

Perceptions of airway protection tools: an international survey on the use of mouthpiece retaining straps in closed-circuit rebreather diving

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Abstract

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Introduction: Rebreather diving carries a high fatality rate (estimated 1.8–3.8 deaths per 100,000 dives), yet its popularity is growing. Among 54 French military divers who lost consciousness underwater, none died when using a mouthpiece retaining strap (MRS) in a team diving setup. Despite this, MRS use remains limited among recreational divers for whom drowning is a major cause of death. This study assessed knowledge, perceptions, and training regarding MRS use within the rebreather diving community.

Methods: An international online survey targeting certified rebreather divers was disseminated via social media. The survey gathered demographic information, diving experience, MRS usage, and details on related training.

Results: A total of 563 responses were collected. Of these, 133 (23.6%) were instructors, and 210 (37.3%) had received MRS training. On a 0 to 100 scale, divers trained on MRS use rated MRS importance higher (median score: 74 [IQR 33–90]) than divers with no MRS training (median: 49 [IQR 16–67]). Barriers to MRS adoption included negative past experiences, poor training, misuse, and concerns about complications during bailout procedures.

Conclusions: While not widely adopted among recreational divers, the MRS is supported by strong safety data. Formal training significantly improves its perceived value and acceptance. Greater involvement from manufacturers, training agencies, and instructors is essential to promote education and encourage MRS adoption as a key safety measure in rebreather diving.

Introduction

The use of closed-circuit rebreathers (CCRs) is rapidly increasing within the technical diving community. By recycling exhaled gas through a carbon dioxide (CO₂) absorbent, CCRs reduce gas consumption and optimise breathing mixtures, enabling longer and deeper dives. However, their complexity increases the risk of technical failures and emergencies.¹ Rebreather diving carries a relatively high fatality rate, estimated at 1.8 to 3.8 deaths per 100,000 dives, with gas toxicity (e.g., hypoxia, hyperoxia, hypercapnia) being a major contributing factor.^{2,3}

Although training standards exist, some practices seem to vary, and approaches are often guided more by personal

beliefs or anecdotal experience rather than by established scientific evidence leading to ongoing controversy within technical diving community.⁴ Even today, the use of a mouthpiece retaining strap (MRS) is not yet fully part of these standards, and not all rebreathers manufacturers are providing it by default.

The MRS is designed to secure the mouthpiece by wrapping around the diver's head and making a seal around the lips. By keeping the mouthpiece in place, it potentially reduces the risk of drowning in the event of mental impairment or unconsciousness. This would allow for a longer window of time in which a successful rescue could be carried out by another diver or a surface observer. While full-face masks (FFMs) also provide airway protection, they are often

considered bulky, technically demanding, and difficult to remove quickly in emergencies. In contrast, the MRS may offer a low-cost, simple, and effective alternative, if correctly used.⁵ Data on its effectiveness remain limited, due to the obvious ethical constraints associated with studying unconscious divers, leading to controversies in the recreational community. Nonetheless, a French Navy study reported zero fatalities and only two moderate cases of water inspiration among 54 CCR divers who suffered loss of consciousness (LOC) while using a MRS.¹ The related benefit implied by this military diving study is likely to be translatable to the recreational diving setting.

Despite these findings, many divers remain reluctant to adopt the MRS. Various arguments are frequently put forward against the use of MRS in diver debates, including concerns about bailing-out, perception of risk, and general discomfort. These reservations may, in part, be attributed to a lack of awareness and suitable training.⁶

This survey aimed to assess the overall knowledge and perception about MRSs among the rebreather diving population and how formal training with a MRS influences divers' perception and voluntary use of the device within the rebreather diving community.

Methods

The study was approved by the Institutional Review Board of the Divers Alert Network (DAN) (#037-24-24). Participation was voluntary, and responses were confidential.

A cross-sectional survey was conducted and disseminated online through the DAN website and social media channels and was further distributed through diving-related news outlets such as InDepth magazine and rebreather-specific groups on social media. Data collection lasted from 2 August to 14 September 2024. The anonymous questionnaire was developed on the electronic data capture platform REDCap (REDCap consortium, Vanderbilt University, Nashville, TN, USA). Certified rebreather divers aged 18 years and older were invited to respond. Participants were presented with an information page outlining the study, which was followed by the collection of written informed consent.

