A Novel Waveform to Extract Exercise Gas Exchange Response Dynamics: The Chirp Waveform

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ABSTRACT

Characterizing exercise gas exchange response dynamics reveals important information about physiological control processes and cardiopulmonary dysfunction. However, current methods for extracting exercise response dynamics typically use multiple step-wise transitions, limiting applicability of this technique. **PURPOSE**: We designed a new protocol (chirp waveform) to extract exercise gas exchange response dynamics in a single visit. We tested the hypothesis that gas exchange response dynamics extracted from chirp forcing would be similar to those extracted from step-wise transitions. **METHODS**: Thirty-one participants (14 young healthy, 7 older healthy, and 10 patients with chronic obstructive pulmonary disease) visited the laboratory on three occasions. On visit 1, participants performed a ramp incremental test to determine the gas exchange threshold (GET). On visits 2-3, participants performed either a chirp or step-wise protocol in a randomized order. Chirp forcing consisted of sinusoidal fluctuations in work rate with constant amplitude and progressive shortening of sine periods. Square protocol consisted of 3 square-wave transitions each of 6 min duration. Work rate amplitude (from 20 W to ~95% of the individual's GET) and exercise duration (30 min) were the same in both protocols. The input-output relationship was characterized using a first-order linear transfer function containing a system gain (K) and time constant (τ) [$G(s)= K/(\tau \times s+1)$]. Parameter identification was performed in Matlab using the Matlab System Identification toolbox. Agreement between measures was established using Bland-Altman analysis and Rothery's Concordance Coefficient (RCC). **RESULTS**: No systematic bias (mean difference of chirp minus square-wave; Δmean) and good reliability was found for $\dot{V}O_2$ K [Δmean: 0.25(1.03) mL/min/W, p=0.179; RCC: 0.773, p=0.004], $\dot{V}O_2$ τ [Δmean: 0.30(7.08) s, p=0.815; RCC: 0.837, p<0.001], and $\dot{V}CO_2$ K [Δmean: -0.19(1.57) mL/min/W, p=0.512; RCC: 0.827, p<0.001]. A systematic bias [Δmean: -6.90(11.65) s, p=0.009] and good reliability (RCC: 0.794, p<0.001) were observed for $\dot{V}CO_2$ τ. **CONCLUSION**: The chirp waveform allows extraction of gas exchange response dynamics similar to those obtained from standard methods, thus overcoming the need for multiple tests.