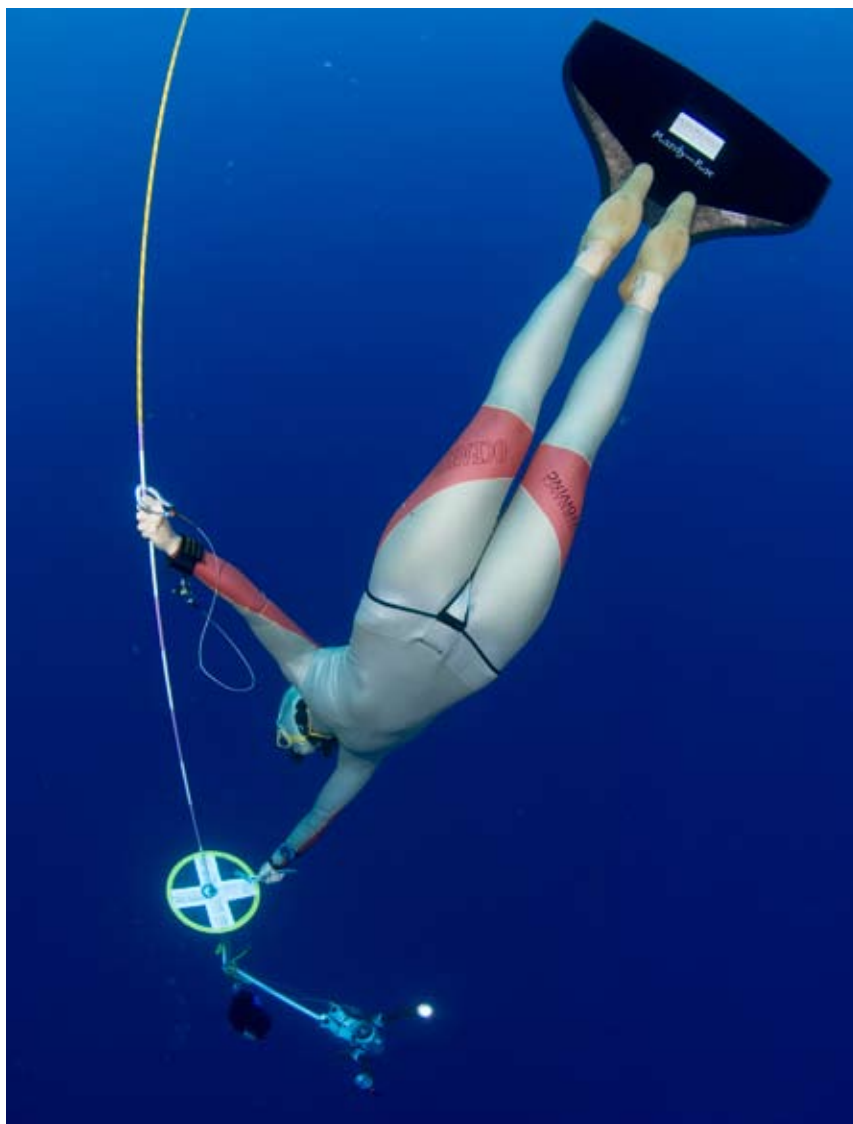


Breath-Hold Diving:

Expanding Our Aquatic Range



Mandy-Rae Cruickshank sets 88m constant ballast world record in 2007.

Breath-hold or apnea diving, also known as freediving, has a long history. It has been used in hunting, gathering, competition and even warfare. Regardless of the reason for breath-hold diving, doing it safely requires an appreciation of the risks and strategies for protection. This article is based on a brief review of the topic.⁵ Additional technical details and references are available in the published paper.

BY NEAL POLLOCK, PH.D.

Freedivers, relying only on the air they can hold in their lungs, operate in a wide range of environments and pursue an assortment of goals. In recent years, freediving has evolved into an increasingly popular extreme competitive sport. Numerous disciplines are now recognized by the International Association for the Development of Apnea (AIDA; <http://www.aida-international.org/>).

These are listed below with their respective record performances. The current no limits depth record of 702 feet (214 meters) for a freediver is mind-boggling. The ambient pressure at that depth is 22.3 atmospheres absolute.

Breath-hold basics

Physiological alterations begin with water immersion. The blood volume in the chest is increased while vital capacity (the total volume of gas in the lung that can be expired or inspired in a single breath) is decreased. Facial immersion, particularly in cool water, initiates the classic diving reflex observed during breath-hold — heart rate and cardiac output are decreased, peripheral vasoconstriction and blood pressure are increased, and the spleen contracts to release more oxygen-carrying red blood cells into the bloodstream.