The survey collected information regarding gender, age, academic background, rebreather diving experience, and whether they had received specific training in the use of the MRS. Participants with prior formal MRS training were asked about their regular use of the MRS, while those without training were asked about their interest in using it. The influence of formal training on users' perception of the MRS was examined. The perceived importance of wearing the strap for safety during rebreather diving was assessed using a scale from 0 ('not important') to 100 ('very important'). Additionally, the degree of agreement with various statements related to the use of the MRS concerning its interests, constraints, comfort, and diver's

personal experience was evaluated. Respondents were able to add free-text comments to more narratively describe diving situations in which they felt the MRS either put them in a dangerous situation or, on the contrary, provided valuable assistance.

STATISTICAL ANALYSIS

Statistical analysis was performed with GraphPad Prism v10.4.1 (GraphPad Software Inc., San Diego, CA, USA). Continuous variables are presented as median and interquartile range (IQR), whereas categorical data are reported as counts and percentages. As data were not normally distributed, comparisons of unpaired continuous variables were performed using the Mann–Whitney test. Categorical comparisons were analysed using the Chi-square test or Fisher's exact test when required by sample size constraints. Statistical significance was defined as a P -value < 0.05 .

Results

POPULATION DESCRIPTION

During the available period of the questionnaire, 887 responses were received. Of these, 324 were excluded due to being from non-rebreather divers or the lack of written consent, resulting in the analysis of 563 valid entries from 59 (10.5%) female, 495 (87.9%) male, two (0.4%) non-binary participants. Seven (1.2%) preferred not to disclose their sex. The age classes were 18–24 for 6 (1.1%), 25–34 for 53 (9.4%), 35–44 for 158 (28.1%), 45–54 for 170 (30.2%), 55–64 for 119 (21.1%) and older than 65 years for 53 (9.4%) divers. Four (0.7%) did not specify age. They were CCR certified for six (2–11) years with a median of 30 (50–100) rebreather diving-hours annually. One-hundred-thirty-three (23.6%) were rebreather instructors and 210 (37.3%) had received formal training on the MRS. Among the 353 (62.7%) who had never been trained on an MRS, 108 (30.6%) did not consider trying a MRS. There was no difference between the trained and untrained groups on gender ($P = 0.6$), or age categories ($P = 0.8$). Table 1 depicts the participants' educational background and rebreather diving experience.

PERCEIVED CONFIDENCE AND COMFORT IN THE USE OF MRS REGARDLESS OF TRAINING

After formal training, the MRS was more widely recognised as an important safety device in CCR diving ($P < 0.0001$, Figure 1). A total of 381 (67.7%) divers believed it could help prevent drowning, while 201 (37.7%) reported it might reduce jaw fatigue. Trained divers were significantly more likely to agree with these statements ($P < 0.0001$, Figure 2). Although few participants ($n = 36$) believed that the MRS made bailout impossible, many acknowledged that it introduces procedural complexity, particularly for those untrained ($P < 0.0001$, Figure 3). The MRS was reported as

Table 1

Background and experience in rebreather diving among the trained and untrained divers on the MRS; BOV – bailout valve; CCR – closed-circuit rebreather; FFM – full-face mask; IQR – interquartile range; y – years

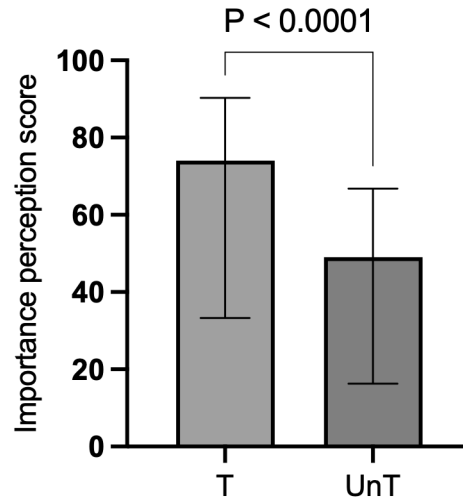
Parameter	Trained (n = 210)	Untrained (n = 353)
Education level, n (%)		
High school or less	41 (19.5)	46 (13)
University	150 (71.4)	281 (79.6)
Other	18 (8.6)	23 (6.5)
Unknown	1 (0.5)	3 (0.8)
Diving training		
CCR Certification (y), Median (IQR)	6 (3–12)	6 (2–11)
CCR Instructors, n (%)	60 (28.6)	73 (20.7)
Diving practice		
Annual CCR dive-hours, Median (IQR)	70 (40–110)	30 (50–100)
Usually have BOV on primary unit, n (%)	74 (35.4)	167 (47.3)
Try/use FFM on CCR, n (%)	27 (12.9)	32 (9)

