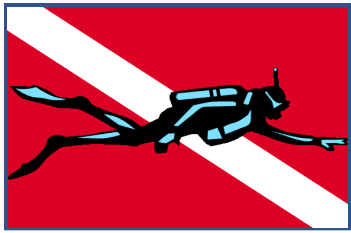


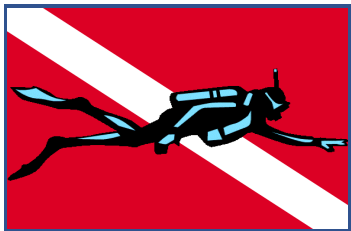
# **Identification of DCS Risk Factors in Recreational Diving**



# DCS Risk Factors in Recreational Diving



- 1993: DAN Europe began collecting recreational diving data.
- 2010: Electronic dive profile recordings were added to the database
- 2017: an originally developed database, including specific questionnaires for data collection, was used for statistical analysis of 39,099 electronically recorded open circuit dives made by 2,629 European divers over a 5 year period (Dive risk factors, gas bubble formation, and decompression illness in recreational SCUBA diving)

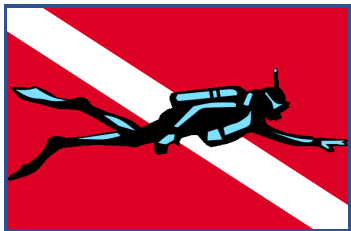


# DCS Risk Factors in Recreational Diving

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- 2024: a study was undertaken to identify the primary risk factors for decompression sickness (DCS) in real-world recreational diving based upon the largest available database (Divers Alert Network Dive Safety Laboratory) DAN DSL ver. 7/2024.
- 127,957 dive records were analyzed
- 5,907 divers (79.8% male, 20.2% female)
- Mean age 39.9 +/-10.7 years (range: 12-78)
- DCS was observed in 628 dives (0.49% of all dives)



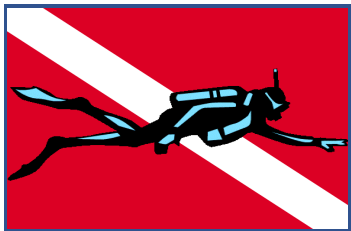
# DCS Risk Factors in Recreational Diving

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Part I:

The Study Results



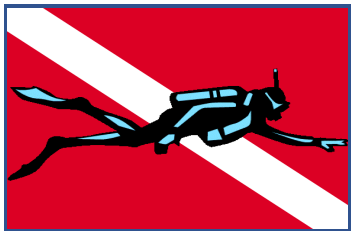
# DCS Risk Factors in Recreational Diving

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Variables shown to have independently influenced the probability of DCS occurrence:

- DSSG
- DSSG\_CMPRT
- GENDER
- FEELING
- THERMAL
- GAS\_COUNT
- EXERCISE
- WORKLOAD
- PURPOSE
- BMI\_CLASS
- DIVE\_NR
- SURF\_INTERVAL



# DCS Risk Factors in Recreational Diving



- DSSG (DAN Surface Supersaturation Gradient): a mathematical metric to measure the specific level of inert gas stress experienced by the body upon returning to the surface. It reflects the End Value Gradient, isolating the exact level of surface supersaturation found in the human body's "leading" (fastest or most heavily gas-loaded) tissue compartment. Calculated according to the Buhlmann ZH-L16C model.
- DSSG Compartment: the number of the conceptual tissue compartment where the maximum DSSG occurs.

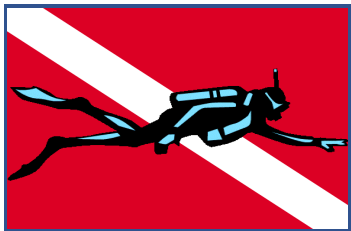


# DCS Risk Factors in Recreational Diving

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- Gender: male or female.
- Feeling: feeling before the dive – if the diver reported being well-rested before the dive, or tired, or exhausted.
- Thermal: thermal comfort during the dive – comfortable, cold, very cold or hot.
- Exercise: before diving – none, light, moderate, and heavy.
- Workload: during the dive – none, light, moderate, heavy, and exhausting.

