and should not be presented by a coach without its serious hazards being explained. While haemoptysis is the visible consequence of acute pulmonary barotrauma, any less severe damage might remain subclinical. Hence, regular competitive apnea diving over a few seasons might carry a chronic cardiopulmonary risk leading from early functional changes to the manifestation of pulmonary hypertension.[9]

Regarding lung squeeze, it should be noted that involuntary contractions of the thorax and diaphragm can produce waves of negative pressure.[10] Once intrathoracic pressure is already negative at great depth, additional negative pressure waves might well damage the pulmonary capillaries.

Finally, the risk of decompression sickness (DCS) after breath-hold dives has been considered by Dr Schagatay. After a breath-hold diver has suffered from cerebral DCS, such athletes should only perform extensive breath-hold activities near a treatment chamber.

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Reply: Safety will increase with knowledge

Dear Editor,

Thank you for the opportunity to respond to Dr Schipke and his colleagues. It seems these writers are responding to a paper promoting extreme breath-hold diving. This is not the case; I am simply describing what people do and attempting to understand their physiology. Since part of the scientific community decided to stop reporting on the physiology behind deep diving in the 1990s, record setting has continued evolving at a tremendous pace. Thus, the lack of involvement of scientists has had little relevance to recruitment to these sports. Turning a blind eye to these activities simply does not work. My target audiences for the reviews were both advanced freedivers and researchers, and my aim to make diving safer. Many divers have appreciated the papers for telling them more about the risks they face. Finally, there is a response from some researchers, albeit a negative one: I was hoping to stimulate renewed interest in researching these factors and potential risks, not a recommendation of 'non-reporting' and neglect.

I share with the writers their concern that these activities are potentially dangerous, but believe they could be made safer by a better understanding of the real and imagined risks. I have also come to realise when studying these divers (after initially sharing the view of the writers that these divers must be careless daredevils) that these sports men and women are not there to take risks but to limit them. Just like climbers using advanced safety systems, they try to reduce the risks to a minimum. The safety routines of these sports can be learned at serious climbing or diving clubs. But how could divers avoid risks unknown to them? This was well put recently by a world record holder in deep diving when thanking me after reading my last paper:

> "*Freediving, just like climbing, is not about taking risks, but on the contrary about how to avoid risk. That's why we need researchers who find out and tell us which the major risks are when we dive, and what isn't a risk. If nobody does – then we are exposed to risk!*"

Many sports and other activities are 'inherently dangerous', but this does not deter us from trying to make them safer.

Why should it in this case? To achieve maximal performance is the goal in most sports, there is nothing surprising or wrong with that. My series of review papers was aimed to provide a state-of-the-art update of our knowledge of the physiology of competitive free diving and, with appropriate rather than negative responses from others, I believe my goal of making diving safer can be achieved. Apart from active divers, who will dive safer when given some serious fact-based information, the target audience for these papers is the scientific community. New data has to be added, we cannot simply parrot old 'facts' when these have been proven wrong by actual performance; more research is needed!

I am grateful for Schipke et al's response as this hopefully might stimulate new research from physiologists who do not turn a blind eye to these extreme sports. To simply dismiss the entire field of research by saying "*freediving is dangerous*" seems to be a very unscientific attitude. If ignorance in any field would make things safer, I would be very surprised. With that said, there are points in the letter that deserve direct comment as they are somewhat surprising, and in some cases make me wonder if they have read my papers carefully enough, as all the points made and the associated risks have been dealt with in my reviews.[1–3]

Extended apnea and hypoxic brain injury

Schipke et al. dismiss the lack of alarming increases of markers of brain damage as of little informative value.[4] Another study looked at cognitive function in divers who have experienced syncope often, without evidence of damage,[5] and both studies were cited in my first review.[1] Negative effects from dive-related hypoxia cannot be excluded, but similar periods and levels of hypoxia are experienced by climbers, sleep apnea and COPD patients and by many highly cerebral diving mammals. While there may be other consequences in the patient groups, it seems the brain tolerates this surprisingly well. Perhaps we do have an ability to cope with this type of hypoxia, at least after training? Hypoxic preconditioning in rats is neuroprotective.[6] If repeated exposure reduces risk, this could be interesting also in other groups, e.g., limiting the impact of stroke. I have studied many competition divers directly after a syncope, and found that they generally recover completely within 3–4 min. Syncope in a competition leads to disqualification, but the situation is quickly resolved by rescue divers performing the blow/tap/talk manoeuvre.[2] To say that long term effects must be suspected is not supported by present scientific evidence, but hypoxia in apnea clearly deserves further study. After years in the field, I know personally some 10 of the 20 best deep divers in the world, and there is nothing wrong with their brains: the most merited man in deep diving is an airline pilot, and the most merited woman has just finished her doctoral degree.

