Does the 'Oxygen cost diagram' reflect changes in six minute walking distance in follow up studies?

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The oxygen cost diagram (OCD) is a simple scale for quantifying a patient's evaluation of his tolerance to exercise frequently used in clinical trials; it has been shown to be well correlated with objective measures of capacity of ambulation such as the 6 min walk test (6' W). This study aimed to determine whether the OCD accurately depicts changes in capacity of ambulation either quantitatively or qualitatively.

OCD ratings were analysed at baseline and after a 1 yr follow-up, in patients treated by non-invasive home mechanical ventilation, as well as objective measurements of pulmonary function [forced expiratory volume in 1 sec (FEV1), forced vital capacity (FVC), arterial blood gases], physical autonomy (6' W), resting dyspnoea (Borg scale) and scores for anxiety or depressive disorders (HAD).

Forty-five patients (24 male, 21 female, aged 62 ± 16 years, mean FEV1: 38 ± 17% of predicted) were evaluated at baseline. OCD ratings were significantly correlated with 6 min walking distance (P < 0.0001)—although with a large variability around the regression line—but not with resting dyspnoea (Borg). Patients were re-evaluated after 352 ± 90 days. Changes in OCD ratings were not significantly correlated with changes in FEV1, FVC, PaO2, PaCO2, 6' W, HAD scores or resting dyspnoea; furthermore—albeit for Borg scores—changes in OCD did not reflect the trend of changes in these parameters.

These results show that although OCD ratings are well correlated with results of a 6' W test, they cannot be used to extrapolate individual performances, because of a large variability around the regression line; furthermore, changes in the OCD over 1 yr did not depict objective changes in 6' W test results, either quantitatively or qualitatively. The use of the OCD in clinical trials should be limited to the description of the patient's perception of exercise tolerance, as a component of health-related quality of life, with the awareness of possible discrepancies between changes in objective performances and changes in OCD ratings.

Introduction

The oxygen cost diagram (OCD) initially published by McGavin et al. (1) is a single 100 mm long vertical line with daily activities listed beside it, in order of increasing metabolic and ventilatory requirements (oxygen cost) (Fig. 1). Patients are asked to indicate on the diagram the point above which they believe their breathlessness will not allow them to go (1). The OCD is therefore the expression of the patient's own evaluation of tolerance to physical activity (or handicap), and capacity to perform everyday chores (shopping, bedmaking, etc.). It is described as a 'disease-specific' health-related quality of life (HRQL) instrument (2).

The OCD has been widely used to analyse response to treatment in clinical trials, or to follow the progression of disease. Indeed, the OCD has been used as a clinical endpoint in studies assessing the subjective and objective benefit of theophylline (3,4), bronchodilators (5), combinations of bronchodilators and theophylline (6,7), inhaled corticosteroids (8,9), diazepam or promethazine (10) on dyspnoea in chronic obstructive pulmonary disease (COPD) or asthmatics, and the effect of angiotensin-converting enzyme (ACE) inhibitors in subjects with chronic heart failure (11). The OCD has also been used in descriptive or comparative studies of specific groups of patients with respiratory impairment (12–15).

OCD ratings have shown moderate but significant correlations with spirometric measurements, arterial blood gases or measurements of respiratory muscle strength, maximal oxygen consumption (VO2 max), and CO

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Brisk walking uphill | Medium walking uphill | Slow walking uphill
---|---|---
Brisk walking on the level | Heavy shopping | Medium walking on the level
Light shopping | Standing | Slow walking on the level
Sleeping

FIG. 1. The oxygen cost diagram, as described by McGavin et al. (1).

diffusion (4,15-18). The strongest correlations reported however were between OCD scores and results of standardized 6 min or 12 min walk tests (6' W) (1,13,16).

Some authors suggest however that, in clinical trials, the OCD has shown moderate reproducibility and that it is less responsive than other dyspnoea scores such as the transition dyspnoea index (TDI) or the Chronic Respiratory Disease Questionnaire (CRQ) (7,19). The present study aimed to determine whether the OCD accurately reflects changes in physical performance by analysing prospectively changes in functional parameters, 6' W tests and dyspnoea ratings in patients treated by non-invasive home mechanical ventilation (NIHV) for predominantly restrictive pulmonary disorders.

