The Effects of Heart Failure on the Muscle Exercise Pressor Reflex

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ABSTRACT

BACKGROUND: During exercise, heart failure (HF) patients exhibit a reduced ability to overcome sympathetic vasoconstriction, which leads to restricted blood flow and exercise intolerance. One regulatory point of this sympathetic activity is the exercise pressor reflex, which reflexively increases blood pressure during exercise to improve perfusion of the active skeletal muscle.
HYPOTHESES: The pressor response during both arm and leg exercise in HF subjects is exaggerated compared to healthy, age-matched control subjects, and the rise in arterial blood pressure is accomplished principally by an increase in systemic vascular resistance (SVR) in HF patients, in contrast to an increase in cardiac output (CO) in healthy, age-matched controls.
METHODS: HF subjects (n=7) and healthy, age-matched control subjects (n=8) performed graded levels of rhythmic handgrip and knee-extensor exercise on separate days. Heart rate (HR), CO, and mean arterial pressure (MAP) were determined with a finometer.
RESULTS: The exercise-induced changes in MAP and CO were not significantly different between HF and control groups during either handgrip or knee-extensor exercise trials. However, for knee extensor exercise, changes in SVR across exercise differed; SVR increased in HF and decreased in the control group.
CONCLUSIONS: HF patients and controls exhibited a similar exercise pressor reflex during both handgrip and knee extensor exercise. However, the rise in MAP was achieved primarily via a rise in SVR in the HF group versus an increase in CO in the control group. This modality-specific adaptation may contribute to exercise intolerance in HF patients.

METHODS

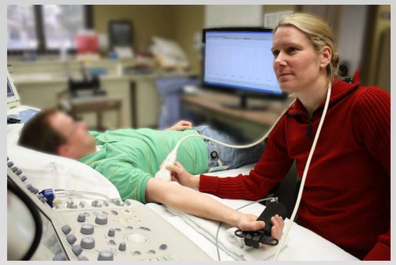
Protocol:

- Dynamic handgrip exercise (1Hz; 15, 30, 45, and 60% of maximum voluntary contraction) was performed using a commercially available handgrip dynamometer (Biopac Systems). Cadence was provided via metronome, accompanied by real-time visual feedback of dynamometer force (Figure 1, left). Knee extensor exercise (1Hz; 0, 5, 10, 15, and 20W) was performed using a customized ergometer (Figure 1, right).

Measurements:

- Arterial blood pressure (MAP) and heart rate (HR) were determined non-invasively (Finapres Medical Systems, Amsterdam, The Netherlands). Stroke volume (SV) was calculated from the arterial pressure waveform using the Modelflow method, which uses an algorithm to compute the aortic flow waveform from an arterial blood pressure pulsation by simulating a nonlinear, self-adaptive (3-element Windkessel) model of the aortic input impedance (Beatscope, version 1.1; Finapres Medical Systems). Cardiac output (CO) was then calculated as the product of HR and SV.

METHODS & RESULTS



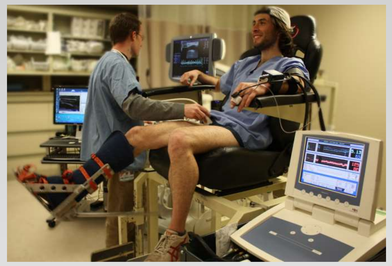


FIGURE 1: Experimental setup for dynamic handgrip (left) and knee extensor exercise (right) modalities. Each exercise stage was performed for 3 min with measurements taken during the last minute, when steady state hemodynamics were achieved. 3 min breaks were given between each work rate.

FIGURE 2: Changes in mean arterial blood pressure (MAP, top row), cardiac output (CO, middle row), and systemic vascular resistance (SVR, bottom row), during handgrip exercise (left column) and knee-extensor (right column), in heart failure patients (black circles) and control subjects (white circles). * Significantly different than control, $P < 0.05$.

