

Energy conservation technique improves dyspnoea when patients with severe COPD climb stairs: a randomised crossover study

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ABSTRACT

In this randomised, crossover trial, 22 patients with severe chronic obstructive pulmonary disease climbed six flights of stairs (108 steps) twice, under two test conditions: (1) energy conservation technique (ECT): participants were asked to rest for at least 5 seconds every three steps and (2) control condition: participants climbed the stairs at their own pace. Significant lower dyspnoea (primary outcome), leg discomfort, minute ventilation and capillary blood lactate under the ECT condition were found, with no change in total task time.

Clinical trial registration NCT03564028

INTRODUCTION

Stair-climbing is reported as a frequent problem by individuals with chronic obstructive pulmonary disease (COPD).^{1–3} These individuals often actively avoid stair-climbing, which can lead to social isolation.⁴ A technique that could help these individuals to climb stairs is energy conservation technique (ECT) by fractionating this task.^{5,6}

We hypothesised that by fractionating the effort during stair-climbing, individuals with severe COPD and functional dyspnoea would experience less dyspnoea.

METHODS

Study design and participants

This randomised, crossover, single-centre trial (Pulmonary rehabilitation unit; Groupe Hospitalier du Havre) was prospectively registered on ClinicalTrials.gov (NCT03564028).

The inclusion criteria were as follows: diagnosis of COPD in accordance with the global initiative for chronic obstructive lung disease (GOLD) recommendations and with functional dyspnoea (modified medical research council scale ≥ 2).

The exclusion criteria were as follows: cardiovascular contraindications to exercise or being incapable of climbing six flights of stairs in less than 15 min. A maximal duration of 15 min was arbitrarily chosen as a cut-off limit for participation. We considered that patients who were this severely deconditioned would likely be unable to complete the whole protocol.

Intervention

Participants were asked to climb six flights of stairs (108 steps, 16 cm high, 30 cm long) twice under two

different conditions (control and ECT) separated by 30 min of rest, in a randomised order.

In the control condition, participants were asked to climb the six flights of stairs at their own pace. They were told they could ‘rest as needed’.

For the ECT condition, participants were asked to rest for at least 5 seconds after each three steps. If they wished, the rest could be longer.

No encouragement was given in both conditions. The interventions were separated by 30 min of strict rest. Patients using oxygen therapy carried their usual portable oxygen on their shoulders. The physiotherapist supervising the intervention remained behind the participants as they climbed to avoid influencing their efforts.

Outcome measures

The primary outcome was end-of-task dyspnoea measured using the modified 0–10 Borg scale.

Secondary outcomes were as follows: leg discomfort (modified Borg scale); pulsed oxygen saturation (SpO₂); heart rate (HR); respiratory rate (RR); oxygen saturation of the vastus lateralis muscle (StO₂); minute ventilation (V_e) and inspiratory capacity; capillary blood lactate; time taken to climb the six flights and the number of rests (defined as ≥ 10 s). SpO₂, HR, RR and StO₂ were continuously recorded during the test. Other outcomes were measured at the beginning and the end of the exercise. Information is available in online supplementary data.

Randomisation and blinding

The order of the conditions was randomised by the research unit using computer software Edgar2 (<http://www.edgarweb.org.uk/>) with a ratio of 1:1. The test sequence (in a sealed, opaque envelope with the inclusion number) was given to the investigator before the start of the first test condition. The inputting of data into the database and statistical analysis were carried out under blind conditions.

Statistical analysis

In all, 22 participants were required (mean difference in dyspnoea of 2 points; SD 2 points: Power 90%; alpha risk ≤ 0.05) (see online supplementary file for details and comments). Data analysis was conducted using SAS V.9.4 software (Cary, NC, USA). Continuous data are presented as means (SD) (or means and



Table 1 Baseline characteristics of the 22 patients

	All (n=22)
Sex (men), n (%)	12 (54.5)
Age	63 (60; 66)
BMI, kg/m ²	25.1 (6.3)
Smoking history, pack years	40 (22)
LTOT, n (%)	5 (22.7)
<i>Lung function</i>	
FEV1, % pred	32 (27; 47)
FVC, % pred	79 (18)
FEV1/FVC, %	37.7 (11.1)
TLC, % pred	112 (22)
RV, % pred	178 (147; 205)
VR/TLC, %	58.2 (7.5)
DLCO, % pred	46 (20)
<i>Arterial blood gases (at rest)</i>	
PaO ₂ , kPa	9.5 (1.3)
PaCO ₂ , kPa	6.0 (1.1)
pH	7.42 (0.03)
HCO ₃ ⁻ , mmol/L	27.5 (26.8; 29.4)
SaO ₂ , %	94.3 (2.7)
<i>Functional capacity and health status</i>	
6MWT (m)	406 (101)
<i>mMRC score</i>	
mMRC 2, n (%)	9 (40.9)
mMRC 3, n (%)	12 (54.5)
mMRC 4, n (%)	1 (4.5)
<i>HAD score</i>	
Anxiety	9 (5)
Depression	7 (4)
<i>SGRQ (% maximum)</i>	
Symptoms	51 (43; 62)
Activities	72 (17)
Impacts	38 (15)
Total score	50 (14)

Mean (SD) or Median (25th;75th).