**Patients and methods**

Since 1994, all patients treated with non-invasive home mechanical ventilation (NIHV) in our referral area have been included in a database and followed prospectively. NIHV had been initiated because of hypercapnic respiratory failure, and all patients suffered from respiratory diseases accepted as well-established indications for NIHV (20). Patients were equipped with either volumetric ventilators (n = 18, Lifecare PLV100®, Eole II®, Dräger EV 800®, Medizin Technik, 6341 BAAR, Switzerland), or barometric ventilators (Respironics BiPAP S or ST®, Medizin Technik), the choice depending on efficacy in correction of arterial blood gases and patient comfort. Patients included in the database undergo periodical, comprehensive evaluations at least once a year. These evaluations are performed electively, the patients being in a stable clinical condition.

The database includes lung function tests, arterial blood gases with and without ventilator, dyspnoea scores (Borg scale and OCD) and scores for emotional disorders; information was recorded on Filemaker Pro® 2.1 software (Claris Corporation, Santa Clara, California U.S.A.). The present study analysed OCD ratings at baseline (i.e. at first elective evaluation after initiation of NIHV) and after a 1 yr follow-up, and correlations with objective measurements of pulmonary function and physical autonomy. Patients with normal OCD ratings (i.e. above 70) were excluded.

**LUNG FUNCTION TESTS**

Forced expiratory manoeuvres were recorded with a Vitalograph Alpha® spirometer (MED, 8050, Zurich, Switzerland). Values recorded were the best of three consecutive manoeuvres, as recommended by the American Thoracic Society (ATS) standards (21). Reference values were published by Quanjer et al. (22). Arterial blood gases were measured by puncture of the radial artery during room air breathing, after at least 6 h without NIHV (Gas analyser: ABL 330®, Copenhagen, Denmark).

**EXERCISE TOLERANCE**

A standardized 6 min walk test (6' W) was performed in a 50 m-long corridor, as described by McGavin et al. (23). Patients were asked to walk at the fastest pace they thought they could maintain for 6 min, without further verbal encouragement. In our institution, 6' W tests are performed in very standardized conditions (location, personnel, absence of verbal stimulation).

**ESTIMATION OF DYSPNOEA AND PHYSICAL DISABILITY**

Resting dyspnoea was estimated by the patient with a Borg scale, a vertical linear 20 cm scale labelled from 0-10, with corresponding verbal expressions of progressively increasing perceived intensity (higher values indicate more severe dyspnoea) (24). The Borg scale was preferred to a simple visual analogue scale (VAS) because of a better between-test repeatability of Borg scores (25). The OCD—a 100 mm weighted vertical visual analogue scale—was used to quantify the patient's evaluation of his tolerance to exercise. (Fig. 1). The OCD lists everyday activities in order of increasing metabolic demand. The scale was submitted to the patients by the same investigators over the whole study period: patients were asked to note on the scale the effort above which they thought their breathlessness would not allow them to go (1).

**SCREENING FOR EMOTIONAL DISTURBANCES**

The 'Hospital Anxiety and Depression' (HAD) questionnaire was used to screen for anxiety or depression; it contains 14 multiple choice questions; seven are oriented towards detection of anxiety disorders and seven towards detection of depression (26). The validated French version was used (27). The authors suggest scoring as follows: < 8: no evidence of depression, 8-10: suggestive of depression or
anxiety; > 10: abnormal values with a high specificity for anxiety or depressive disorders.

STATISTICS

Spearman's rank correlation was used to test for association between OCD ratings and ordinal or interval data. McNemar's test was used to compare trends between OCD changes and other recorded parameters. Statview 4.1 software for Macintosh (Abacus Concepts, Berkeley, California, U.S.A.) was used for statistical analysis. Values are mean ± SD unless otherwise stated.

Results

Forty-five patients (24 male, 21 female) were included for baseline analysis. These patients suffered from predominantly restrictive disorders: kyphoscoliosis (n = 11), obesity-hypventilation syndrome (n = 17), neuro-muscular diseases (n = 4) and post-tuberculosis syndrome (n = 8). Three patients suffered from severe bronchiectasis; two patients had severe hypercapnic COPD. Patients were aged 62 ± 16 years (mean ± SD, range: 20–80); mean body mass index (BMI) was: 29 ± 9.5 kg m⁻² (range: 12–50); pulmonary function tests were: forced expiratory volume in 1 sec (FEV₁) (% of predicted): 38 ± 17 (18–88); forced vital capacity (FVC) (% of predicted): 50 ± 21 (18–92); arterial oxygen tension (PaO₂): 8.3 ± 1.6 kPa (5.3–11.7); arterial carbon dioxide tension (PaCO₂): 6.4 ± 1.0 kPa (4.9–9.3); pH: 7.40 ± 0.03 (7.35–7.48); 6' walk test: 372 ± 96 m (40–469). HAD scores for anxiety were: 4.2 ± 3.5, and for depression: 5.6 ± 3.4; two patients had scores above 10 indicating an anxiety disorder and four had scores indicating depression. Resting dyspnoea scores (Borg) were: 2.0 ± 1.4 (0–6); OCD scores were: 51 ± 12 (25–79).

