Apnea trained athletes: rather marine mammals than humans?

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Introduction: Diving mammals are unable to breathe underwater. In order to remain and survive underwater, they developed several physiological mechanisms, e.g. the diving response. The diving response is characterized by bradycardia (slow heart rate), peripheral vasoconstriction (narrowing of blood vessels), a rise in blood pressure and a redistribution of the blood flow to regions that are most sensitive to hypoxia, such as the brain and the heart (i.e., O_2-conserving effect). Humans show a similar response during apnea. This response, which is initiated by apnea and augmented by facial immersion in (cold) water, is more pronounced in apnea-trained athletes than in untrained humans[1,2]. We hypothesized that there would be a difference in average heart rate (HR) fall between dynamic apneas with facial immersion and apneas in air during exercise. In a second hypothesis, a larger HR fall was expected for the apnea-trained athletes compared to non-apnea-trained athletes (controls).

Methods: In this experimental study, the bradycardic response of 10 female apnea-trained athletes (height: 1.64 ± 0.08 m, body weight: 57.6 ± 6.7 kg, body fat: 20.6 ± 3.5 %, VO_2max:2457 ± 354 ml/min) was compared with the response of 10 matched controls (height: 1.65 ± 0.05 m, body weight: 59.3 ± 5.6 kg, body fat: 18.5 ± 4.5 %, VO_2max: 2396 ± 318 ml/min). All subjects performed two 40-minutes endurance tests on a cycle ergometer in a random order at 25% of their maximal power output. Every 4 minutes, they performed a 30 seconds apnea while cycling, with facial immersion (FIA) in cold water (15°C) or in air (AA) (18°C). This was repeated 7 times every test. During both conditions, the HR of the subjects was recorded continuously. Absolute (bpm) and relative (%) HR drop represent the difference between the HR plateau during cycling and the lowest HR reached during apnea. Statistical analysis was done using a repeated measures (M)ANOVA. Significance was set at $p<0.05$.

Results: For the entire group, FIA as well as AA resulted in a significant fall in HR ($p<0.001$). Both average absolute (FIA: 48 ± 11 bpm vs. AA: 36 ± 15 bpm; $p<0.05$) and relative (FIA: 37 ± 7 % vs. AA: 28 ± 11 %; $p<0.05$) fall in HR were significantly larger during FIA compared to AA. Apnea-trained athletes were able to sustain 92 % of all the apneas completely. Controls only completed 36 %. No significant differences were found in average absolute and relative HR drop during the apneas with and without water between the apnea-trained athletes (FIA: 50 ± 11 bpm; 39 ± 6 %; AA: 40 ± 16 bpm; 31 ± 12 %) and the controls (FIA: 45 ± 10 bpm; 34 ± 7 %; AA: 32 ± 14 bpm; 24 ± 10 %).

Conclusions: AA is sufficient to elicit a significant bradycardia as a part of the diving response. However, and in line with our first hypothesis, during FIA, where the facial cold receptors and thus the trigeminal nerve are stimulated, this response is more pronounced. In contrast to our second hypothesis, no differences in absolute and relative HR drop were found between apnea-trained athletes and controls. It is possible that breath-holding for 30 seconds was too short to bring out the full response in the apnea-trained individuals. Also, the specific environmental conditions during testing (water and air temperature) as compared to their natural training environment can have a different effect on the responses. Lastly, hydrostatic pressure, which was absent during facial immersion, might be necessary to elicit a complete response.

Keywords: mammals; humans; diving response; dynamic apnea; bradycardia

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