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Key Words

Decompression illness, treatment sequelae, fitness to dive.

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WOMEN IN DIVING

Robyn Walker

Abstract

The issue of female fitness to dive is really no different from male fitness and both genders should be assessed on an individual basis. The physiological features exclusive to women which have an influence on diving fitness are few. A literature review covering these topics is presented.

Introduction

Female divers are no longer considered a rarity and the image of scuba diving being a male dominated sport is long past. Previously much has been written on the topic of female divers, as if the very presence of oestrogen imparts an ominous prognosis. However, the issue of female fitness to dive is really no different from male fitness and both genders should be assessed on an individual basis. The physiological features exclusive to women which have an influence on diving fitness are few and a literature review covering these topics is presented.

Performance

Females typically have a lower threshold for peak sports performance than males and generally can produce less power, speed and have lower work capacity and stamina. As a consequence a female can not generally achieve a maximal oxygen consumption per kilogram equivalent to a male.¹

Females possess a higher percentage of body fat which persists despite training. A 20 year old sedentary female has approximately 25% fat, a trained female 10-15% fat and a trained male 7-10% fat. Trained males have relatively more muscle(40% of total body mass) while comparatively fit women have only 23% muscle.¹

Thermal Stress

Females are able to conserve energy more efficiently than males. Their increased body fat provides better insulation from heat loss as well as increased buoyancy. Females have fewer sweat glands and sweating begins at a higher core temperature, so conserving heat. However, this increases a female's susceptibility to over heating when sitting, fully kitted up, in the sun.

Females have a lower basal metabolic rate (BMR). Overall, women are more susceptible to heat loss than men

due to an increased conductive heat loss due to their slightly higher surface area to volume ratio, their smaller muscle mass and thus less metabolically active tissue to generate heat during activity.¹ The Korean Ama (female free divers) adapted to their environment, with water temperatures as low as 10°C, and were found to have a higher BMR, higher shivering threshold, greater skin fold thickness, greater peripheral vasoconstriction and the ability to tolerate a lower rectal temperature than females from the same village who did not dive. It is noteworthy that since the introduction of wetsuits in 1976 these adaptations have been lost.²

Effect of physiological differences

The effect of these physiological differences on female recreational divers is small. Recreational divers are rarely required to sustain maximal aerobic endurance for prolonged periods. Both male and female divers should learn to dive well within their own physical limitations. Even if females are more susceptible to hypothermia proper equipment should ameliorate this disadvantage.

Decompression Illness

There has been a common perception that women have an increased susceptibility to decompression illness (DCI), perhaps due to their increased body fat percentage, however, reputable studies in this area are lacking.

Bassett³ looked at the incidence of altitude DCI in the United States Air Force from 1966-1977. Of these 104 cases, 32 (31%) occurred in women. Statistically significant differences were found between males and females with DCI in weight, height and body build. A larger number of women reported a history of vascular or migraine headaches, more females experienced the onset of bends at altitude and females experienced more cutaneous manifestations than males. The author concluded females were four times more susceptible to altitude DCI than males, have more cutaneous symptoms, have more rapid onset of bends pain and have more recurrences and more lasting effects of DCI compared to males exposed to the same altitude exposure. The application of these results to hyperbaric exposures is uncertain as diving and altitude exposures result in different inert gas saturation profiles.

Bangasser⁴ conducted a retrospective study of 649 female divers by questionnaire. The reported incidence of DCI in female instructors was compared with male instructors and the findings are presented in Table 1.

These results suggested a 3.3 fold greater incidence of DCI in females. However, there are several major weaknesses in this study; the study is retrospective and

TABLE 1
REPORTED DCI IN INSTRUCTORS

	Number of dives	Cases of DCI (suspected or confirmed)	Incidence
Females	44,154	10	0.023%
Males	43,126	3	0.007%

From Bangasser.⁴

therefore not all conditions are known, cases with insufficient data may not have been fully scrutinised, no criteria existed to determine if DCI actually occurred and the diagnostic evaluations were based solely on the respondents' replies. It is highly unlikely that divers incapacitated by accidents or those suffering from fatalities were accounted for and later studies have also shown that if males and females are of comparable fitness the differences in rates of DCI disappears.