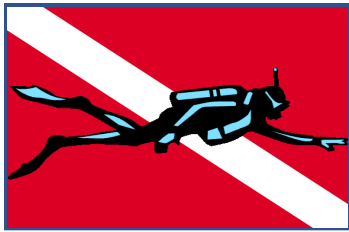


# DCS Risk Factors in Recreational Diving

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- Purpose: recreational, instructional, guidance, student, technical, other.
- BMI Class: calculated from height and mass data submitted.
- Dive Number: number of dives in a series
- Surface Interval: time on the surface from the previous dive.
- Gas Count: the number of different gases used on the dive.



# DCS Risk Factors in Recreational Diving



To calculate the probability of DCS [P(DCS)] from our logistic regression model, one can use the logistic function:

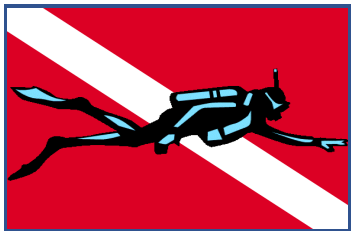
$$P(\text{DCS}) = \frac{1}{1 + e^{-Z}}$$

where Z is the linear predictor, constructed from the coefficients:

$$\begin{aligned} Z = & -16.2976 \\ & + 13.9063 \cdot \text{DSSG2} \\ & - 0.2338 \cdot \text{DSSG\_COMPRT} \\ & + 1.5330 \cdot \text{GENDER\_N} \\ & - 1.2014 \cdot \text{FEELING\_N} \\ & + 1.0405 \cdot \text{THERMAL\_N} \\ & + 1.0537 \cdot \text{GAS\_COUNT} \\ & + 0.7254 \cdot \text{EXERCISE\_N} \\ & + 0.4779 \cdot \text{WORKLOAD\_N} \\ & + 0.3065 \cdot \text{PURPOSE\_N} \\ & - 0.1591 \cdot \text{BMI\_CLASS\_N} \\ & - 0.0638 \cdot \text{DIVE\_NR} \\ & - 0.0404 \cdot \text{SURF\_INTERVAL} \end{aligned}$$

So, the final probability formula:

$$P(\text{DCS}) = \frac{1}{1 + \exp(-Z)}$$



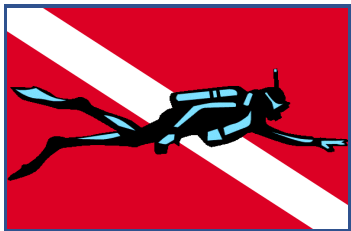
# DCS Risk Factors in Recreational Diving

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## GENDER:

- In the univariate analysis, DCS occurred 3.289 times more often in females than in males.
- Gender was also identified as an independent predictor of the DCS probability.
- Results can imply that females have the odds of DCS increased independently from other parameters by 363%.



# DCS Risk Factors in Recreational Diving

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BMI (Body Mass Index) =  $\text{kg/m}^2 = (\text{lbs/inches}^2) \times 703$

< 16.0 “Severely Underweight”

16.0 – 16.9 “Moderately Underweight”

17.0 – 18.4 “Mildly Underweight”

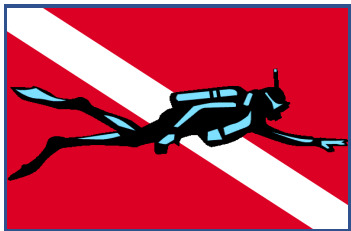
18.5 – 24.9 “Normal”

25.0 – 29.9 “Overweight”

30.0 – 34.9 “Moderately Obese” (class I)

35.0 – 39.9 “Severely Obese” (class II)

$\geq 40.0$  “Very Severely or Morbidly Obese” (class III)

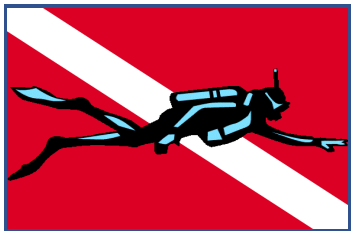


# DCS Risk Factors in Recreational Diving

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- The probability of DCS, depending on BMI classification in the univariate analysis showed a U-shaped curve.
- In the multivariate analysis, the lower BMI class, especially below the normal range was associated with a 15% increase in DCS odds.