incompatible with their diving configuration by 27 (12.9%) trained and 89 (25.3%) untrained divers ($P = 0.0004$). Trained divers more frequently reported that the MRS may have been both a helpful aid and, at times, a source of danger (Table 2). However, there was no significant difference between groups in the proportion of divers who had experienced a situation in which the MRS could have potentially prevented an accident ($P = 0.06$). Three divers reported a LOC underwater while using the MRS, with all experiencing favourable outcomes.

Drawing on the more narrative comments from divers about their experiences using the MRS, 43/353 (12.2%) written responses from untrained divers and 56/210 (26.7%) from divers trained to use the MRS were noted. In both cases, divers highlighted the additional workload the MRS is adding to the bail-out procedure and the possible issues it can create with the mask strap when attempting to remove the MRS (e.g., “*Complication during bailout process unless attached to a BOV. In case of a flooded unit or caustic cocktail it would be an even worse scenario*”). Some divers also insist on the importance of training to avoid or limit these issues, or the need for a mouthpiece and a lip cover who fit the user for the system to be fully effective (e.g., “*The strap interacts with the mask and adds more steps to bailout. I did several bailout exercises and got some water in the loop on a few. It might be different if you are trained on it from the start*”). A total of only 6/563 (1.1%) divers in this survey also highlighted that the MRS might have saved them during an emergency or a loss of consciousness (e.g., “*It (MRS) kept the mouthpiece in while fighting a lift bag when I was in odd orientations. It would have had a*

Figure 1

Self-reported MRS importance for rebreather diving safety; scale 0 to 100 (not important to very important); T – trained; UnT – untrained



wet loop without it in that situation”, “*My CCR read PpO₂ incorrectly and caused hyperoxia. Because I was wearing a FFM that helped prevent me from drowning*”, “*During a high PpO₂ alert, I had to use my BOV. Without a MRS, the BOV would be not comfortable for long dive because of the weight of mouthpiece*”, “*During wreck diving I got falling pipe on my head and lost consciousness. The MRS saved my life.*”), and some suggested combining it with a bailout valve (BOV) to limit the loss of time when switching to the open circuit bailout. Many divers have also pointed the lower jaw fatigue while using the MRS, as well as its efficacy to keep the mouthpiece in place when they received a fin kick from their buddy and one also mentioned that he doesn’t use the MRS while cave diving with a helmet.

CONSIDERATION OF CONTINUED USE OF A MRS AFTER TRAINING

Of the 210 divers trained in the use of the MRS, 138/209 (66%) reported using it more than half the time and these will be considered ‘regular’ MRS users in the following text, with 127/138 (92%) of them doing so essentially invariably. In contrast, 7/71 (9.9%) used it about half the time, 13/71 (18.3%) less than half, and 51/71 (71.8%) had never used an MRS after their course. These latter groups are considered occasional (or non-) users. Training was received during recreational or technical diving classes for 191 (91%) divers, military courses for nine (4.3%), commercial or scientific diving for seven (3.3%), and other occasions (including possible self-training) for three (1.3%).

Occasional (or non)-users were more experienced and more frequently held CCR instructor certification (Table 3). There were no significant differences in gender ($P = 0.2$), age categories ($P = 0.8$), or educational background ($P = 0.9$). A BOV was used by 46/138 (34.1%) of regular users and

Figure 2

Perceptions on the potential interests and discomfort of wearing MRS following a specific training in rebreather divers; A – agree; D – disagree; IDK – ‘I don’t know’; NA – not applicable; N – neutral; SA – strongly agree; SD – strongly disagree; T – trained; UnT – untrained