Arterial blood gases were collected on room air for patients who were normoxic at rest and under oxygen for patients with LTOT.

BMI, body mass index; DLCO, carbon monoxide transfer factor; F, female; FEV1, forced expiratory volume in one second; FVC, forced vital capacity; HAD, Hospital Anxiety Depression Scale; LTOT, long-term oxygen therapy; M, male; mMRC, modified Medical Research Council scale; 6MWT, Six Min Walk Test; PaCO₂, arterial partial pressure of carbon dioxide; PaO₂, arterial partial pressure of oxygen; RV, residual volume; SaO₂, arterial oxygen saturation; SGRQ, St George's Respiratory Questionnaire; TLC, total lung capacity.

95% CI for the difference between the two conditions) or medians (Q1; Q3) depending on the normality of the distribution (Shapiro–Wilk test). A treatment effect test (adjusted for period), a period effect test (adjusted for treatment) and a test for the interaction between treatment and period were successively used to assess the respective effect of treatment, treatment sequence and the first-order carryover risk. These three effects were analysed using a Student t-test or a Mann–Whitney test according to the distribution of the data (the specific calculations used for the crossover analysis are detailed in the supplementary data.⁷ Changes within

each of the conditions were compared using a paired t-test or a Wilcoxon test, depending on the normality of the distribution. In the case of a significant interaction between treatment and period (first-order carryover risk), only the first sequence was analysed.

Intention-to-treat analysis (with imputation of the missing data by the median value of the opposite condition for a given variable) was carried out.

RESULTS

Between July 2018 and April 2019, 52 patients were admitted to our department for pulmonary rehabilitation. Of these, 23 were eligible for participation, 1 declined to participate (online supplementary figure 1), thus 22 were included (median, (IQR) age=63 (60; 66) years and FEV1=32 (27; 47) % of predicted value). The baseline characteristics of the participants are presented in table 1.

The values of the intention-to-treat analysis are provided in table 2. The p values of the interaction between condition and order are presented in online supplementary table 1. The level of dyspnoea was significantly lower at the end of the task in the ECT test condition compared with the control condition (median between conditions differences = -1.00 (-3.50; -1.00)) (table 2, figure 1, online supplementary figure S2).

Leg discomfort was significantly lower in the ECT condition (table 2, figure 1, online supplementary figure 3). Capillary blood lactate, VE, total rest time (rests of ≥10s) were also significantly lower in the ECT condition (table 2, figure 1).

There were no differences in outcomes between test conditions for total task time, SpO₂, StO₂ or RR (table 2).

All 22 participants reported feeling less breathlessness during the ECT condition and 14 preferred the ECT condition.

DISCUSSION

This is the first study to propose and evaluate an ECT for stair-climbing in patients with severe COPD with activity limitation and anxiety.

Physiological studies have shown that fractionated exercise helps to optimise aerobic metabolism by reducing oxygen consumption, lactate production and facilitating the partial restoration of phosphocreatine during the rest period.⁸ This reduces the ventilatory requirement, along with dyspnoea and muscle fatigue, leading to an improvement in exercise tolerance in individuals with severe COPD.⁸ In our study, the change in ventilatory pattern with a reduction in minute ventilation at the end of the task could explain the improvement in symptoms and the need for long rests with the ECT. Although the total standardised rest time could be longer when climbing stairs using an ECT (5 s rest every three steps), the total time to climb the stairs is not necessarily longer. This information can be useful in terms of patient education. The carryover effect observed for the total test time demonstrates that the technique should be adapted to the severity of the patient's condition: patients with milder conditions might benefit from less frequent or shorter rests. Further studies are required to evaluate (i) if this ECT (5 s/3 steps) is appropriate for real life or if the ratio (rest time/number of steps) should be modified to facilitate its use and (ii) if the ECT reduce their apprehension in relation to stair-climbing.^{3,4}

CONCLUSION

The application of an ECT to a stair-climbing task significantly reduced dyspnoea without affecting the time taken to complete the task in individuals with severe COPD.

