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Influence of Changing Gravity and Exerted Exhalation Linkage between Oxygen Uptake and Cardiac Output

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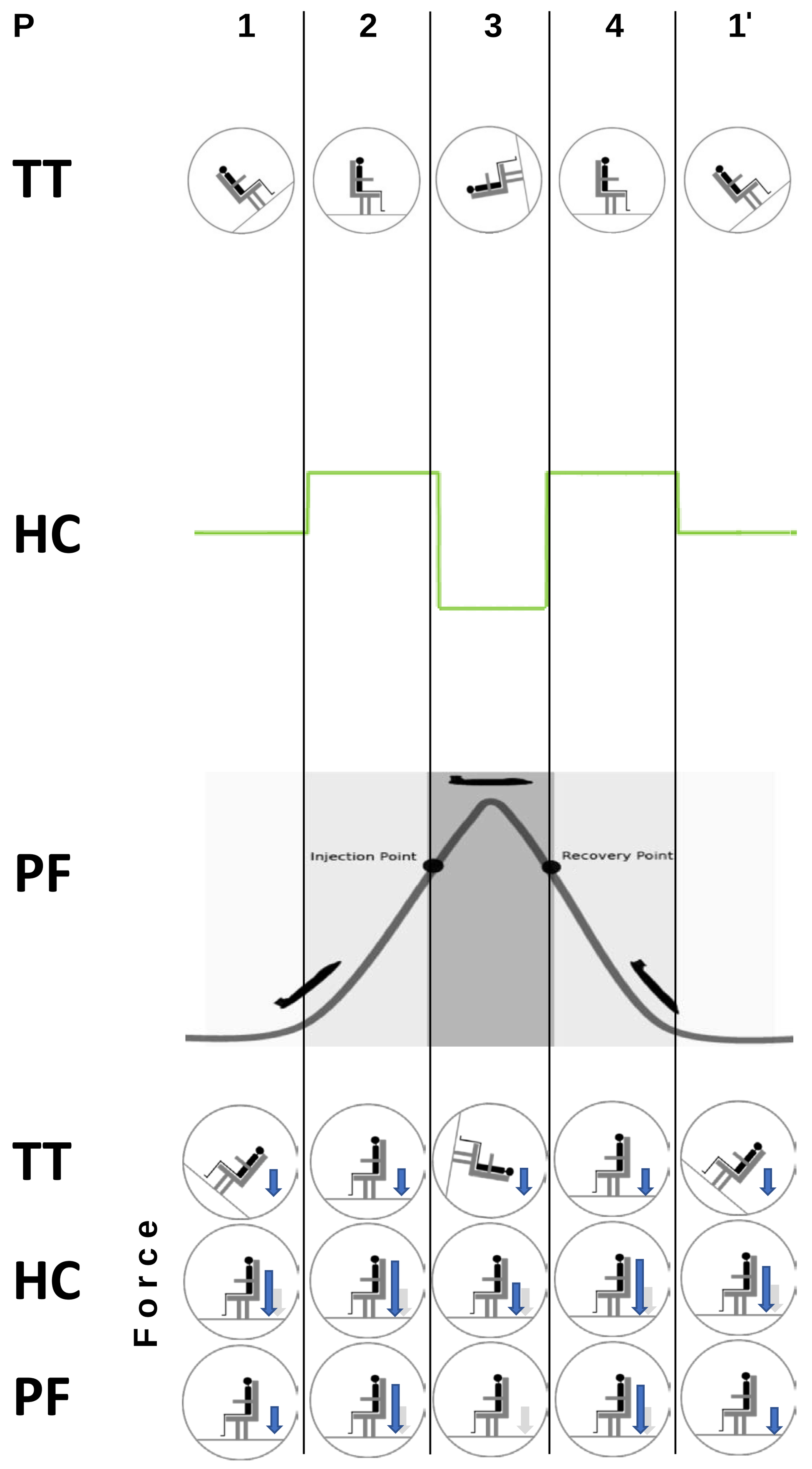
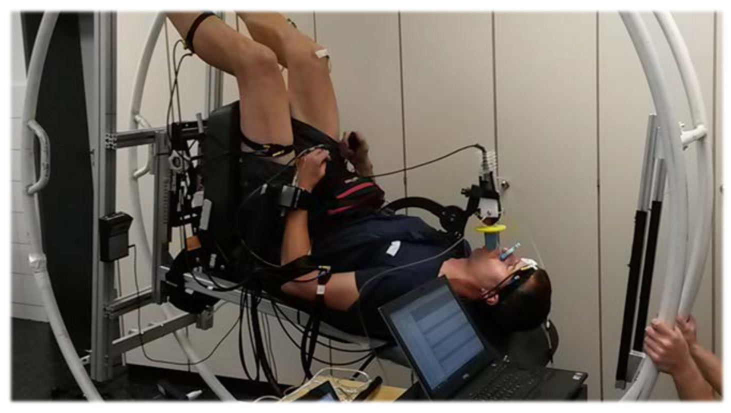
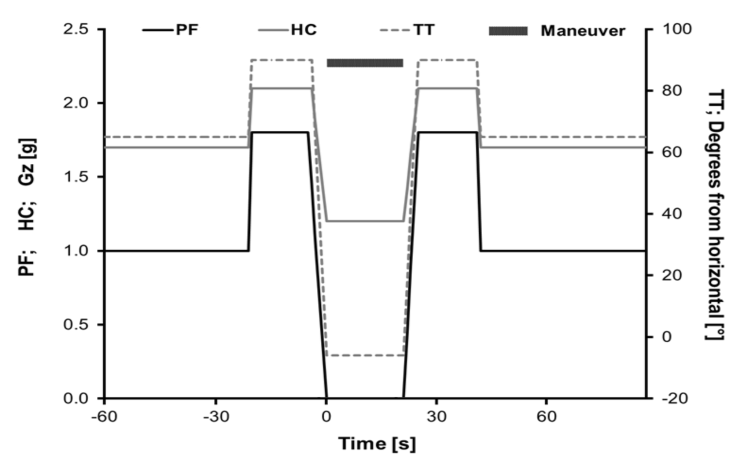
Introduction: Changing gravity in G_z-axis influences cardiovascular factors such as stroke volume (SV), heart rate (HR), blood pressure (BP), peripheral resistance and perfusion as well as pulmonary components: lung perfusion, alveolar aeration and arterio-venous oxygen difference in the tissue. Parabolic Flight (PF) runs compared to Human Centrifuge (HC) and Tilt Table (TT) maneuvers induce similar changes in pulmonary oxygen uptake in the resting and exercise condition without metabolic processes. The aim of this study was to show the influence of changing gravity in G_z-axis on pulmonary oxygen (V'O_2) uptake, carbon-dioxide (V'CO_2) exhalation and cardiac output (Q').