I agree completely that people can die from breath-hold diving and that deep divers are potentially at greater risk. Only, competition diving is not dangerous per se. In the approximately 40,000 competition dives in the six existing competition disciplines organised by AIDA International, the leading diving competition federation, there have been no fatalities to date. Diving alone is, however, dangerous; diving on a sled as in non-competition record attempts has indeed involved lethal accidents. Spearfishing also causes casualties, as does training without the proper safety measures in place. To learn from competition diving is the best we can do to increase safety in freediving. If all freedivers were using the safety systems used in diving competitions, fatalities would fall to a minimum. That is why these safety systems have been described in detail in my reviews.[2,3]

Barotrauma

This was not a training recommendation – I simply report what people do. I also report the possible side effects in my review: that this may lead to capillary rupture and pulmonary oedema. Surprisingly often it does not. Why? Are there protective mechanisms? How about researching this? Scuba divers are told how to avoid barotrauma, drowning and decompression sickness (DCS); why not give freedivers the same information? Many scuba divers die each year, but this activity is not categorically advised against, yet scuba diving is physiologically much more unnatural than freediving, and there are no mammalian counterparts to compare our responses with to see whether they are protective or pathological. Competing athletes in all sports try to fool, if not physics, at least physiology. That is an inherent quality of sport. In the case of the described diving and training methods, however, all competition divers already know these 'tricks', but they may not be aware of the possible side effects.

Glossopharyngeal insufflation (GI) and exsufflation (GE)

Again, risks and effects pointed out by the authors have been dealt with in my review.[3] Trumpeters will likely be at twice the risk according to their own reference, with lung pressures of 150 mm Hg.[7] Our group was the first to describe GI in divers scientifically, including pointing out (but not proving) the potential risks.[8,9] The study by Chung et al used maximal GI, which is not normally used by divers, and also, as noted by these authors, the supporting pressure from water may counteract the development of pneumomediastinum.[7] Total lung capacity (TLC) being lower in an immersed diver, it may be that an immersed diver can use GI to reach normal 'dry' TLC before diving, without side effects. The conclusions by Chung et al. are more tentative and nuanced than Schipke et al would have us believe, and these matters clearly deserve further study.

Lung squeeze and diaphragmatic contractions

As known to all divers, not only can diaphragmatic contractions produce waves of negative pressure, but they will during every extended dive.[10] However, at least 90% of all deep divers present back at the surface without any

signs of side effects. This is good news. Why is this so? And why not in the remaining, perhaps 10%, of divers? Are there mechanisms that could be protective in other groups as well? Again, a problem worthy of deeper scientific study.

Decompression sickness

Although the possibility of DCS after repeated apnea diving has been pointed out by others, we reported the first Doppler bubble score grade 1 in a freediver after a single deep dive.[3] This is alarming, especially as diving gets progressively deeper. I recommend strongly that chamber facilities should always be provided to deep freedivers – not only to those with previous DCS – and that freediving tables should be developed. Post-dive oxygen is already being used as divers become more aware of the potential DCS risk.[3]

Whilst the deepest diving in the variable weight and no-limits disciplines is certainly not something I would recommend, the people doing this nevertheless provide a model for studying extreme survival. From a natural science perspective, it is interesting to try to understand how this is at all possible. This may also be useful for other survival situations, not the least in emergency medical situations. I believe better understanding of how our bodies work is a good thing, and that it will increase survival in many different situations. I remain uncertain in what ways my reviews could be considered "*uncritical*" and how these writers suggest we go about our common goal, to make diving safer, without trying to better understand how our bodies work when we dive. To ignore good news and report only the bad is unscientific. The only way to make the divers listen is by gaining their trust. This is not done by banning their sport, but by providing solid facts. That is, I believe, our job as scientists.

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Key words
Breath-hold diving, hypoxia, physiology, decompression sickness, barotrauma, safety, letters (to the Editor)

Diving medicine for scuba divers

Dear Editor,

Diving medicine for scuba divers by Edmonds, Thomas, McKenzie and Pennefather is a web-based book available as a free, downloadable text. Recently it has had to move to a different web host. Thus, it and all bookmarked subdirectories will no longer be available at the old address, which one needs to delete and replace with a new one: <www.divingmedicine.info>.

Since the text was made available almost three years ago, there have been over 30,000 downloads. Because we do not apply copyright restrictions, dive instructors and clubs are encouraged to supply copies to their clients and members; diving physicians have supplied specific chapters to their diver patients. Thus we have no idea of the actual number of copies distributed.

We have upgraded the text, and so even those with downloaded copies should now replace them with the 2012 4th edition. Our appreciation goes to all those who have made suggestions for corrections and modifications.

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Key words
Textbook, world wide web, recreational diving, letters (to the Editor)