Diving response: an argument for the Aquatic Ape Theory in human evolution?

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Introduction: In contrast to the widely accepted evolution theory where apes left the trees to live in the African savanna, the Aquatic Ape Theory suggests human ancestors came to ground-level to live in aquatic environments close to riverbeds and in coastal regions[1]. Humans are believed to have developed adaptations to an aquatic lifestyle. One of those adaptations is the diving response (DR). DR is characterized by bradycardia (slow heart rate) and peripheral vasoconstriction (narrowing of blood vessels), resulting in a blood pressure increase and a blood flow redistribution to the hypoxia sensitive regions (i.e., O_2-conserving effect)[2]. Japanese fisher women, called Amas, are still utilizing this feature to dive for seafood. The aim of this study was to explore which physiological characteristics influence the heart rate (HR) drop during dynamic facial immersed apneas in apnea-trained and non-apnea-trained (controls) athletes.

Methods: This experimental study recruited 20 healthy athletes of which 10 apnea-trained (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) and 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 passed lung function tests (forced vital capacity (FVC), forced expiratory volume in 1s (FEV1), Tiffeneau-Pinelli index (FEV/FVC*100)), 5 maximal static apnea trials in air and a maximal incremental ramp cycling test. All subjects then executed a 40min cycling endurance test at 25% of their maximal power output. Every 4 minutes, a 30s apnea while cycling with facial immersion (FIA) in cold water (15°C) was performed. HR was monitored continuously. Absolute (bpm) and relative (%) HR drop represent the difference between the HR plateau during cycling and the lowest HR reached during apnea. Two-way Repeated Measures Anova, followed by Paired Samples T-tests were executed to analyze HR drop during dynamic apnea. One-way Manova was used to explore differences in apnea-trained athletes and controls. Pearson correlations were calculated to investigate possible relationships between physiological characteristics and HR drop. Significance was set at $p<0.05$.

Results: Maximal breath hold time (BHT) was significantly longer in apnea-trained athletes compared to controls (161±29s vs. 113±39s; $p=0.005$). No significant differences in lung function, maximal ventilation and breathing frequency were found between apnea-trained subjects and controls. During the 40min cycling test, no differences in HR drop appeared between both groups. The length of the sustained dynamic apnea was significantly longer in the apnea-trained group (30±0s vs. 24±5s; $p=0.002$). During every apnea, the absolute average HR of the entire group dropped (48±15 bpm) significantly compared to the HR plateau ($p<0.001$ for every apnea). Significant correlations between the Tiffeneau-Pinelli index and the relative HR drop during dynamic apnea ($R=0.508$, $p=0.022$) and between breathing frequency and the length of the sustained dynamic apnea ($R=-0.632$, $p=0.004$) were found in the entire group.

Conclusion: The decrease in HR during dynamic apnea with facial immersion, suggests that the parasympathetic stimulus overrules the sympathetic stimulus caused by cycling[2]. This phenomenon can be explained by the evolutionary O_2-conserving effect of DR. In contrast to previous studies, no differences in average HR drop were found between apnea-trained and control subjects[3]. Moreover, the apnea-trained group had a significantly longer maximal BHT and a longer sustained apnea during cycling. The lack of differences in lung function between the groups suggests the apnea trained group was not as specifically trained as in other studies. Correlations found between Tiffeneau-Pinelli index and HR drop and between breathing frequency and length of sustained dynamic apnea, suggest that lung function plays a role in DR.

Keywords: human evolution; aquatic ape theory; diving response; dynamic apnea; bradycardia

References

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