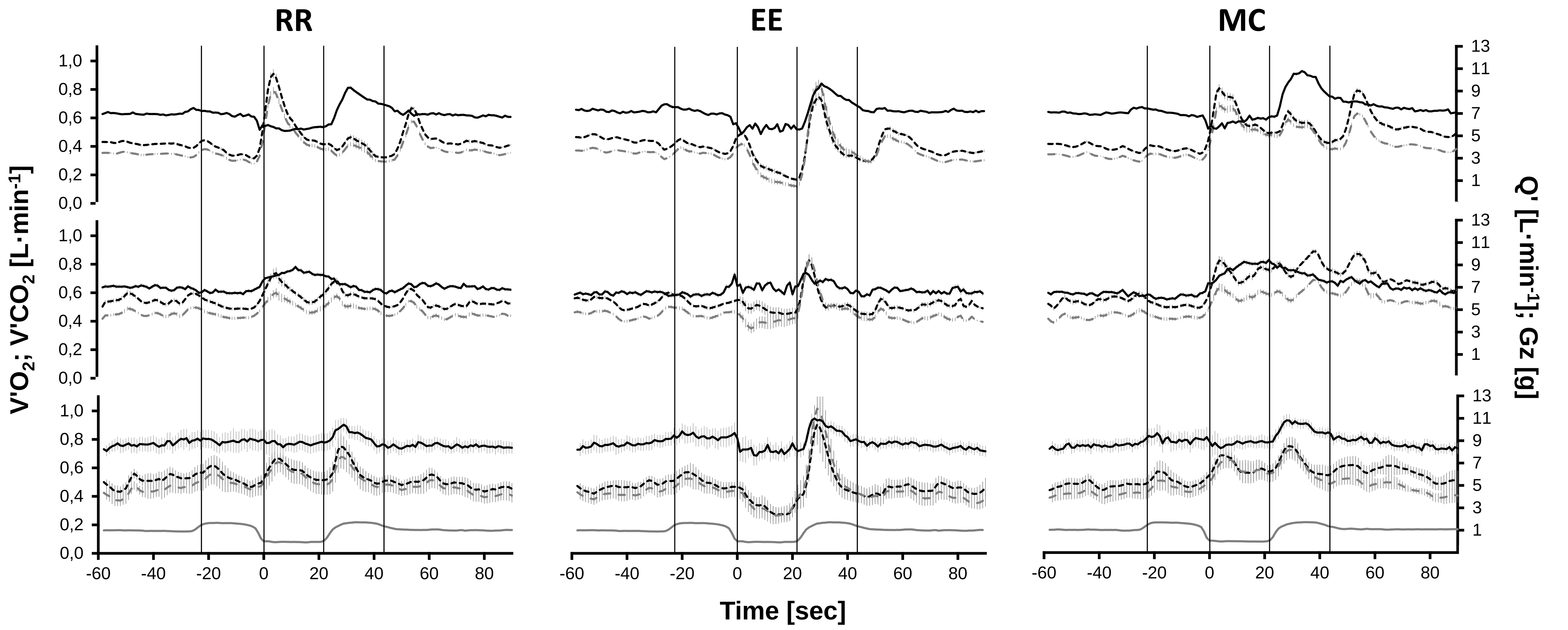
Methods: Analogous to PF, tests were performed on TT as a model and in a long-arm HC as a simulation applying a G_z-acceleration protocol. The arising G_z during aeronautical invariable and time dependent parabola cycles were transcribed for TT as 65° for the equivalent of earth gravitational force (P_1), 90° as pull up (hyper-G, P_2), -6° as µ-G (transition, P_3), 90° as pull down (hyper-G, P_4). For HC the G_z-profile was programmed: P_1 = 1.7, P_2 = 2.1, P_3 = 1.2, and P_4 = 2.1. During PF G_z-forces occurred: P_1 = 1.0, P_2 = 1.8, P_3 = µ-G, and P_4 = 1.8. During recurring P_3 subjects performed within the 22 sec randomized relaxed rest (RR), or exerted exhalation (EE) maneuvers (jet pilot forced pressure ventilation), or continuous maximum muscle contraction (MC) of lower extremities and abdomen. Physiologic parameters V'O_2 and V'CO_2 were obtained by spirometry and analyzed breath by breath considering Beaver corrections. Heart rate (HR) was recorded by ECG and analyzed beat to beat. Blood pressure (BP) was measured with Portapres M2. SV was calculated from BP using the model flow algorithm. The product of HR and SV is the calculated Q'.