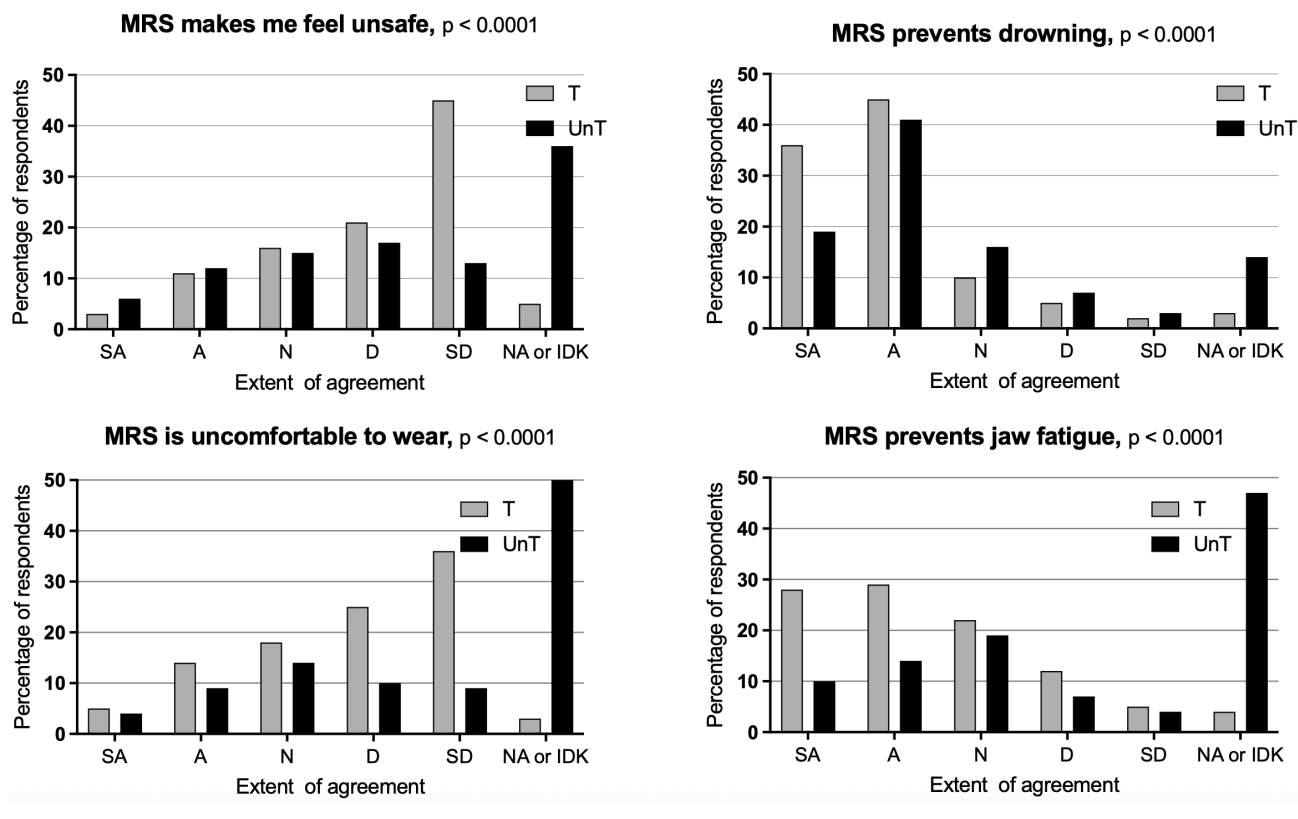
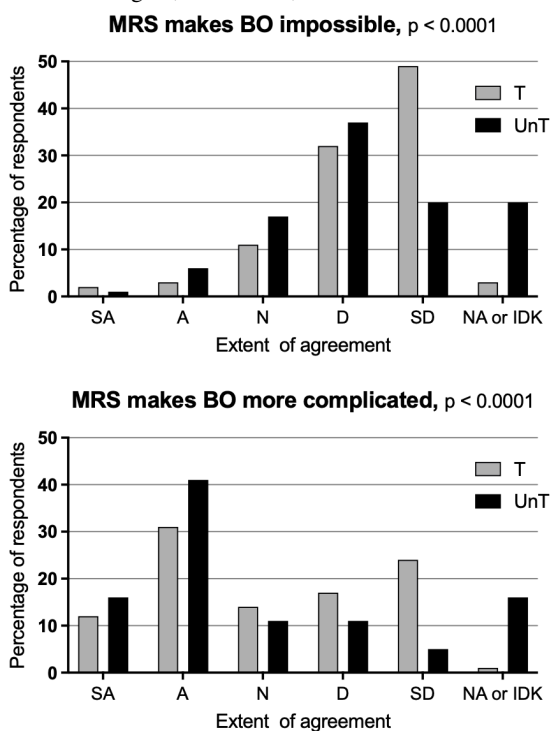