# DCS Risk Factors in Recreational Diving

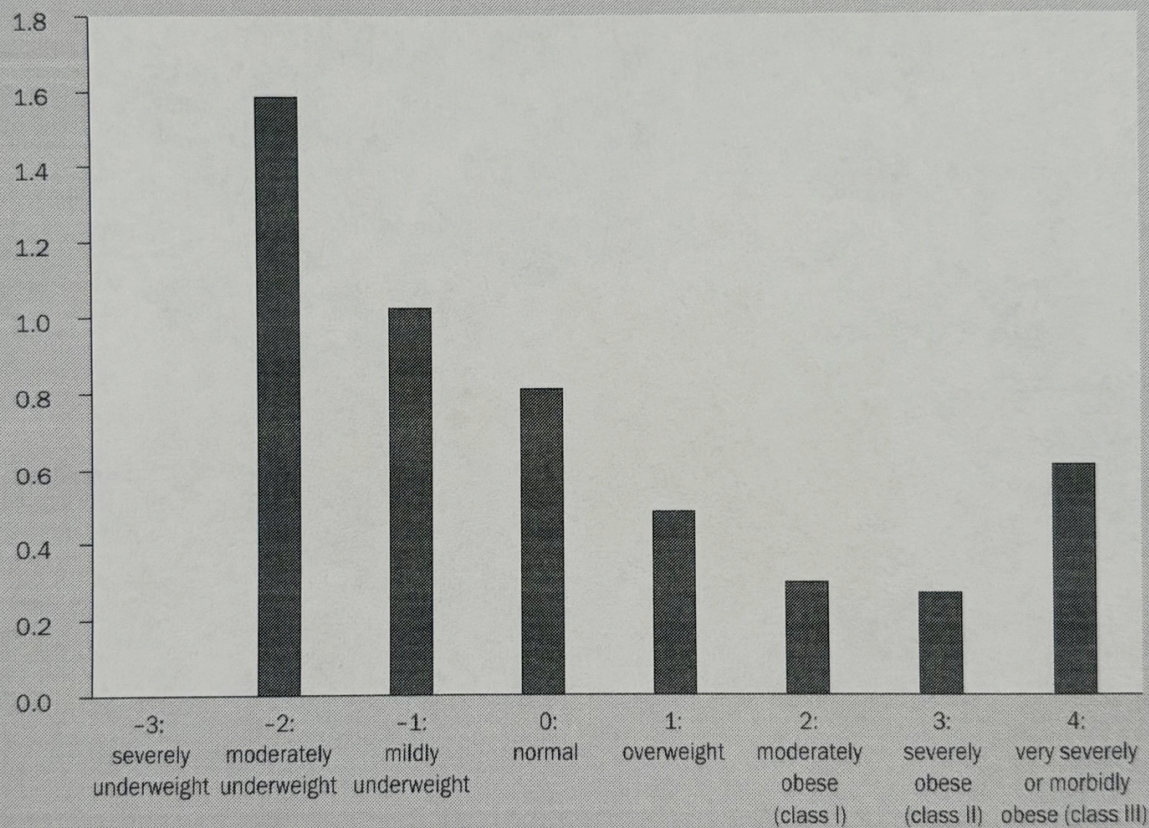
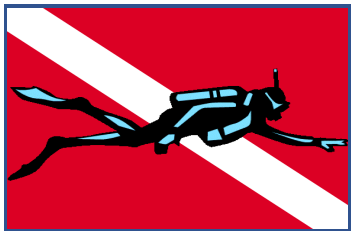


Figure 6. Probability of decompression sickness (DCS) depending on body mass index (BMI) classification (univariate analysis)

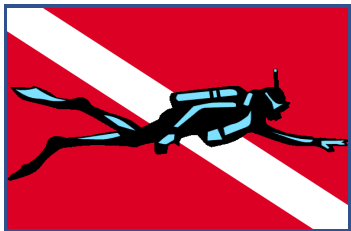


# DCS Risk Factors in Recreational Diving



FEELING: how well-rested the diver felt at the beginning of the dive.