Results: Nine subjects having flight medical certificate and signed written inform consent (age: 31 ± 3 y, weight: 79 ± 7 kg, height: 181 ± 7 cm, BMI: 24 ± 2 kg*m^{-2}) were exposed 15 times to repetitively changing gravity in G_z-axis in the model TT, simulated in HC, and in reality during PF. The cycles with the same action (RR, EE, and MC) were averaged and analysed comparatively for each set up (TT, HC, and PF).



Conclusions: The increase in V'O_2 (corresponding V'CO_2) and Q' during P_3 of the resting condition is not related to muscular work. The earlier peak in V'O_2 during this phase cannot be explained by increasing Q'. It is assumed that blood is pooled in the post lung venous vessels in front of the left ventricle. If performed EE maneuver this effect is attenuated (intra-pulmonary pressure). After the EE phase, the peak in V'O_2 during P_4 reflects a high blood flow through the lungs and a refill from the periphery of the lung venous vessels. Considering the MC condition, the increase in Q' was pronounced and remained increased until the end of the following P_1. V'O_2 increased with an initial overshoot and remained augmented for the following time up to 90 sec after these maneuvers. The results suggest that pulmonary gas exchange measurements might be used to estimate lung perfusion and/or pooling of blood in the venous system of the lung during changing gravity in Gz-axis.

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