Figure 3

Perceptions of the interaction between MRS and bailout (BO) procedures; A – agree; D – disagree; IDK – ‘I don’t know’; NA – not applicable; N – neutral; SA – strongly agree; SD – strongly disagree; T – trained; UnT – untrained



27/71 (38%) of other divers ($P = 0.5$). The median MRS safety rating scale from 0 to 100 was 82 (71–98) for regular MRS users vs 22 (7–50) for other divers ($P < 0.0001$). Their instructors specifically emphasised the use of the MRS during CCR courses for 121/138 (87.7%) regular users and for 52/71 (73.2%) of individuals who later discontinued its use ($P = 0.001$). The MRS was judged not compatible with diving configuration for 3/138 (2.2%) of regular users and 24/71 (33.8%) of others ($P < 0.0001$). Among occasional (or non)-users, 19/71 (26.8%) reporting experiencing a dangerous situation involving a MRS, compared to 2/138 (1.5%) of regular users ($P = 0.009$). Conversely, 66/138 (47.8%) users considered a MRS helped them during a dive, versus 6/71 (8.5%) of occasional (or non-) users ($P < 0.0001$). There was no significant difference in the proportion of divers who recalled a past incident they believed could have been prevented by using an MRS ($P = 0.1$).

Discussion

Mouthpiece retaining strap adoption is still not widespread within the recreational CCR diving community. Formal training on the use of the MRS significantly enhances its perceived value, leading to its recognition as a crucial safety component in diving. Moreover, the influence of instructors, along with divers’ personal experiences, whether of safety benefits or adverse situations, appears to be linked to their continued use of the MRS (or not) after training.

Table 2

Personal experience with the use of a mouthpiece retaining strap (MRS) during closed circuit rebreather (CCR) diving; 'trained' refers to CCR divers with specific training in use of a MRS whereas 'untrained' refers to CCR divers without such training

Opinion	Trained (n = 210) n (%)	Untrained (n = 353) n (%)	P
A MRS puts me in dangerous situation	21 (10.0)	13 (3.7)	0.002
A MRS has helped me during a dive	72 (34.3)	30 (8.5)	< 0.0001
I can think of at least one accident that could have been prevented with a MRS	74 (35.2)	97 (27.6)	0.06

Table 3

Comparison of diving experience and qualification between regular and occasional (or non-) users following MRS training; CCR – closed circuit rebreather; IQR – interquartile range

Parameter	Regular users, n = 138	Occasional (or non-) users, n = 71	P
Years CCR certified Median (IQR)	5 (2–10)	10 (5–17)	< 0.0001
Annual CCR dive hours Median (IQR)	58 (40–100)	100 (50–200)	< 0.0001
CCR instructors, n (%)	31 (22.5)	29 (48.3)	0.005

Loss of consciousness resulting from a gas toxicity accident was rarely reported by interviewed CCR trimix divers,⁴ though a survivor bias might affect such data. Inappropriate breathing gas was frequently observed in CCR fatalities suggesting a potentially higher incidence of LOC with lethal outcomes in this population.^{3,7} In contrast, military diving protocols may dramatically improve survival rates following these events.¹ Indeed, protective airway systems (MRS or FFM) have long been employed in military and commercial diving. Despite existing safety evidence^{1,5} and the position of the rebreather training council,⁸ only 37% of CCR divers in the present study have received formal MRS training mostly during their initial CCR training. Three (0.5%) of them reported a LOC event during a CCR dive and were wearing a MRS. Among them, two declared not having received specific training in its use, though all considered that this device had prevented them from drowning. Similarly in the French Navy study, Gempp reported zero fatalities and only two moderate cases of water aspiration among 54 CCR military divers who lost consciousness while using a MRS.¹ It is important to clarify that none of the divers in the Gempp report died, contrary to misinterpretation elsewhere.⁵ The three fatalities reported didn't occur in the subset of the 54 LOC divers, but they involved divers who became trapped in wrecks and subsequently drowned.¹ The military's enforced use of airway-protective systems and rigorous team-diving protocols appear pivotal in converting potential fatalities into survivable incidents. Without these safety measures, the outcomes would very likely have been markedly worse.

