Modeling Gender Differences in Heart Rate During the Diving Reflex: Insights into Physiological Adaptability

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Background. The diving reflex helps mammals sustain apnea and reduce oxygen consumption through bradycardia. Its physiological mechanisms and clinical implications are unclear, but it may be affected by temperature, depth, and physiology.

Objective: Our aim was to model the gender differences in the HR reduction due to diving reflex, by using a linear and exponential mathematical model.

Methods: The study enrolled 28 volunteers (11 men, age = 26.0+-8.48; 17 women, 24.23+-8.87). It comprised three consecutive phases, with baseline heart rate measurement (5 mins) preceding three apneas (immersing the face in cold-water) interspersed with 1-minute rest periods, followed by a recovery phase lasting 10 mins. The heart rate was monitored using a firstbeat sensor, and we computed the LF, HF power, and LF/HF ratio. To model the bradycardia during the diving phase, we used an exponential function rr = a + b*exp(tau*t) fitted to the RR-interval time series normalized by the mean baseline heart rate.

Results: During the first apnea period, men exhibited a stronger bradycardia response with a time constant of tau_male=0.11 compared to women with tau_female=0.03. However, the value was similar for the second and third apneas, suggesting an adaptation. The mean LF/HF tend to decrease after the first apnea, more prominently in females, and then started to increase until it surpassed the basal value: mean LF/HF males: 2.74 (basal), 2.82 (after apnea 1), 2.34 (after apnea 2), and 3.3 (recovery), mean LF/HF females: 2.58 (basal), 2.19 (after apnea 1), 2.57 (after apnea 2), and 2.87 (recovery).

Conclusions: Our findings suggest that there are gender-specific differences in the diving reflex, which can be quantified by the exponential model and the balance between sympathetic and vagal activities. These differences highlight the adaptability of the human body to extreme conditions, and further investigation into the underlying physiological mechanisms is warranted.

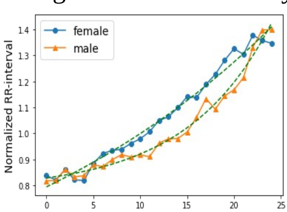

Figure 1. Average normalized RR-interval during the first apnea, along with the fitted exponential models (indicated by dashed lines)

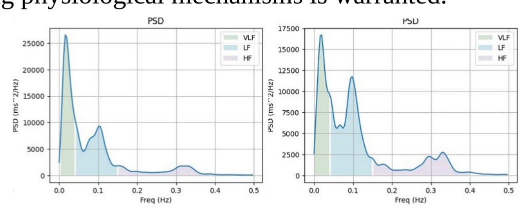

Figure 2. RR-interval PSD during basal and recovery