

# Body Fat Underwater

Scuba diving is a physical activity, and one relevant parameter of a human physique is the amount of fat in a person's body. In this article, we would like to take a look at how more or less body fat makes scuba diving less or more safe.

Unfortunately, the research into both body fat and decompression safety suffers from less than ideal data: The most commonly used indicator for obesity is the body mass index (BMI). BMI is calculated as weight (in kilograms) divided by the square of height (in meters). Because it considers only weight and height, BMI does not account for differences in body composition (i.e., fat vs. muscle).

To assess decompression safety, we have to rely on bubble studies (venous gas emboli, VGE). While bubbles formed in a person's veins are not a good predictor for DCI, they can be an indicator of decompression stress. Just as with the studies using BMI, we need to work with what we have.

## Decompression Illness

Scuba divers who paid attention to their theory lessons during their open water course will remember that body fat is considered a risk factor for decompression illness. The basic argument is that fat (adipose tissue) is relatively poorly vascularized (has fewer blood vessels per volume than muscles), which leads to a slower release of inert gas during ascent. Also, nitrogen in particular dissolves well in fat. Taken together, these factors are thought to increase the DCS risk in divers with higher body fat content.

A study analyzing a large database of recreational dives compiled by DAN only partially confirms this<sup>1</sup>. The researchers analyzed 39099 dives, recording the body weights and heights of the divers performing these dives, as well as the DCS incidence. In 970 of these dives, they also measured the VGE (bubbles) using Doppler ultrasound.

BMI caused a weakly significant increase in bubble formation, an effect mostly due to the higher susceptibility of the female divers in the study. Curiously, the average BMI of divers who had suffered an actual DCI hit in the study was slightly lower than that of divers who had no symptoms (24.5 vs. 25.6). This could be due to the low prevalence of DCI in general and small sample size: Only 320 divers suffered DCI; the BMI difference is not statistically significant.



In contrast, a study of Mexican fishermen using surface-supply (compressor) diving to forage for lobsters and sea cucumbers<sup>2</sup> showed a significant correlation between DCI and BMI. Divers with higher BMI got bent more frequently and more severely. There are several important differences from the first study: Compressor dives often have much riskier profiles, with multiple ascents and descents to retrieve lobsters. These fishermen often spend considerable time underwater, with daily bottom times ranging from 12 up to 260 minutes. The fishermen had BMIs of  $34.5 \pm 4.7$ . Unless they were all exceptionally muscular, their body fat percentages were far higher than those of the recreational divers examined in the study using the DAN database. To put things in perspective, a person who is 175 centimeters tall would weigh 75 kilograms with a BMI of 24.5 (DAN database study), and 105 kg with a BMI of 34.3 (Mexican fishermen).

A US Navy study<sup>3</sup> also found a higher incidence of DCI among divers with a greater body fat percentage. We can assume that military divers perform harder work than recreational scuba divers, and that this difference contributes to the higher DCI incidence in Navy divers with more body fat.

Another, older study is quite valuable in this context because it didn't use BMI but measured the body fat percentage of divers by applying a weak electric current, and then measured bubbles using Doppler ultrasound<sup>4</sup>. Divers in this study did a single decompression dive to 35 meters, with two decompression stops at 6 and 3 meters.

This study did *not* find a relationship between body fat percentage and post-dive bubble formation – just as the study using the DAN database. The divers in this study were quite lean, with body fat percentages ranging from 26% to 4%. The extremely low, latter value would be that of a very lean lightweight boxer on fight day. Again, within this narrow range of body fat and conservative diving protocols, the researchers did not find a relationship between body fat and DCI risk.

A review of obesity and diving<sup>5</sup> correctly points out that obesity is not a monolithic condition but comes with a number of associated problems. These comorbidities include breathing problems, heart problems, high blood pressure, and diabetes. Each of these problems can be exacerbated when underwater. A diver is exposed to water pressure and will be physically active by swimming. This could be harder for divers with excessive body fat not due to the adipose tissue itself, but due to breathing problems developed as a consequence of being overweight. It's not just the DCI risk which changes with extra body fat.