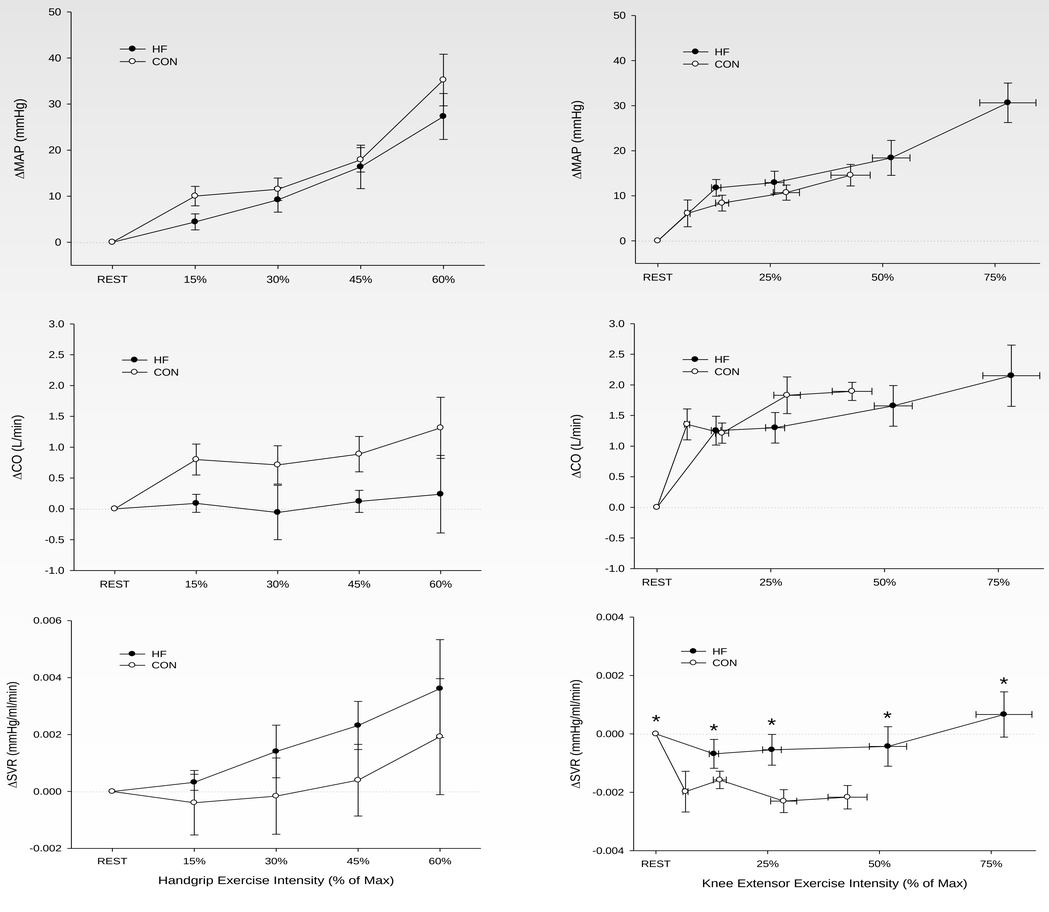


Table 1: *Subject characteristics and medications.*

	Controls (n=8)	Heart Failure (n=7)
Subject Characteristics		
Age (yrs)	65±1	66±3
Weight (kg)	97±12	99±6
Height (cm)	174±1	181±2*
Body mass index (kg/m²)	32±4	30±1
Systolic blood pressure (mmHg)	121±2	116±3
Diastolic blood pressure (mmHg)	68±4	72±3
Maximum voluntary contraction (kg)	27±2	24±2
Single-leg knee-extensor maximum (watts)	37±4	21±2*
Ischemic cardiomyopathy	---	5/7
Non-ischemic cariomyopathy	---	2/7
Left ventricular ejection fraction (%)	---	28±3
NYHA Class II/Class III	---	6/1
Diabetic	---	2/7
Medications		
B-adrenergic antagonist	---	7/7
Thiazide diuretic	---	7/7
ACE inhibitor	---	7/7
Angiotensin type 1 (AT1) receptor antagonist	---	1/7
Statin (HMG-CoA reductase inhibitor)	---	7/7
Aldosterone antagonist	---	6/7
Antiarrythmic agent	---	5/7

*Significantly different from control, P<0.05.

DISCUSSION

- HF patients and age-matched, healthy controls exhibited a similar exercise pressor response during both handgrip and knee extensor exercise.

- During handgrip exercise, the HF and control group also had similar changes in CO and SVR at all exercise intensities.

- However, for knee extensor exercise the relative contributions of CO and SVR to achieve the rise in MAP differed between the HF and control group. In the HF group, the rise in MAP was achieved primarily via a rise in SVR, and in the control group the rise was achieved via elevated CO.

Together, these data suggest that the exercise pressor response during handgrip and knee-extensor exercise is similar, but the mechanism underlying this hemodynamic response differed between groups during knee-extensor exercise. While an increase in CO can produce a beneficial rise in blood flow, the increase in peripheral resistance seen in HF patients may actually restrict blood flow in the exercising muscle. This adaptation may contribute to exercise intolerance in HF patients.

Funded in part by the Medical the American Federation of Aging Research Medical Student Training in Aging Research (MSTAR) Program, the American Heart Association (SDG 0835209N), the National Institute of Health (1 P01 HL091830-01A1), and the Veterans Administration Rehabilitation Research & Development Service (E6910R).