Table 2 Effects of energy conservation technique condition versus control condition on breathlessness and physiological variables at the end of exercise (intention-to-treat analysis)

Variables	Energy conservation technique		Control		Condition effect Between conditions differences (95% CI) or (25th; 75th)	P value
	Baseline	End-exercise	Baseline	End-exercise		
Breathlessness (mBorg)	0.0 (0.0; 0.5)	3.0 (2.0; 4.0)***	0.0 (0.0; 1.0)	5.0 (4.0; 6.0)***	-1.00 (-3.50; -1.00)	<0.001
Leg discomfort (mBorg)	0.0 (0.0; 0.0)	2.0 (0.0; 2.0)***	0.0 (0.0; 0.0)	3.0 (2.0; 5.0)***	-1.00 (-3.00; 0.00)	0.006
SpO2 (%)	92.8 (3.5)	85.3 (6.3)***	93.1 (3.2)	84.8 (7)***	0.53 (-1.54; 2.61)	0.6
StO2 (%)	66.0 (6.1)	57.8 (9.6)*	67.9 (6.3)	57.2 (8.3)***	2.18 (-0.63; 4.99)	0.12
Heart rate (bpm)	85.5 (12.3)	108.0 (13.6)	86.7 (17.3)	103.9 (22.2)	5.26 (-6.01; 16.53)	0.34
Respiratory rate (cpm)	20.0 (18.0; 22.0)	27.0 (23.0; 30.0)***	20.5 (18.0; 22.0)	28.0 (26.0; 32.0)***	-1.00 (-4.00; 1.00)	0.14
Minute ventilation (L/min)	11.2 (3.5)	19.1 (6.7)***	10.9 (3.8)	27.6 (8.6)***	-8.68 (-12.00; -5.37)	<0.001
Inspiratory capacity (L)	1.8 (0.6)	1.7 (0.5)*	1.9 (0.7)	1.5 (0.5)*	0.14 (-0.02; 0.31)	0.08
Lactate (mmol/L)	2.1 (1.8; 2.7)	2.9 (2.0; 3.4)**	1.5 (1.4; 2.0)	4.5 (3.5; 6.1)***	-2.30 (-3.90; -1.10)	0.013
Number of breaks (defined as break ≥ 10 s) 0.0410	-	0.0 (0.0; 0.0)	-	3.0 (1.0; 4.0)	-	<0.001
Total duration of breaks (s)	-	0.0 (0.0; 0.0)	-	54.0 (10.0; 140.0)	-54.00 (-136.00; 0.00)	<0.001
Total task time (s)	-	372.5 (73.0)	-	341.6 (128.5)	30.91 (-58.64; 120.50)	0.48

Continuous data are presented as means (SD) or means and 95% CI for the difference between the two conditions) or medians (Q1; Q3) depending on the normality of the distribution. Effect of intervention, intervention sequence and the first-order carryover risk were analysed using a Student's t-test or a Wilcoxon test, depending on the normality of the distribution. Changes within each of the conditions were compared using a paired t-test or a Wilcoxon test, depending on normality.

mBorg, modified Borg scale from 0 to 10 (0: no fatigue or dyspnoea, 10: maximal effort); SpO2, pulsed O2 saturation. For HR, the median number of breaks taken during test and the total task time, there were a significant interactions with the order of the conditions tested (respectively p=0.0480 for HR, p=0.0410 for the median number of breaks and p=0.0158 for total task time); therefore, only the first sequence was analysed in each case.

*p<0.05 for before–after analysis of a condition; **p<0.01 for before–after analysis of a condition; ***p<0.001 for before–after analysis of a condition.

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Contributors Trial concept and design: GP, CM, YC, JCB and GR; acquisition of data: GP, CM, and YC; supervision of the study: BL, JQ; analysis and interpretation of data: NA, GP, GR and JCB, drafting the article: GP, CM, YC, TB, FEG, JCB and

GR; revising it critically for important intellectual content and final approval of the version to be published: all authors. GP had full access to all trial data and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Competing interests None declared.

Patient consent for publication Not required.

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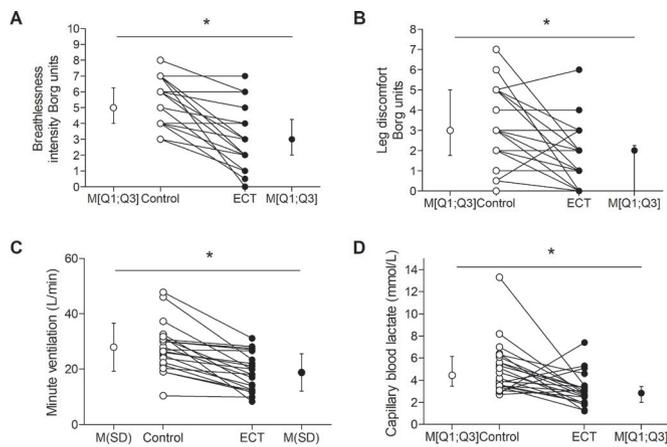


Figure 1 (A) Breathlessness; (B) leg discomfort; (C) minute ventilation; (D) capillary blood lactate at the end of the task in the ECT condition versus the control condition during the ascension of 108 steps (six flights). Data in panels A, B and D are presented as individual data and medians (25th;75th). Data in panel C are presented as individual data and mean ± standard deviation. *p<0.05. ECT, energy conservation technique