Zwingleberg et al.⁵ compared females with males in a review of the incidence of DCI in deep diving at the Naval Diving and Salvage Training Centre (NDSTC). Deep diving was defined as 38 -86 m (125-285 ft) on air and 36-90 m (120-300 ft) on heliox. Bottom times were mostly less than 20 minutes with dive duration ranging from 8 minutes-2 hours 6 minutes. The study was in two parts, the first comparing females to males in a general review of DCI incidence on deep dives, and a second female-male buddy matched analysis on deep dives involving females.

Twenty nine female divers took part. No female divers developed DCI while 8 male divers did, 4 on air and 4 on heliox. Three of the cases were classified as Type I DCI and 5 as Type II. The overall incidence of DCI for male deep dives was 1% (1.91% for heliox and 0.6% for air). For the male-female matched pairs there was a 1.3% increased risk for DCI in males. The authors concluded women divers are at no greater risk of developing DCI under similar bounce dive exposures but caution against the extrapolation of these results to all dive exposures. United States Navy female divers have sustained DCI on long duration, experimental or saturation dive profiles as have males. In the NDSTC study dives the exposures were of short duration with only short half-time compartments becoming supersaturated. The authors concluded these results can be applied to sports diving models. Saturation and experimental dives may well be different as the "slow" compartments will have the major influence on decompression rates and the higher body fat percentage in females may well increase the risk.

DCI has been associated with altered clotting activity, specifically increased platelet aggregation.⁶ Markham et al.⁷ studied the behaviour of washed platelets during different phases of the menstrual cycle and the differences in aggregation of male and female washed platelets in response to decompression stress and arachidonic acid. Their study did not support the possibility that platelets aggregate differently during the menstrual cycle, however, it did support the existence of a sex difference in platelet aggregation that is not altered by external factors, e.g. decompression stress. Females compared to men do have increased sensitivity of platelets to aggregation. The importance of this increased sensitivity to the development of DCI in females is unknown.

No evidence exists in the literature of a difference in susceptibility to pulmonary barotrauma or cerebral arterial gas embolism between the sexes and the incidence of patent foramen ovale is equal in both.

Menstrual Cycle

For most healthy active women, changes associated with their menstrual cycle are negligible and cause minimal interruption to their lives. Severe "premenstrual syndrome" if disabling, may disqualify a woman from diving for this part of their cycle, however, this occurs in only a minority of females.

Brown⁸ compiled a small survey on female divers "The Michigan Sea Grant Survey" and found that 89.9% of females dive whilst menstruating without any physical or psychological problems. Of those who did not dive 4.8% were menopausal or had not had the opportunity to dive whilst menstruating.

Rudge⁹ examined the role of menstrual history in the development of altitude chamber decompression sickness (DCS) in USAF female personnel undertaking hypobaric exposures. Records were available for 81 personnel. This study demonstrated a clear correlation between the incidence of DCS and time since start of the last menstrual period. A higher number of subjects developed DCS (both type I and type II) earlier in the menstrual cycle (0-4 days). He concluded women were at higher risk of developing altitude DCS during menses, with the risk decreasing linearly as the time since the last menstrual period increases. This study did not address likely mechanisms for the findings and its application to female divers is unknown.

Oral contraceptive pills (OCP) are known to be associated with an increased risk of thromboembolism as they accelerate blood clotting, increase platelet aggregation and are associated with an increased blood concentration of some clotting factors.¹⁰ There is, however, no evidence to suggest that OCPs alter a female's

susceptibility to DCI and the risk of becoming pregnant is of far greater concern.

There is no evidence to suggest menstrual flow attracts sharks and no evidence of increased shark attacks on menstruating divers.

Pregnancy

Diving during pregnancy is a controversial subject. Questions such as, "Does diving increase the risk of foetal abnormality?", and, "What is the incidence of foetal DCI?" remain unanswered.

Bolton¹¹ surveyed 208 female divers of whom 136 had dived during pregnancy. The average depth of the dive was 13 m (42.6 ft), Twenty four had dived to 30 m (99 ft) during the first trimester. The frequency of birth defects was significantly greater in pregnancies during which females dived but this was still within the range of the normal population.

