

# Obesity and diving

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## Key words

Obesity, decompression sickness, medical conditions and problems, health status, review article

## Abstract

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Obesity has long been accepted as one of the many risk factors for developing decompression sickness (DCS) when diving. Whilst body fat is a great heat insulator, there are a number of disadvantages to an obese person diving. These disadvantages range from the physical restriction of wetsuits, to concurrent medical pathologies and the higher demands on the cardiovascular and pulmonary systems whilst swimming. The high solubility of nitrogen in lipids and fats results in 5.4 times as much storage of nitrogen in fat as muscle tissue. This increases supersaturation of fat with nitrogen and significantly increases the risk of developing DCS. Whereas, historically, dive medicals precluded obese people from diving, a review of the literature would suggest that a sensible approach to diving and the medical examination can minimise risks of DCS to the obese patient.

## Introduction

Decompression sickness (DCS) is a disease that arises as a consequence of bubbles forming within tissues.<sup>1,2</sup> Inert gases, such as nitrogen and helium, enter the body through the lungs during inspiration. At depth, and therefore under pressure, gas dissolves in the blood and is carried to the tissues into which it diffuses.<sup>3</sup> The process is repeated in reverse as gas is transported back to the lungs for exhalation.<sup>4</sup> It is widely held that when a state of supersaturation occurs during decompression, the tension of dissolved gas exceeds ambient pressure, and bubbles form.<sup>1,2</sup> In 1880 Paul Bert found that the DCS bubbles are composed almost completely of nitrogen and a small amount of water vapour.<sup>5</sup> The amount of nitrogen it takes to saturate a diver will depend on the diving depth and individual characteristics of size and body composition.<sup>2</sup> Many factors, including obesity, may be associated with the development of DCS.

Nitrogen bubbles form in watery tissues (blood, muscle) and fatty areas (subcutaneous fat, peri-articular and para-spinal fat).<sup>5-7</sup> Nitrogen is 5.3 times more soluble in fats/lipids than in water.<sup>5,8</sup> Blood supply to adipose tissue, however, is poor, and the release of nitrogen from adipose tissues is slow.<sup>6,9</sup>

The main advantage of obesity in divers is the tendency for adipose tissue to be a good energy source and an excellent insulator.<sup>8,10</sup> In comparison with the overwhelming risks to obese divers, however, this advantage fades into insignificance.

## Obesity

Whilst body mass index (BMI) is regarded as one of the best predictors of adiposity, individual physique must be taken into consideration and, on occasion, skin fold measurements taken to indicate percentage body fat.<sup>6,10-12</sup> The BMI is calculated by dividing the individual's weight (kg) by the square of the individual's height (m).<sup>5,10</sup> Obesity is generally

accepted as a BMI greater than 30 kg/m<sup>2</sup>.<sup>5,11</sup>

## Obesity and DCS

Increased BMI implies an increased fat content of the body. This increased body fat leads to increased nitrogen storage and hence possible excessive nitrogen bubble formation and thus increased risk of development of DCS.<sup>2,5,7,8,12,13</sup>

As early as the mid-nineteenth century, it was observed that "corpulent" caisson workers were more likely to suffer from DCS than others, whilst on the basis of animal research in the early 1900s, it was recommended that plump men be excluded from high-pressure caissons. In a group of 932 caisson workers, the odds ratio for DCS in obese versus non-obese men was 2.2 (CI 1.3-3.9, P < 0.01).<sup>14</sup>

US Navy divers with the highest quartile skin fold thickness (20% overweight) have been reported to have an increased risk of developing DCS.<sup>6,12</sup> Those 25% or more overweight have been estimated to have a tenfold increased risk of developing DCS.<sup>7,15</sup> On average, DCS in USN divers was experienced by overweight compared with lean individuals.<sup>7</sup> Other USN studies have been inconclusive, possibly because few obese divers were included in the study groups. It has been suggested that increased age leads to increased risk of DCS, but that with increased age there is a tendency towards increased adiposity and decreased fitness.<sup>1,13,14</sup> Altitude studies have also suggested that increased body weight was associated with an increased risk of DCS in aviators.<sup>16</sup> Overall, it is difficult to establish clearly the influence of obesity on the incidence of DCS, since DCS is an uncommon event with multiple variables and most studies were poorly designed and ingrained with diving dogma.

Dive computers are increasingly relied upon by recreational divers. These dive computers are programmed with dive tables that are calculated for the average-sized individual and do not take into consideration obese divers.<sup>2,9,13</sup>

Understandably, therefore, the use of dive tables by obese divers is also increasing their risk of developing DCS.

### **Obesity and fitness**

Obesity often implies a decrease in exercise tolerance and poor physical fitness.<sup>1,2,6</sup> The increased cross-sectional area of the obese diver has been interpreted to mean a larger workload due to additional 'drag' through the water.<sup>8</sup> Whilst poor exercise tolerance implies impaired ability to self-rescue, there are also implications as to the obese person's ability to perform 'buddy' duties.<sup>6</sup> It has been postulated that poor aerobic fitness is a possible cause of increased individual susceptibility to DCS.<sup>13</sup> Additionally, aerobically trained individuals have a lower risk of developing DCS because they have a lower risk of developing venous bubbles. Broome et al (1995) found that aerobically trained pigs are less likely to develop DCS than a control sample of untrained pigs.<sup>2</sup>

### **Obesity and co-morbidities**

Obesity is often found to co-exist with other medical problems. In the diving environment, these co-morbidities can be exacerbated, or lead to the development of new problems. At the extreme, co-morbidities can result in an increased chance of sudden death. Obesity itself can cause the individual to have developed ventricular enlargement/hypertrophy.<sup>17</sup> Likewise, the increased size of the individual increases the circulating blood volume and thus the cardiac output will have increased. Carbon dioxide (CO<sub>2</sub>) retention, left ventricular dysfunction and hypoxaemia can all lead to increased pulmonary artery pressures.<sup>17</sup> Additionally, cardiac arrhythmias may exist and worsen when the individual dives.