- If the diver reported being well-rested before the dive, DCS occurred in 0.51% of cases.
- If the diver reported being tired or exhausted, DCS occurred in 0.29% of the dives.
- In multivariate analysis, a negative self-reported feeling before the dive reduced DCS odds by 70%.



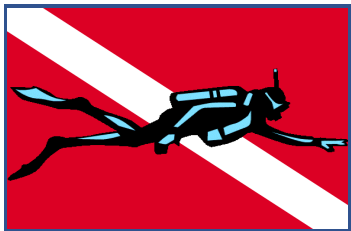
# DCS Risk Factors in Recreational Diving

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## EXERCISE:

- In univariate analysis, if divers were not exercising before the dive, DCS occurred in 0.38% of the cases.
- If exercise was described as light, DCS occurred in 0.78% of the cases.
- If exercise was described as moderate or heavy, DCS occurred in 0.25% of the cases.
- In multivariate analysis, the exercise was the independent factor, doubling the risk of DSC.



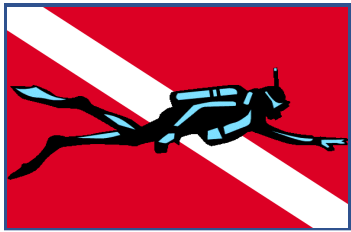
# DCS Risk Factors in Recreational Diving

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## WORKLOAD:

- The DCS rate in dives with workload reported was 0.67%.
- This value is significantly higher than in those dives where no significant workload was reported by the diver – 0.39%.
- Multivariate analysis reported this effect to be independent from other factors, with the increase of DCS odds by 61% with the workload.



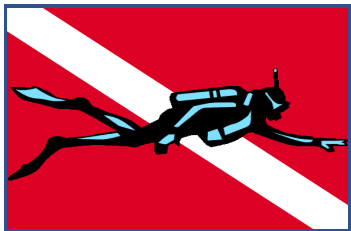
# DCS Risk Factors in Recreational Diving

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## Further Notes:

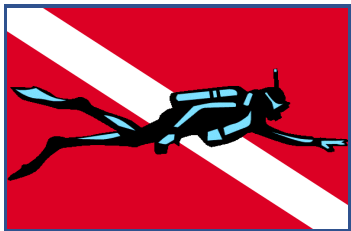
- DSSG: the most critical parameter affecting the risk of DCS.
- PURPOSE: in the multiparameter analysis, diving for technical purposes increased DCS odds by 36%.
- Dive Number & Surface Interval: the number of dives in series and surface interval from the previous dive negatively correlated with the DCS odds, when each additional dive reduced DCS odds by approximately 6% and each hour at surface reduced DCS odds by 4%.



# DCS Risk Factors in Recreational Diving



- THERMAL: in the univariate analysis, the highest DCS rate was in dives where divers reported thermal comfort (0.51%); and, this was higher than when feeling either cold/very cold or hot (0.16%, 0.28% respectively). In the multivariate analysis, the increase in thermal comfort, from cold to comfortable and hot, was positively associated with DCS risk.



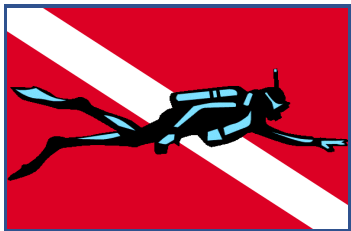
# DCS Risk Factors in Recreational Diving

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## Part II:

### Some Issues Regarding the Study

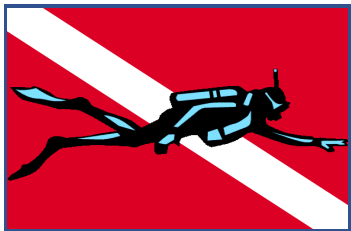


# DCS Risk Factors in Recreational Diving

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- Self-reporting in statistical studies introduces significant vulnerabilities. The most critical issues stem from **response bias**, where participants alter answers to look socially favorable, and **recall decay**, where memory fades over time.
- **Reference Bias**: different individuals apply different personal or cultural standards when evaluating subjective questions, making uniform measurements difficult.