Fife et al.¹² inserted a Doppler probe around the umbilical vessel in near-term foetal sheep. Compression and decompression produced marked evidence of foetal bubbling while no evidence of DCI was noted in the mother. They concluded that bubbles were much more likely to form in the foetus than the mother. Other researchers initially confirmed these findings, however, once control experiments were performed, it became obvious that bubbling only occurred in the instrumented animals. Current opinion is that bubbles are less likely to form in the foetus than the mother. If the mother does develop DCI, bubbling in the foetus may occur. Bubbles in the foetus are likely to be more ominous than in the mother due to the differences in foetal anatomy and physiology. The lungs in an adult act as an effective bubble filter whilst in the foetus most of the blood bypasses the lungs by passing through the ductus arteriosus and patent foramen ovale. Therefore any bubble in the foetus may pass directly to the cerebral circulation as a cerebral arterial gas embolism.

Animal studies have shown an increased rate of foetal loss when the mother is exposed to a decompression insult.¹³ The impression is the closer to term the higher the risk.

There are no reports in the diving literature of air embolism affecting a pregnant diver. Taylor¹ reported 15 cases, in the obstetric literature, of air embolism from sexual encounters, all occurring in young women in their second or third trimester where air was forcibly blown into the vagina. In 12 of the 15 cases there was maternal and foetal death. One patient was treated with hyperbaric oxygen for 39 hours with resultant moderate neurological defects in the mother and a stillborn infant. The conclusion was air embolism of the uteroplacental bed appears lethal.

Other points for the pregnant potential diver to consider are the effects of morning sickness and pregnancy induced gastro-oesophageal reflux, both of which are associated with an increased risk of vomiting underwater.

The fit and function of dive equipment may be compromised as the pregnancy progresses. Where does a woman secure her weight belt?

Uterine blood flow may be compromised during periods of increased demand and increased sympathetic activity, both of which occur during diving. Erratic abrupt shifts in flow dynamics are more likely to compromise uterine blood flow than a gradual increase or sustained aerobic activity. Marine envenomation carries undefined foetal toxic effects and specific antitoxins may also hold risks for the foetus.

Foetal risks of hyperbaric oxygen

A potential problem for the foetus is oxygen toxicity. Diving on compressed air exposes the foetus to an increased partial pressure of oxygen and the mainstay of treatment regimes for diving accidents is recompression on 100% oxygen. In the foetus, ductus arteriosus blood flow decreases dramatically when the oxygen tension in the pulmonary circulation increases. The foetal pulmonary bed is exquisitely sensitive to oxygen tension and responds with vasodilatation when the oxygen tension rises. There is consequently a shift from a foetal to a neonatal blood flow pattern.¹ This shift will reverse when the oxygen tension falls but it is unknown whether this has long term sequelae for the foetus. Therefore, even though pregnancy does not clearly increase the maternal incidence of DCI, the foetus may be at severe risk if a diving accident occurs.

Post-partum

There are no contraindications to women diving while breast feeding, however it is generally recommended that women do not dive until six weeks post partum to avoid intrauterine infection.

Mammary implants.

Vann et al.¹⁴ exposed mammary implants to various simulated dive profiles followed by altitude exposures to simulate aircraft travel. The implants were observed for bubble formation and volume changes. Minimal volume changes occurred after each dive although numerous bubbles formed reaching their maximal size in 3 hours. When the implants were exposed to high altitude following a dive significant volume changes occurred. The volume changes were least for saline and greatest for gel saline implants. The authors concluded that bubble

formation in breast implants might occur after shallow saturation diving but it is unlikely to result in tissue damage. However, in the unlikely event of prolonged deep saturation diving followed immediately by flying in an unpressurised aircraft at 9,100 m (30,000 ft) the resultant bubble formation might be of sufficient magnitude for tissue trauma to occur!

Summary

The assessment of fitness to dive of a fit non-pregnant female is identical to that of a fit non-pregnant male. The true risk of diving while pregnant, for both the mother and foetus, is unknown. All women divers should be advised of the potential risks of diving when pregnant. Most women will probably accept pregnancy as a 9 month self limiting condition and elect not to dive along with reducing their alcohol intake and medication usage.

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Key Words

Women, fitness to dive, physiology, decompression illness.

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