## **Conclusions: no extra risk at low to moderate body fat, but beware of severe obesity**

I think it's reasonable to say that body fat in a low to intermediate range will not influence the risk of DCI after a recreational scuba dive. Slimming down from your average body to the shredded physique of a bodybuilder will not decrease your DCI risk. But once you get to the point of serious beer belly ownership, the excess body fat does increase the likelihood of DCI. This is probably exacerbated when the extra body fat is combined with significant exertion underwater, as is the case with the navy divers and Mexican fishermen.

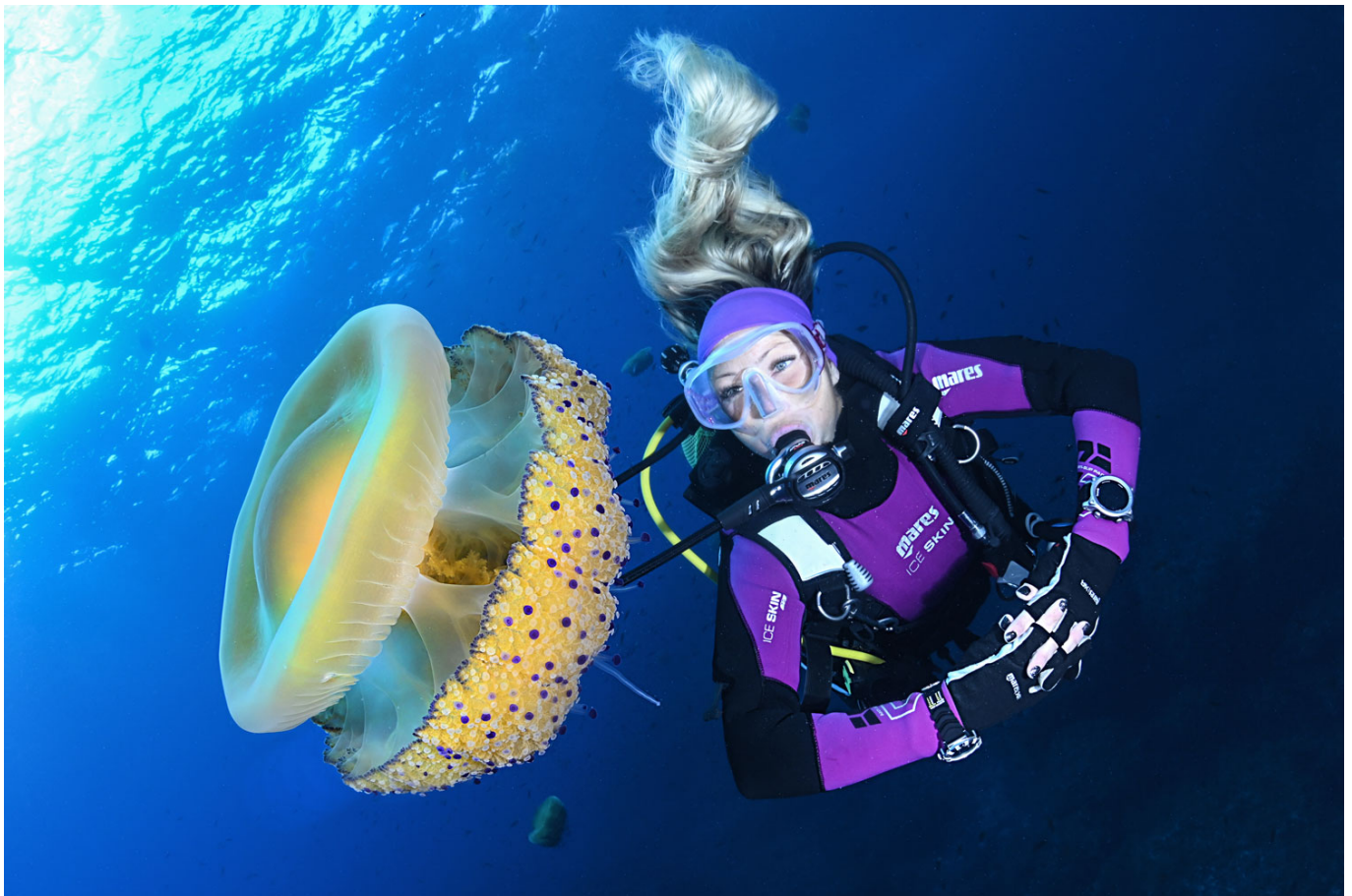
Generally, the leaner you are, the healthier and the fitter for scuba diving you will be. However, scientific research from the last few decades seems to tell us that an extra kilogram of body fat from a week of holiday feasting added to an otherwise reasonably lean body will *not* put you at a higher risk of DCI.