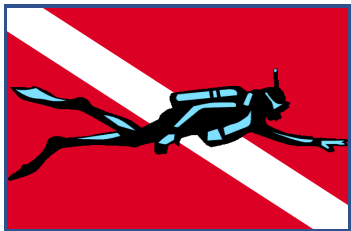


# DCS Risk Factors in Recreational Diving

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- From the article Statistics is hard to get right, a number of questions regarding data collection are brought up. In particular where did the DCS data come from, because the questionnaire on the current version of the Diver Safety Guardian (DSG) portal where data is uploaded does not ask about symptoms of decompression sickness. Did the DCS cases come from calls seeking medical assistance?
- Additionally, ~130K dives, by < 6000 divers means someone did a huge number of reported dives – did their personal characteristics skew the data?



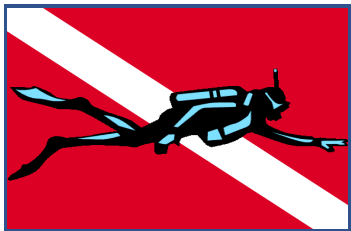
# DCS Risk Factors in Recreational Diving

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## Part III:

# What Do We Do With the Study Results



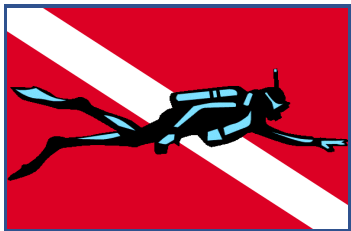
# DCS Risk Factors in Recreational Diving

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## GARMIN FITNESS TRACKER:

- **GENDER**: asked for during the initial setup. It generally uses this information to help their fitness and training algorithms (like VO2 max and calorie burn).
- **BODY MASS INDEX (BMI)**: your height and weight are inputted during the initial setup (and can be edited anytime). It can calculate your BMI from the information you enter.



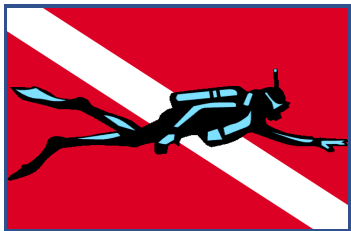
# DCS Risk Factors in Recreational Diving

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## GARMIN FITNESS TRACKER:

- **BODY BATTERY**: highly accurate at tracking overall energy trends and relative recovery. It uses Heart Rate Variability (HRV), resting heart rate, and movement data to evaluate your physiological stress and recovery levels. (**Feeling?**)

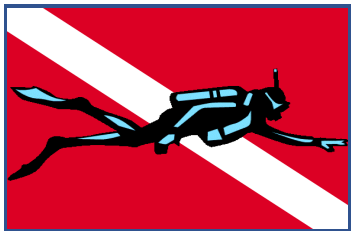


# DCS Risk Factors in Recreational Diving



## GARMIN FITNESS TRACKER:

- **STRESS**: tracks physiological strain by calculating your Heart Rate Variability (HRV). A high STRESS score (75-100) simply means your autonomic nervous system is in a “fight-or-flight” state rather than a resting state. When the intervals between your heartbeats are highly consistent, it means your sympathetic nervous system (“fight-or-flight”) is dominant, which the watch registers as high stress. (**Exercise?**)



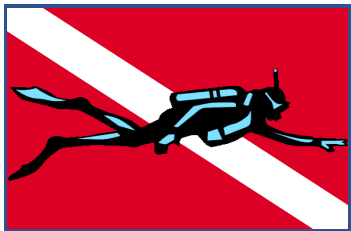
# DCS Risk Factors in Recreational Diving

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## GARMIN FITNESS TRACKER:

- **TRAINING LOAD**: is an excess post-exercise oxygen consumption (EPOC) based metric designed to help understand the physiological impact and resulting recovery demands of your activities. (**Workload?**)



# DCS Risk Factors in Recreational Diving

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Going forward, after further research and experimentation, dive computer algorithms may be “fine-tuned” to the individual by including results of these studies.