

Synchronizing Cardiac Cycle Phase with Foot Strike to Optimize Cardiac Performance in Patients with Chronic Systolic Heart Failure and Cardiac Resynchronization Therapy (CRT)

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ABSTRACT

Despite advances in medical and Cardiac Resynchronization Therapy (CRT), patients with chronic systolic heart failure (HF) have persistent symptoms including dyspnea on exertion and exercise intolerance. Novel strategies to improve exercise performance in these patients, such as optimizing cardio-locomotor coupling, could be particularly beneficial to improve functional capacity. For example, runners display a lower heart rate and higher oxygen pulse, suggestive of a higher stroke volume (SV), when foot strike occurs in diastole. Whether patients with HF undergoing CRT can similarly increase SV is unknown.

PURPOSE: To compare the effects of diastolic versus systolic foot strike timing on exercise hemodynamics in patients with HF and CRT. **METHODS:** Ten patients (Age: 58 ± 17 years, 40% Female) with HF and previously implanted CRT pacemakers completed repeated 5-minute bouts of walking on a treadmill at a fixed but individualized speed (range: 1.5-3mph). Participants were randomized to walking to an auditory tone to synchronize their foot strike to either the systolic (ECG R-wave; 0 or $100\% \pm 15\%$ or R-R interval) or diastolic phase ($45 \pm 15\%$ of the R-R interval) of their cardiac cycle. Participants were included if $\geq 50\%$ of their steps were valid (i.e. in time). Patients wore a chest strap with an attached ECG sensor and accelerometer (Counterpace^R). Foot strike timing and associated valid step counts were assessed via Counterpace^R or post-hoc analysis of foot strike waveforms. Cardiopulmonary parameters were measured breath by breath via indirect calorimetry and cardiac output was measured via acetylene rebreathing, with SV calculated as the quotient of cardiac output and heart rate. **RESULTS:** There was no difference in oxygen uptake between conditions (1.02 ± 0.44 vs. 1.04 ± 0.44 L/min, $P=0.298$). When compared to systolic walking, stepping in diastole was associated with higher SV (Diastolic: 80 ± 28 vs. Systolic: 74 ± 26 ml, $P=0.003$) and cardiac output (8.3 ± 3.5 vs. 7.9 ± 3.4 L/min, $P=0.004$); heart rate (paced) was not different between conditions (101 ± 15 vs. 103 ± 14 bpm, $P=0.300$). Mean arterial pressure was significantly lower during diastolic walking (85 ± 12 vs. 98 ± 20 mmHg, $P=0.007$). **CONCLUSION:** In patients with HF and previous CRT, synchronizing foot strike with diastole during walking increased SV and cardiac output and reduced arterial pressure. Our findings indicate that in such paced hearts, diastolic stepping increases oxygen delivery and decreases afterload, which may facilitate increased exercise capacity. Therefore, if added to pacemakers, this cardio-locomotor coupling technology may maximize CRT efficiency and increase exercise participation and quality of life in patients with HF.