Obesity increases the incidence of ischaemic heart disease and therefore increases the risk of a cardiac event.<sup>8,11</sup> Hypertension is common in the obese and there is a greater mortality rate in the hypertensive obese than in lean counterparts.<sup>11,17</sup> Hyperlipidaemia is also associated with increased body fat.<sup>7,11</sup> Hypertension and hyperlipidaemia are known risk factors for cardiac events.<sup>7</sup>

Pulmonary disease is found in about a quarter of the obese.<sup>17</sup> In addition to this, the physical changes associated with excess weight restrict movement and increase cavity pressures. Excess adipose tissue surrounding the chest wall reduces compliance and forced vital capacity. Increased abdominal pressure reduces functional residual capacity (FRC) and increases dead space, thus leading to increased pulmonary shunt. This results in increased CO<sub>2</sub> retention and hypoxia.<sup>11,17</sup> An adjunct to this is an increase in workload which itself increases oxygen consumption and CO<sub>2</sub> production.

Diabetes mellitus is a known co-morbidity of obesity. Swings in glucose levels during the stress and exertion of diving may increase the risk of drowning.<sup>11</sup> There are also

increased rates of gastro-oesophageal reflux disease, which in turn offers its own risks to diving.

### **Obesity and medications**

Many appetite suppressants have psychotropic effects and their CNS interactions with nitrogen under pressure are unknown. They may also elevate blood pressure thus potentially increasing cardiovascular stress.

### **Obesity and dysbaric osteonecrosis (DON)**

The possibility that obesity poses an increased risk of developing DON has been raised.<sup>10,18</sup> The incidence may vary according to the conditions of the hyperbaric exposure. Risk factors include the degree of obesity, number of dives, depth, decompression profile, and rate of compression. In the 1970s the rate of DON in Japanese fishermen reached 50–60% and was attributed to adiposity.<sup>18</sup> Research has found a significant incidence of DON in obese mice compared with thin mice.<sup>19</sup>

### **Obesity and immersion**

Immersion offers its own effects on the human body. The water pressure alone moves approximately 700 ml of blood from the periphery into the thorax. This vascular congestion reduces elastic recoil of the lungs and reduces FRC.<sup>17</sup> The blood pressure and cardiac output will increase causing a diuresis and thus a decrease in blood volume.<sup>17</sup> Surrounding water pressure also exerts a force against the rib cage, reducing chest wall compliance, and abdomen, causing elevation of the diaphragm and thus further reducing FRC.<sup>17</sup> Upon descent, gas density increases. This, combined with the reduced chest-wall compliance, may lead to the obese diver experiencing a large increase in the work of breathing.

The diving wetsuit will impose further restrictions on the obese diver. As the wetsuit compresses the skin, cutaneous blood is shunted centrally exacerbating the already congested lungs. Additionally, the wetsuit will restrict chest wall movement, further decreasing compliance and increasing the work of breathing.<sup>17</sup>

The obese person needs a larger wetsuit increasing buoyancy, which means that the obese person needs to wear a considerably heavier weight belt.<sup>8</sup> Due to the lower level of fitness, the obese person uses more oxygen when diving, therefore they either have shorter dive durations or need to use larger tanks. The combined effect is that the obese diver may have limited ability to rescue themselves or their buddy and difficulties accessing the dive launch from the water.<sup>8</sup>

### **Current protocols**

Some authors have called for obesity to be a contra-indication to diving (> 20% excess weight).<sup>6,12</sup> There are, however, some advantages to the obese being able to exercise in a weightless environment.<sup>8</sup> A less harsh view, with the aim of

minimising risks on an individual basis, may be a better way to proceed.<sup>6</sup> A thorough medical examination is advocated, including fasting blood tests and exercise tolerance testing. A sensible approach to diving is also recommended. This includes an attempt to improve cardiovascular fitness, and introduce slower ascent rates, fewer dives in 24 hours and a reduction of bottom time by 25–50%.<sup>1–3,8,9,13,15</sup> Reducing cardiovascular load by avoiding diving in strong currents and tides is also suggested.<sup>7</sup> With these guides implemented and a good general understanding of the risks involved, the obese diver can minimise poor outcomes.<sup>3,6</sup>

It has been suggested that new, safer tables be developed incorporating current knowledge of physiology. The challenge has been set to improve models “to cover more of the people more of the time”.<sup>3</sup>

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## Explosion in Peruvian chamber

A 65-year-old patient of the Hyperbaric Clinic in San Borja, Peru, was incinerated recently after a powerful explosion in a monoplace oxygen chamber. An unauthorised camera in the chamber was thought to be the cause, but the Clinic would not comment. The explosion, which blew in the door and windows of the surrounding room, occurred minutes after the patient entered the chamber. According to criminology experts, death occurred in a matter of seconds. Alfonso Gonzales, a representative of the Peruvian Hyperbaric Medicine Society, said that this centre did not have a registered doctor or technicians. “We had already warned the Ministry of Health and other institutions of this fact”, said Dr Gonzales. Hyperbaric medicine has been practised in Peru for ten years.

**Editor's comment:** This case reaffirms yet again the need for meticulous management and the highest safety standards, combined with properly trained staff, in hyperbaric facilities.