High blood pressure during breath-hold diving is not a physiological absurdity

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TO THE EDITOR: In a 2009 article, Sieber et al. (4), having found “normal” blood pressures (BPs) using a sphygmomanometric method in subjects performing breath-hold dives to 10 m of depth, suggested that the very high BPs we recorded invasively in two healthy expert breath-hold divers diving to 6 ATA (50 m) in our pressure chamber (2) were artifacts caused by our recording system. They also argued that our “alarming values” of BP are incompatible with normal physiology, despite the fact that BPs of the same magnitude have also been recorded in healthy breath-holders in other laboratories (1, 3).

Sieber et al. (4) suggest that the reference chamber of our pressure transducer (model CDXIII, Cobe Cardiovascular Labs, Arvada, CO) did not keep pace with the ambient pressure changes during the dives. Surprisingly, they disregard the following information in the methods of our paper (2): “The system had been tested in separate (unmanned) compressions for absence of pressure and temperature biases.” Sieber et al. (4) attempted to verify their hypothesis of a technical bias in our recording system but, while trying to reproduce our recording situation, employed a different type of transducer and experimental set-up. Thus the pressure bias they recorded has no apparent bearing on our experimental methodology. This conclusion is strengthened by recently repeated tests in our laboratory using the original pressure profile and transducer actually employed in the original study (2) as well as an identical, unused transducer; tests that again showed no relevant artifacts. Thus we feel confident that our published measurements of BP in the simulated deep breath-hold dives (2) are free of methodological errors.

Scrutinizing our results, Sieber et al. (4) chose to analyze only the BP recording in Fig. 5B, ignoring the one in Fig. 5A, which contradicts their arguments. They gave no consideration to the possibility that the BP reduction during the “ear-clearing” stops in Fig. 5B might have a physiological explanation. It is well known that the Valsalva maneuver, often used for ear clearing, can impede venous return and reduce cardiac output and blood pressure. Looking at Fig. 5A the same way as these authors analyzed Fig. 5B yields a very different outcome: during the first compression stop, the BP increased to the highest level in the entire dive (292/168 mmHg); during the second stop, the BP remained in the 250/150 mmHg range. The absence of drops in BP would be expected if the diver achieved ear clearing by swallowing or using the Frenzel maneuver, neither of which increases intrathoracic pressure. The reduction in BP during the bottom stay and ascent in diver RM (Fig. 5B) agrees perfectly with the bradycardia-based halving of cardiac output during these dive phases (Fig. 4, 25° in Ref. 2).

Different diving conditions in the Sieber et al. study and ours may explain differences in outcome. The divers in the Sieber et al. study wore wetsuits in 26°C water. Thus their skin temperatures were considerably higher than in the divers in our study who were unprotected against the temperature of 25°C. Cool water is likely to enhance the circulatory diving response. Furthermore, in the Sieber et al. study, the divers, sitting still at 10 m for the 50- to 60-s-long BP measurement procedure were, during that time, probably in a relatively stable circulatory state. By contrast, except for two 5- to 6-s interruptions of descent and 16 s at the bottom, the divers of our study underwent dynamic depth changes of between 1.2 and 0.8 m/s. Thus they experienced continuous changes in physiological stressors. In sensory physiology, dynamically changing stimulation is known to be often more effective than static stimulation. It might be that the shrinking, respectively, expanding lung/chest volume during compression/decompression acted particularly forcefully on the mechanism, so far unexplained, that causes the diving response to be more pronounced at low lung volumes than at large.

In conclusion, we hold that our observations during actual diving conditions demonstrate genuine physiological and quantitatively correct BP increases. Clearly, the frequency in the general breath-hold diving population of the reactions we have observed cannot be determined from our measurements in two blood-related divers. However, since 4/10 subjects in Sieber et al.’s study had diastolic BPs reaching 100 mmHg or more when diving, one may hypothesize that those subjects, if exposed to dynamically changing depth, would have developed even more impressive BP changes.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

REFERENCES