There are no strong data quantifying the degree to which a MRS reduces risk for recreational divers, especially if

they are diving solo, but this has once again emerged as a concern, as highlighted in the recent Rebreather Forum 4 statements one of which says "*The forum recognises the use of correctly deployed MRS as a strategy for avoiding loss of the mouthpiece and minimization of water aspiration in the event of loss of consciousness underwater*".⁹ Recently, some manufacturers have begun integrating these systems into recreational diving equipment and it is now a requirement for CE standards (European standard EN14143; 2013). However, a lack of proper instruction may lead to the perception within the recreational diving community, that a MRS is an unsafe or ineffective tool.

No significant impact of age or education level was associated with MRS use. However, more frequent divers, and especially instructors, were more likely to have received MRS training. Paradoxically, instructors and the most active divers used a MRS less often. This tendency, where the most experienced individuals may be the least diligent about their own safety, is also well known within the mountaineering community.¹⁰ It was expected that most untrained divers and non-users would report fewer events, whether favourable or hazardous, during the use of the MRS, simply because of less frequent use. Unfortunately, the survey cannot confirm whether untrained divers actually use the MRS, although some mentioned doing so in open comments. Two-thirds of divers, regardless of whether they were formally trained or regular MRS users, recognised that it could help prevent drowning, especially when their dive training included instruction on its use. Their perception of comfort benefit was more muted: the main criticism centred on increased procedural complexity, which was cited as a primary reason

for opting not to use the device. The extent and manner in which instructors emphasise the MRS during training appears to influence its uptake. Thus, raising instructor awareness and ensuring proper MRS training are essential prerequisites for broader acceptance among recreational divers. Interestingly, 61% of those trained always use the MRS, while 24% never use it, highlighting that training alone doesn't automatically guarantee adoption.

Beyond improving training on the MRS, it also seems that some progress should be made to develop systems that will fit different morphotypes to improve comfort and lips sealing. The need for quick removal systems also seems relevant to improve engagement with the MRS, as well as the need for the certification agencies to develop proper training programs on how to use it. Rapid removal becomes critical in some scenarios such as caustic cocktail; this can be facilitated by a quick-release clip and proper skill development in the procedure. Correct use of an MRS is of paramount importance because merely having it around the neck is not enough to ensure safety, and the MRS needs to be tight enough to ensure a proper seal between the lips and the lip-covering flange. Indeed, some divers self-reported issues with their MRS, mainly related to incorrect use or insufficient training. The association with a BOV may also reduce the risk as it allows to switch from the breathing loop to an independent open circuit system without removing the mouthpiece.

LIMITATIONS

This study faced several limitations. The dissemination channel may have introduced recruitment bias, and the response rate is unknowable. Since the dissemination took place within the DAN framework and other groups with a similar mindset (e.g., InDepth Magazine readers or technical diving social media groups), it is possible that the responding divers are more safety conscious than the rebreather community at large potentially creating a selection bias. The limited information regarding the frequency and potential use of the MRS by untrained divers may constrain the interpretation of our findings. It is plausible that some respondents categorised as untrained were, in fact, self-taught users who did not report this as an alternative form of training, thereby limiting a comprehensive assessment of MRS use within this population. Additionally, diving behaviours may vary depending on the region.⁴ The lack of information about the divers' country of origin and the exclusive use of English language may result in overlooking a significant portion of the rebreather diving community, which may have different perspectives.

Conclusions

This survey suggests an influence of formal training on use of a MRS and its positive perception and use. The MRS is still not widely adopted within the recreational rebreather diving

community. However, survey data and operational evidence suggest it may serve as a valuable safety aid, particularly when combined with proper training. Many arguments suggest that combining a MRS and BOV can provide critical protections in periods of great stress and hazard. While not universally applicable to every configuration or diver preference, improved training and equipment compatibility can help divers make informed decisions about its use. Manufacturers, training agencies, and instructors all have a role in enhancing MRS education and encouraging informed, context-appropriate adoption. Furthermore, as pointed by the Rebreather Training Council, "*MRS devices should not be seen as an independent solution, but may offer some protection from drowning, especially when used properly, and in concert with other safe diving practices (e.g., completing pre-dive checklists, careful monitoring of gas supplies, buddy/team-based diving, progressive experience building, and skill refinement)*".⁸

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