

Increased oxygen uptake and utilization in the peripheral muscles, rather than cardiac function reserve, may be determinants of increased peak VO₂ by cardiac rehabilitation in heart failure

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Background: Peak oxygen consumption (peak VO₂) is a major prognostic parameter in heart failure (HF). Previous studies have shown a relationship between peak VO₂ and impaired oxygen uptake and utilization in the peripheral muscles. The purpose of this study was to clarify the determinant of increased peak VO₂ by cardiac rehabilitation (CR) in patients with HF.

Methods: We performed echocardiography during upright ramp bicycle cardiopulmonary exercise test in 30 HF patients (61±1 years of age, 80% male) before and 6 months after CR. HR reserve was determined as the change in HR from rest to peak exercise, expressed as a percentage of the predicted maximal HR reserve. Elastance index (EAI) and LV end-systolic elastance index (ELVI) were derived as the ratio of end-systolic pressure to stroke volume index and end-systolic volume index, respectively. End-systolic pressure was estimated from the equation $0.9 \times$ brachial systolic

blood pressure. Ventriculo-arterial coupling (VAC) was calculated as the quotient of EAI and ELVI. The ratio of LDEDVI to E/e' mean was used to evaluate LV diastolic compliance. Systemic vascular resistance index was calculated as mean arterial pressure divided by echocardiography calculated cardiac index and multiplied by 80. The arterial venous oxygen content difference (C (A-V) O₂ gradient) was calculated by using the Fick equation as: VO₂/echocardiography calculated cardiac output.

Results: Peak VO₂ and C (A-V) O₂ gradient were increased by CR. However, heart rate reserve, systolic reserve, VAC, diastolic reserve and vasodilation reserve were unchanged by CR (Table 1).

Conclusions: Increased oxygen uptake and utilization in the peripheral muscles, rather than cardiac function reserve, may be determinants of increased peak VO₂ by CR in HF.

	pre	post	p
peak VO ₂ (ml/kg/min)	16.0±0.3	17.6±0.3	0.004
peak VO ₂ /HR (ml/kg)	8.6±0.3	9.8±0.3	0.004
peak watt (watt)	102.6±1.8	110.5±1.8	0.005
rest HR (/min)	77.1±2.2	73.3±2.2	0.230
peak HR (/min)	122.1±3.1	120.7±3.1	0.721
ΔHR (%)	60.9±4.1	65.3±4.1	0.461
Heart Rate Reserve (%)	58.2±3.8	57.4±3.6	0.873
rest LVEDVI (ml/mm ²)	47.4±1.8	45.1±1.6	0.360
peak LVEDVI (ml/mm ²)	51.5±2.6	44.3±2.8	0.073
Δ LVEDVI (%)	10.0±5.8	8.1±5.8	0.818
rest LVESVI (ml/mm ²)	25.1±1.4	21.9±1.3	0.107
peak LVESVI (ml/mm ²)	23.8±2.1	18.4±2.3	0.100
Δ LVESVI (%)	-12.1±5.2	-4.0±5.0	0.277
rest LVEF (%)	49.5±1.7	55.3±1.6	0.020
peak LVEF (%)	57.5±1.7	60.2±1.8	0.307
ΔLVEF (%)	22.1±4.8	11.8±4.7	0.144
rest Stroke Volume Index (ml/mm ²)	22.2±1.0	23.2±0.9	0.474
peak Stroke Volume Index (ml/mm ²)	27.8±1.4	26.2±1.5	0.464
ΔSVI (%)	36.1±8.3	19.5±8.3	0.175
rest C (A-V)O ₂ (mg/dl)	0.002±0.003	0.006±0.003	0.361
peak C (A-V)O ₂ (mg/dl)	0.006±0.001	0.009±0.002	0.039
Δ C(A-V)O ₂	159.3±34.9	286.6±34.9	0.018
rest e' (cm/sec)	6.4±0.3	7.1±0.3	0.100
peak e' (cm/sec)	8.0±0.5	9.2±0.5	0.092
Δe' (%)	29.4±5.6	33.6±4.7	0.572
rest E/e'	15.7±3.0	10.4±2.6	0.201
peak E/e'	11.8±0.6	11.0±0.5	0.375
ΔE/e' (%)	-0.6±6.5	7.7±5.5	0.345
rest EAI (mmHg/ml/mm ²)	5.4±0.5	5.1±0.4	0.588
peak EAI (mmHg/ml/mm ²)	5.4±1.0	6.9±1.0	0.316
ΔEAI (%)	0.04±0.1	0.15±0.1	0.436
rest ELVI (mmHg/ml/mm ²)	6.7±0.5	6.9±0.4	0.772
peak ELVI (mmHg/ml/mm ²)	9.5±0.6	9.5±0.6	0.983
ΔELVI (%)	50.5±13.8	54.1±11.9	0.850
rest VAC	1.06±0.21	1.02±0.18	0.869
peak VAC	0.87±0.19	0.82±0.19	0.833
ΔVAC (%)	-32.9±5.9	-20.6±5.4	0.157
rest LVEDV/E/e' mean (ml)	4.25±0.23	4.49±0.18	0.424
peak LVEDV/E/e' mean (ml)	4.45±1.35	5.60±1.26	0.433
ΔLVEDV/E/e' mean (%)	1.15±28.6	32.4±22.7	0.409
rest SVRI (dyne/sec/cm ⁵)	5.48±0.31	5.40±0.27	0.857
rest SVRI (dyne/sec/cm ⁵)	3.16±0.67	4.83±0.65	0.098
ΔSVRI (%)	-39.3±11.2	-13.1±9.7	0.102

Table 1