In normal respiration, a period of apnea (an absence of breathing) follows every inspiration. It is the duration of the apnea that sets apart the unconscious breath-hold from the longer, voluntary breath-hold that occurs during freediving. The rising concentration of carbon dioxide in the blood is primarily responsible for the drive to end breath-hold. The breaking point can be postponed by altering the physiological conditions in the blood or

COURTESY PLATT PHOTO

by increasing the individual tolerance to such conditions.

Extreme breath-hold efforts are not without risk. Injury and death do occur, the latter most commonly with unsupervised divers. Techniques for improving breath-hold performance are best practiced in a controlled setting with responsible oversight. This can be done through professional training programs, which are increasing in numbers.

Manipulative practices

Reduce metabolic demand

One of the simplest ways to extend breath-hold time is to reduce physical effort and thus the metabolic demand. Comparing the record performance between no-fin and fin subdisciplines of dynamic apnea and constant weight illustrates the energetic advantage of using fins. The static apnea and no-limits disciplines demonstrate the extremes of what can be accomplished on a single breath of air if the diver uses minimal physical effort. Persons swimming while breath-holding are well served by using the most efficient technique possible.

Distraction

A variety of manipulative practices can be employed to prolong breath-hold time. A simple strategy involves the use of distraction. For example, a relatively inexperienced apnea diver nearing the voluntary breakpoint may experience a brief but significant reprieve if he or she tries to swallow a couple of times before ending the breath-hold dive. It will be difficult to swallow and the distraction involved can temporarily reduce the sense of urgency to breathe.

Hyperventilation

The most well-known manipulative practice used to increase breath-hold time is hyperventilation. The basis for its effectiveness is the difference between the high concentration of carbon dioxide in the body and the low concentration in



MARINE LANG PHOTO

Mandy-Rae Cruickshank's sets 2002 static apnea world record, Kirk Krack safety.

AIDA-recognized competitive freediving disciplines and records (as of June 13, 2008)⁵

Discipline	Description	Record Performance	
		Male	Female
Static Apnea (min:s)	resting, immersed breath-hold in controlled water (usually a shallow swimming pool)	10:12	8:00
Dynamic Apnea — with fins (ft [m])	horizontal swim ¹ in controlled water	801 (244) ¹	673 (205) ¹
Dynamic Apnea — no fins (ft [m])	horizontal swim ¹ in controlled water	610 (186) ¹	489 (149) ¹
No Limits (ft [m])	vertical descent to a maximum depth on a weighted sled; ascent with a lift bag deployed by the diver	702 (214)	525 (160)
Variable Weight (ft [m])	vertical descent to a maximum depth on weighted sled; ascent by pulling up a line with kicking	459 (140)	400 (122)
Constant Weight — with fins (ft [m])	vertical self-propelled swimming to a maximum depth and back to surface; no line assistance allowed	367 (108)	295 (90)
Constant Weight — no fins (ft [m])	vertical self-propelled swimming to a maximum depth and back to surface; no line assistance allowed	282 (86)	197 (60)
Free Immersion (ft [m])	vertical excursion propelled by pulling on the rope during descent and ascent; no fins.	354 (108)	269 (82)

¹ horizontal swim



CRAIG GENTRY PHOTO

Mandy-Rae Cruickshank competing at the 2006 World Freediving Championships.

Glossopharyngeal breathing

Glossopharyngeal insufflation (also known as ‘lung packing’ or ‘buccal pumping’) increases available gas above normal vital capacity. This involves gulping air in a series of small volumes after the point of normal full inspiration has been reached. This technique does allow additional gas to be stored, but aggressive efforts may also disrupt circulation and cause dizziness, tunnel vision, loss of consciousness and possibly pulmonary barotrauma.

Glossopharyngeal exsufflation (also known as ‘reverse packing’) involves using the muscles of the mouth and throat to draw air out of the lungs when the lung volume is near or below residual volume. This technique can be used to enable middle ear equalization at depths deeper than would otherwise be possible.

Dietary factors

Increased competition means that small advantages can make a critical difference in a freediver’s final ranking. Studies of dietary intake and breath-hold performance have produced variable results. It is likely that further efforts will be directed at developing optimal dietary patterns for competitors.

Breath-hold safety

Training and supervision

Safety in breath-hold requires a respect for reasonable guidelines. The impressive safety record maintained in competitive events can be replicated at other levels of involvement only if suitable protections are in place. As a primary rule, divers should not conduct breath-hold dives alone. The finding that more than half of the recently reported fatal breath-hold incidents were unwitnessed indicates a fundamental problem in practice.⁶ While often impossible to confirm, it is likely that manipulative breath-hold practices were involved and that in many cases the ready presence of others could have provided timely intervention.

normal air. Increasing ventilation beyond that required to meet metabolic needs (in a word, hyperventilation) can rapidly reduce carbon dioxide levels in the blood. A breath-hold dive begun after hyperventilation can be prolonged since the drive to breathe will not develop until the normal trigger point of carbon dioxide is reached.

