

## Diving Medicine Online



# Exercise, Diving and the Heart

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## Work and Exercise

Diving can effect the heart and blood vessels mainly by the amount of exercise involved. Exercise produces a need for increased oxygen to produce increased activity, and the heart and circulation are affected in some way by any form of exercise. In diving, the circulatory system is affected by several forces acting on the heart and blood vessels. Some of these are:

- changes in pressure, secondary to breathing a high density gas mixture which increases the pressures in the heart (afterload).
- A high oxygen concentration (hyperoxia) can slow the heart rate, a commonly observed phenomenon.
- An increase in hydrostatic pressure can alter electrical conduction in the heart.(excitability and conduction speed)
- During decompression, bubbles (gaseous pulmonary embolism) may increase right heart pressures and cause a paradoxical embolism in patients with a right-to-left shunt (patent foramen ovale).
- Immersion, (getting into the water to the neck), increases the blood flowing into the heart (preload).
- Hypothermia also plays a role causing vasoconstriction (afterload), slowing the heart rate. These factors may disturb cardiac function and expose patients with heart disease to accidents during underwater diving.

## Exercise Causes an immediate response

Exercise generally causes an immediate response in the cardiovascular system. This response includes local blood flow changes which then cause reflexes that then cause an increased cardiac output (how much blood the heart is pumping out). From the cardiovascular standpoint, exercise is any activity that raises the resting oxygen consumption above basal levels. Thus swimming, walking with heavy gear, climbing ladders and performing heavy labor relating to diving are all sensed by the heart and cardiovascular system as forms of exercise and require an increased output.

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## Functional reserve

The normal heart has a backup reserve and the heart at rest is working at a small percentage of its maximal capacity. Measurement of how hard the heart can perform may be necessary to find out if there are any limitations due to heart disease. A reduction in the ability of the heart to pump enough blood to meet maximal needs can go undetected unless it is tested and found to be diminished.

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## Exercise Stress Testing

**Exercise stress testing** is used to measure cardiovascular reserve when assessing the heart. Used mainly to detect coronary disease, its application in testing for cardiac reserve in divers is also important and useful. A diver should be able to exercise on the treadmill without chest pain, severe shortness of breath, or blood pressure changes.

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## Radionuclide Studies

The physical stress imposed by diving can be simulated by the use of radionuclide (isotopes) standard clinical tests and an assessment of capability to dive can be made from the results.

In dealing with patients with heart disease, it is important to understand the relationships among external physical work, myocardial oxygen consumption, and blood flow to the myocardium. Understanding these relationships will provide the basis for assessing the performance of an individual with heart disease, and determining their ability to dive.

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## Cardiac Work, Oxygen Consumption, and Blood Flow

### Increased Heart Muscle Blood Flow

As the work demands of the heart increase the heart does not greatly increase its extraction of oxygen. Usually only a small increase in oxygen extraction occurs (e.g., an increase of 2 ml of oxygen per 100 ml of blood from a baseline of 10) whereas **large increases in myocardial blood flow provide the increased oxygen needs** when myocardial work load increases.

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Why is hypertension so damaging to the heart muscle?

Increased cardiac work arises from increases in arterial pressure with little change in the amount of blood flow passing through the heart (pressure work), or by increases in blood flow with almost constant pressure (volume work) (Wiggers and Sarnoff). It is possible to experience diving environments which produce either primarily pressure work on the heart or- primarily volume work on the heart. For example, isometric work associated with heavy lifting raises the arterial blood pressure and causes an increase pressure load on the heart, whereas the work associated with swimming causes an increase flow demand on the heart and results in a volume load. The studies of Samoff et al demonstrated that a **pressure work load is more demanding in terms of myocardial oxygen consumption than an equivalent volume load. It is important to remember this difference when considering the diver with hypertension.**

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## Coronary Artery Disease

Other studies have shown that the heart muscle depends on increasing blood flow to supply oxygen demands: when flow restrictions occur due to narrowed arteries to the

heart, the muscle cannot obtain adequate oxygen by increasing oxygen extraction, and oxygen deficits occur during exercise. Chronic pressure or volume overload-induced muscle enlargement of the heart, decreased blood flow in the heart arteries (coronaries), and congenital heart disease (valvular and septal defects) all may affect myocardial oxygen consumption, myocardial blood flow, and blood flow distribution to the myocardium. Better understanding of these blood flow principles will aid significantly in assessing the diver with heart disease.

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## Physical Fitness

Divers need to obtain a physical fitness that allows maximum oxygen consumption. This is the ability to do work, such as swimming a reasonable distance with diving gear without getting too short of breath, and be able to help a partner who has been injured or requires assistance to return to the boat. **One way of adjusting to the fitness needs of diving is to carefully plan your dives, avoiding situations requiring excess physical exertion above and beyond your physical capacities. This works well for the elderly diver or the diver who has physical incapacities. The best way is to exercise regularly.**

For diving fitness, a moderate exercise program that can be done 4-5 days a week is adequate for the casual diver. Swimming is the best exercise for diving, but jogging, walking, biking or rowing should do the same thing---increase your pulse rate, breathing rate and oxygen intake. Conditioning improves the maximum oxygen intake. You should establish a **target heart rate**, which can be determined by the formula:

$$\text{Target Heart Rate} = (220 \text{ minus age}) \times .70$$

When you exercise you should aim for a pulse rate derived from this formula with a five minute warm-up, the 30 minutes of keeping your pulse rate at the target, followed by 5 minutes of cool down. If you are over 35 years of age you should get a medical examination before beginning the exercise program; this should include an Exercise Stress Test. Once started, you should take 2-3 months to build up to your **target**, then take 40 minutes 5 days a week to maintain yourself at your target level.

### References:

1. Medical Seminars Lectures
  2. Diving Medicine, Alfred A. Bove, MD, PhD
  3. Diving and Subaquatic Medicine, Edmonds, Lowry and Pennefeather.
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