus. Ann Sci Meeting Aerospace Med Assoc. Washington: Aerospace Med Assoc, 1968.

7 Fife W. Effects of diving on Pregnancy. 19th UMS Workshop. Bethesda: Undersea Med Soc, 1978.

8 Fife W, Simmang C and Kitzman J.V. Susceptibility of fetal sheep to acute decompression sickness. *Undersea Biomed Res* 1978; 5: 287-292.

9 Stock et al. Responses of fetal sheep to simulated no decompression dives. American Physiological Society Jan 1980

10 Gilman S.C, Green K.M, Bradley M.E and Biersner R.J. Fetal development; effects of simulated diving and hyperbaric oxygen treatment. *Undersea Biomed Res* 1982; 9: (4) 297-304.

11 Gilman S.C, Bradley M.E, Green K.M and Fischer G.J. Fetal development: Effects of decompression sickness and treatment. *Aviat Space Environ Med* 1983; 54: (11) 1040-1042.

12 Assali et al. Effects of hyperbaric oxygen on utero-placental and fetal circulation. *Circulation Res* 22: 573-588.

13 Bolton M.E. The diving habits and obstetric course of pregnant scuba divers. *SPUMS J* 1979; 9: (Oct-Dec) 24-25.

14 Zwingleberg K.M, Knight M.A and Biles J.B. Decompression sickness in women divers. *Undersea Biomed Res* 1987; 14 : (4) 311-317.

15 Nunnerley S.A. Heat,cold, hard work and the woman diver. Women in Diving: 35th UHMS Workshop. Bethesda: Undersea and Hyperbaric Med Soc, 1986.

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Dr Margie Cole's address is 168 Bennett Road, St Clair, New South Wales 2760, Australia.

THE DRUG-AFFECTED DIVER

Ian Unsworth.

The drug-affected diver is not something which has been considered very much. I am going to discuss two aspects. Initially illicit drugs, Table 1, because drugs of that sort are a fact of today, and secondly I will mention drugs we tend to call "medications", just to remind us that many medications prescribed by practitioners and self-prescribed by divers indeed do affect the diver's ability to work or perform or just to be safe underwater.

Illicit drugs

Illicit drugs are a fact of today and it is going to be very difficult to act in this area as far as divers are concerned. I believe there are three reasons, why divers, both sport and commercial, might take drugs illicit soft drugs and hard drugs in combination with diving or going under pressure.

TABLE ONE

ILLICIT DRUGS

Cannabis (Marihuana)
Cocaine
Heroin
Amphetamines
Barbiturates
Angel Dust

One is a deliberate attempt to enhance psychiatric (yes, it is psychiatric) pleasure of drugs. This would apply to sport divers. Then, commercial divers misguidedly use illegal or illicit drugs as an attempt to enhance their underwater performance, and thirdly perhaps there is a certain ignorance among divers, both commercial and sport, that there is an additive affect of diving on a wide range of medications.

I think we should consider primarily the recreational use of these drugs. The true addict does not occur in either sport or commercial diving. By the true addict I mean someone who is so 'hooked' on agents like heroin that he is not going to spend his money getting a fill for an air tank, he is not going to spend his money on buying diving equipment or taking a charter boat out, he wants all his available cash to supply his habit. I think there are very, very, very, few genuine hard addicts in diving. I do not think it is possible for them to exist.

But the recreational use of drugs is, I think, very important and is very dangerous. Heroin is not commonly considered a recreational drug. They are first of all the