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Short communication

Low exertional inspiratory capacity is not related to dynamic inspiratory muscle weakness in heart failure

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ABSTRACT

Reduction in inspiratory capacity (IC) during exercise has been reported in chronic heart failure (CHF). Since inspiratory muscle dysfunction may be present to a variable degree, the assumption that IC reduction during exercise represents an increase in end-expiratory lung volume must be made with caution. This interpretation is flawed if patients develop dynamic inspiratory muscle strength reduction, i.e., progressively lower esophageal (Pes) pressures as the IC maneuvers are repeated. Sixteen CHF patients and 9 age-matched controls performed an incremental exercise test with serial IC and respiratory pressure measurements. Regardless whether IC decreased or not with exercise (N = 4 and N = 12, respectively), Pes,IC remained stable. This was confirmed by similar Pes,sniff immediately upon exercise cessation ($p > .05$). No association was found between changes in IC and related Pes from rest to peak exercise. Owing to the lack of dynamic inspiratory muscle weakness, non-invasive indexes of lung mechanics can be reliably obtained from exercise IC in CHF.

1. Introduction

Reduction in inspiratory capacity (IC) during exercise has been described across the spectrum of chronic heart failure (CHF) severity, being inversely correlated to peak aerobic capacity (Papazachou et al., 2007). The IC represents the true operating limits for tidal volume (V_T) expansion during exercise and importantly influences breathing patterns and peak ventilatory capacity (Guenette et al., 2013). Interestingly, improving cardiac function by cardiac resynchronization resulted in higher IC and lower dyspnea during exercise in these patients (Laveneziana et al., 1985)

Exercise-induced reduction in IC, however, may be secondary to high end-expiratory lung volume (dynamic hyperinflation) if total lung capacity (TLC) is consistently reached at end-inspiration (Guenette et al., 2013); alternatively, a low IC might merely reflect failure to reach TLC due to progressive impairment in inspiratory muscle strength or poor effort as exercise progresses (Langer et al., 2014). Patients with heart failure show reduced resting static lung compliance associated with either restrictive or obstructive ventilatory patterns on resting lung function, thus increasing the propensity for expiratory airflow limitation. Heart failure patients with resting expiratory flow limitation have been shown to decrease dynamic IC in the setting of increased ventilatory demand of exercise (Dubé et al., 2016). The other hypothesis is particularly concerning in CHF, a patient population in which inspiratory muscle weakness is prevalent (Evans et al., 1995; Hughes et al., 1999) and parallels exertional dyspnea and functional deterioration (Mancini et al., 1992; Kasahara et al., 2015).

Dynamic respiratory mechanics, however, has never been extensively studied in CHF (Guenette et al., 2013; Dubé et al., 2016). The aim of the present study, therefore, was to investigate the behavior of dynamic inspiratory muscle strength according to the presence or absence of IC reduction during exercise in patients with CHF and compare with healthy controls.

2. Methods

2.1. Study population

We recruited stable, non-obese patients with clinical diagnosis of CHF and left ventricular ejection fraction < 45% by echocardiography. Subjects matched for sex and age were recruited from the community to serve as healthy controls. Exclusion criteria included forced expiratory volume in 1s/forced vital capacity below the lower limit of normal (LLN), and any other disorder potentially contributing to impaired exercise capacity. Ethical approval was obtained from the Institutional Ethics Committee (N° 14-0512) and all subjects signed written informed consent.

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Table 1
Characteristics of studied participants.