The primary risk of pre-breath-hold hyperventilation is hypoxia and loss of consciousness. While hyperventilation can greatly reduce carbon dioxide stores, it does little to increase oxygen stores. Loss of consciousness due to hypoxia can develop before the diver feels any urge to breathe. For the diver, the risk is increased with the magnitude of the hyperventilation. While the hazards of hyperventilation were well described almost 50 years ago, imprudent use remains a factor in many fatal incidents.^{2,3,4,6}

The risk of losing consciousness due to hyperventilation is greatest during the ascent phase of a breath-hold dive. In addition to the continued consumption of oxygen, the decreasing ambient pressure produces a rapid drop in the concentration of oxygen in the blood — with the greatest drop in the shallowest water where the relative pressure change is maximized. Loss of consciousness will commonly occur just before the diver surfaces or shortly after surfacing but before the oxygen in the first inspired breath can reach the brain. This condition is best referred to as hypoxia of ascent. The term ‘shallow-water blackout’ is ambiguous since it was first used to describe the loss of consciousness associated with the use of closed-circuit oxygen rebreathers.

Effective direct supervision includes the pre-breath-hold, breath-hold and 30 seconds post-breath-hold periods. A simple two-person, one-up-one-down buddy team with committed direct supervision can provide effective protection for shallow diving situations. As dive depths increase, a group of three (one-down, two-up) may be preferable. Allowing a recovery period of twice the dive duration is a reasonable practice. That practice also ensures that one of the divers available at the surface for backup is at least partially rested. Problems can arise when dive depths approach individual limits. The breath-hold performance of a potential rescuer may be badly compromised by the stress of an emergent condition.

More advanced activities require a more extensive support network and should be conducted only with experienced groups prepared with thoughtful planning, proper equipment and monitoring, and emergency protocols.

Buoyancy

Buoyancy is an important consideration for breath-hold divers. The hazards during ascent far outweigh the benefits of an easy descent when a diver is overweighted. Buoyancy is lost under pressure, more so when a compressible suit is worn, increasing the effort required and oxygen consumption during ascent. A negatively buoyant diver will rapidly sink if consciousness is lost. This will make it more difficult, or in some cases impossible, for a timely rescue. For safety reasons, it is recommended that divers are weighted to be neutrally buoyant at a depth of approximately 15 feet (4.5 meters).

Restricted hyperventilation

A balance between prolonging breath-hold and reducing the risk of loss of consciousness is possible by restricting the amount of pre-breath-hold hyperventilation. Limiting hyperventilation to two or three maximal ventilatory exchanges immediately before the breath-hold will increase breath-hold time but it is probably

also safe for most leisure circumstances. An alternative approach is to arbitrarily restrict breath-hold time.

A proposal in 2006 called for breath-hold by recreational freedivers to be voluntarily limited to 60 seconds.¹ This would allow for varying patterns of hyperventilation and physical activity with minimal risk of loss

Learning from the mistakes of others is an important strategy to promote safety for all.

of consciousness. The only tool required to make it work is a watch with a countdown function set to beep at 45 or 50 seconds as appropriate for the depth to remind the diver when to begin to ascend.

Flotation vests

Flotation vests designed specifically for breath-hold diving represent a potentially important safety tool now under development. These will automatically inflate if an adjustable user-preset time at depth is exceeded. While such devices will not eliminate the risk of blackout or the risk of inspiring water during a loss of consciousness, they will reduce the mortal risk of such events by returning the diver to the surface.

Reporting freediving incidents

Communicating the details involved in both fatal and nonfatal breath-hold incidents is another tool to improve the safety of current and future freedivers. Learning from the mistakes of others is an important strategy to promote safety for all. The ability to share salient details should encourage divers to reflect on and, where appropriate, improve their own practices. Since 2005 Divers Alert Network has included breath-hold cases in the annual report on diving safety. Primarily focused on fatal incidents, the program is expanding to capture nonfatal events.

Conclusions

Breath-hold diving is experiencing a growth in popularity that reflects an impressive evolution of record-setting performance. Safe participation in competitive events is fostered by a wide range of carefully developed regulations and protocols. Appropriate safety protocols are required for all breath-hold divers. The elimination of solo freediving and the incautious use of hyperventilation would have the greatest positive impact on the population at risk. Continued development of appropriate and accessible training programs and the regular communication of incident case reports are important strategies to increase awareness of both risks and appropriate practices.



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About the Author

NEAL W. POLLOCK, Ph.D., is a member of the DAN Research department and a research physiologist at the Center for Hyperbaric Medicine and Environmental Physiology, Duke University Medical Center (neal.pollock@duke.edu).