# Body fat and thermal insulation

But, is body fat even all bad? Some of the most accomplished divers on the planet are enormously fat. These are of course not human divers, but marine mammals, which use thick layers of specialized fat (called blubber) to insulate themselves from the sometimes icy seawater they live in.

Body fat can play a similar role in human divers. It's notable that in many traditional societies, such as the Haenyeo in Korea, apnea divers foraging underwater for mollusks and crustaceans are often women. In a healthy (non-obese) population, women have higher body fat percentages than men.

Maintaining heat in a human body immersed in water is a complex process. There is much more to it than reduced heat flow through a subcutaneous layer of insulating fat. Brown fat cells which are concentrated, but not exclusively occurring around internal organs, are not just insulators but active heat sources. Heat-generating muscle shivering and a re-distribution of warm blood from the limbs to the core further complicate the matter. Body fat only plays one instrument in the orchestra of human thermobiology.



Elevated body fat is often associated with a lower metabolism, and hence less intrinsic heat production. Leaner people seem to shiver more, and thus make up for their thinner insulation layer. Another example for the complexity of human thermobiology is that in humans at rest, muscles provide an effective additional layer of insulation<sup>6</sup>. With exercise (and use of muscles) this insulating function of the muscles is lost. The total insulation is more similar to what would be expected from the passive layer of fat alone.

Cooling down when immersed in cold water is not just a topic for scuba divers, but also for shipwrecked sailors. The interest in this topic is hence significant, and physiologists have come up with equations which describe how a person's core temperature cools down<sup>7</sup>. The term in the equations describing the role of

body fat in core temperature loss is generally linear: Having twice the body fat doubles the thermal insulation effect.

## Conclusion two: It works, but don't overdo it

In conclusion, while the details of human cooling during immersion are tricky, body fat undoubtedly keeps you warmer underwater. This should not be an encouragement to anyone to binge eat in order to fatten up and stay warm. However, understanding the connection between body fat and thermal isolation is useful: A change in exercise regimen or diet can alter a person's body composition quite significantly, and we are better off when we understand the resulting altered response to heat loss during dives.

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<sup>1</sup> Cialoni, D., Pieri, M., Balestra, C., & Marroni, A. (2017). Dive risk factors, gas bubble formation, and decompression illness in recreational SCUBA diving: analysis of DAN Europe DSL data base. *Frontiers in Psychology*, 8, 1587.

<sup>2</sup> Mendez-Dominguez, N., Huchim-Lara, O., Chin, W., Carrillo-Arceo, L., Camara-Koyoc, I., Cárdenas-Dajdaj, R., & Dogre-Sansores, O. (2018). Body mass index in association with decompression sickness events: cross-sectional study among small-scale fishermen-divers in southeast Mexico. *Undersea & Hyperbaric Medicine*, 45(4).

<sup>3</sup> Dembert, M. L., Jekel, J. F., & Mooney, L. W. (1984). Health risk factors for the development of decompression sickness among US Navy divers. *Undersea biomedical research*, 11(4), 395-406.

<sup>4</sup> Carturan, D., Boussuges, A., Burnet, H., Fondarai, J., Vanuxem, P., & Gardette, B. (1999). Circulating venous bubbles in recreational diving: relationships with age, weight, maximal oxygen uptake and body fat percentage. *International journal of sports medicine*, 20(06), 410-414.

<sup>5</sup> Mouret, G. M. (2006). Obesity and diving. *Diving And Hyperbaric Medicine-South Pacific Underwater Medicine Society*, 36(3), 145.

<sup>6</sup> Park, Y. S., Pendergast, D. R., & Rennie, D. W. (1984). Decrease in body insulation with exercise in cool water. *Undersea biomedical research*, 11(2), 159-168.

<sup>7</sup> Wheelock, C. E., Bartman, N. E., Pryor, R. R., Pryor, J. L., & Hostler, D. Prediction of core temperature during prolonged cold weather immersion in thermally protected men and women. *Proceedings of the Human Factors and Medicine Panel*, 349, 17-19.