Variable	CHF (n = 16)	Controls (n = 9)
Age, yrs	59 ± 9	56 ± 12
Male:Female, n	11:5	6:3
Height, cm	165 ± 11	164 ± 10
BMI, kg/m^2	25.7 ± 3.4	24.7 ± 3.1
Smoker: current/former/never	2/7/7	0/1/8
Smoking burden, pack-yrs	53 ± 31	26[a]
Modified MRC dyspnea scale, 0–4	0.8 ± 0.8	0 ± 0*
NYHA functional classification, n (%)		
I	13 (81)	–
II	3 (19)	–
Chronic heart failure etiology, n (%)		–
Idiopathic cardiomyopathy	9 (56)	–
Ischemic cardiomyopathy	4 (26)	–
Alcoholic cardiomyopathy	1 (6)	–
Hypertensive cardiomyopathy	1 (6)	–
Endomyocardial fibrosis	1 (6)	–
Medication, n (%)		
Beta-blockers	15 (94)	1 (6)*
Angiotensin-converting enzyme inhibitors	10 (63)	0 (0)*
Angiotensin II receptor antagonist	4 (25)	1 (6)
Aldosterone receptor antagonist	9 (56)	0 (0)*
Diuretics	10 (63)	0 (0)*
Pulmonary Function		
FEV_1, L (% pred)	2.52 ± 0.74 (82 ± 19)	2.81 ± 0.56 (98 ± 8)*
FVC, L (% pred)	3.08 ± 0.88 (79 ± 16)	3.48 ± 0.70 (97 ± 8)*
FEV_1/FVC, (%)	82 ± 7	81 ± 2
FEV_1/SVC, (%)	81 ± 8	79 ± 2
$FEF_{25–75\%}$, L.s^{-1} (% pred)	2.54 ± 0.97 (83 ± 39)	2.65 ± 0.65 (98 ± 15)
TLC, L (% pred)	5.48 ± 1.27 (96 ± 15)	5.76 ± 0.81 (109 ± 10)*
SVC, L (% pred)	3.10 ± 0.95 (84 ± 23)	3.54 ± 0.71 (105 ± 7)*
IC, L (% pred)	2.54 ± 0.81 (87 ± 18)	2.60 ± 0.53 (102 ± 24)*
FRC, L (% pred)	2.94 ± 0.67 (91 ± 18)	3.01 ± 0.54 (77 ± 46)
RV, L (% pred)	2.38 ± 0.64 (130 ± 38)	2.09 ± 0.44 (90 ± 63)*
RV/TLC, (% pred)	129 ± 24	106 ± 13*
DLCO, (mmol/min/kPa)	5.57 ± 1.39 (67 ± 11)	6.54 ± 1.42 (79 ± 11)
DLCO/VA (mmol/min/kPa/L)	1.18 ± 0.23 (81 ± 14)	2.17 ± 1.15 (86 ± 11)
Pes Sniff, cmH_2O	−67 ± 18	−73 ± 17
MIP, cmH_2O	−76 ± 28	−97 ± 16
MEP, cmH_2O	113 ± 42	130 ± 49
Echocardiogram		
LVEF, %	31 ± 6	–
LV end-diastolic volume, mL	208.7 ± 44.5	–
LV end-diastolic diameter, cm	6.4 ± 0.6	–
LV mass, g	275.7 ± 59.9	–
PSAP, mmHg	32.6 ± 8.3	–
RV diameter, cm	2.2 ± 0.4	–

Values are means ± SD or number (%).
Abbreviations;: CHF = chronic heart failure; BMI = body mass index; MRC = medical research council; NYHA = New York Heart Association; % pred = percentage of predicted values; FEV_1 = forced expired volume in 1 s; FVC = forced vital capacity; SVC = slow vital capacity; $FEF_{25–75\%}$ = forced expiratory flow at 25–75% of forced vital capacity; TLC = total lung capacity; IC = inspiratory capacity; FRC = functional residual capacity; RV = residual volume; DLCO = diffusing capacity of the lung for carbon monoxide; DLCO/VA = DLCO corrected for alveolar volume; Pes Sniff = maximum inspiratory esophageal pressure during Sniff maneuver; MIP = maximal inspiratory mouth pressure; MEP = maximal expiratory mouth pressure; LVEF = left ventricular ejection fraction; LV = Left ventricle; PSAP = pulmonary systolic arterial pressure; RV = right ventricle.

* $p < .05$.

[a] Data related to one subject.

2.2. Procedures

The participants performed resting pulmonary function tests and symptom-limited cycle (Corival®, Lode, Groningen, Netherlands) incremental (5–10 W/min) cardiopulmonary exercise test (Vmax Encore®, CareFusion, Yorba Linda, USA) with serial measurements of IC (Guenette et al., 2013). Prior to testing, subjects were familiarized with the technique for performing IC measurement. After 4 stable tidal breaths, subjects received a verbal prompt to begin the maneuver ("at the end of the next normal breath out, breathe all the way in") and then verbal encouragement to make a maximal effort and hold the breath for, at least, 1s before relaxing back to pre-maneuver breathing. In general, two reproducible IC maneuvers (i.e., within 10% of the largest acceptable value) were performed at rest, 2-min intervals thereafter and at the end of exercise. A reduction in IC was defined as a peak exercise-rest difference of more than 150 mL. Symptom intensity was inquired before IC maneuvers. Esophageal (Pes) pressure was obtained using thin-walled balloon catheters (Ackrad®, Laboratories Inc, USA) coupled