Correlation between OCD and baseline data is shown in Table 1. There was no correlation between OCD and BMI. Correlation with distance walked during standardized 6' W tests was highly significant (rho = 0.65, P < 0.0001), as shown in Fig. 2, with however a wide variability of individual values around the regression line. r² was 0.437. OCD was also strongly correlated with anxiety scores (HAD A: rho = -0.59, P = 0.0003).

FOLLOW-UP DATA

All patients were re-evaluated after 352 ± 90 days. Pulmonary function tests at follow-up visit were: FEV₁ (% of predicted): 38 ± 17 (range: 15–79); FVC (% of predicted): 51 ± 22 (16–95); PaO₂: 7.9 ± 1.8 kPa (5.2–12.8); PaCO₂: 6.1 ± 0.9 kPa (4.7–8.4); pH: 7.39 ± 0.02 (7.33–7.45); 6' walk test: 319 ± 101 m (103–500). HAD scores for anxiety were: 4.7 ± 3.8, and for depression: 6.3 ± 3.6. Resting dyspnoea scores (Borg) were: 12 ± 2.0 (0–7); OCD scores were: 51 ± 15 (25–79).

| TABLE 1. Correlations* between oxygen cost diagram ratings and functional parameters, resting dyspnoea and Hospital Anxiety and Depression scores |
|---------------------------------|--------|-------|
|                                  | n      | Rho (*) | P (*) |
| Functional parameters           |        |        |
| FEV₁ (% of predicted)           | 45     | -0.68  | 0.6   |
| FVC (% of predicted)            | 45     | -0.24  | 0.11  |
| PaO₂ (kPa)                      | 45     | 0.19   | 0.21  |
| PaCO₂ kPa                       | 45     | -0.19  | 0.19  |
| 6 min walking distance (m)      | 45     | 0.645  | <0.0001 |
| Resting dyspnoea (Borg scale)   | 45     | -0.18  | 0.24  |
| Hospital Anxiety and Depression scale |
| Scores for anxiety              | 45     | -0.59  | 0.0003|
| Scores for depression           | 45     | 0.06   | 0.73  |

* Spearman’s rank correlation. For abbreviations see text.

Fig. 2. Relationship between 'oxygen cost diagram' ratings and distance walked during a standardized 6 min walk test (Spearman's rank correlation, rho = 0.65, r² = 0.437, P < 0.0001).
Changes in pulmonary function and walk tests over this period were as follows: for FEV₁: 1 ± 8 % (−16, +33%); for FVC: −1 ± 17 % (−53, +44%); for PaO₂ (kPa): −0.4 ± 0.5 (−4.9, +4.7); for PaCO₂ (kPa): −0.3 ± 0.3 (−1.2, +0.4); for 6' W: −15 ± 80 m (−197, +150). Changes in dyspnoea scores (Borg) were: −1 ± 2.3 (−5, +5.7); changes in OCD were: −2 ± 13 (−25, +45). Average change in HAD scores was: −0.2 ± 3 (−13, +5) for anxiety, and −0.3 ± 3 (−4, +6) for depression. Although mean values for the above mentioned parameters were similar after follow-up, there was a wide variability in individual values for changes in all parameters tested, as shown in Fig. 3 for 6' W.

Correlations between changes in OCD ratings and changes in functional parameters, resting dyspnoea or HAD scores are shown in Table 2. No significant relationship was found between changes in OCD ratings and changes in FEV₁, FVC, PaO₂, PaCO₂, distance walked on a 6' W test, Borg resting dyspnoea scores, or HAD anxiety and depression scores. McNemar's test was used to determine whether OCD ratings followed the same trend as other parameters recorded (i.e. did both parameters increase or decrease simultaneously?). OCD did not significantly reflect the trends in changes of FEV₁, FVC, PaO₂, PaCO₂, distance walked on a 6' W test, or HAD scores as noted in Table 2 and Fig. 3. However, although there was no significant relation between Borg scores and OCD scores in terms of magnitude of change (rho = −0.03, P = 0.85), trends were significantly related (i.e. when resting dyspnoea increased, OCD scores decreased).

**Discussion**

The present study analyses the changes over a 1 yr period in pulmonary function tests, capacity of ambulation, resting dyspnoea and OCD ratings in patients treated by NIHV for predominantly restrictive disorders. To our knowledge, the only studies using the OCD in patients with NIHV were descriptive studies on smaller groups of patients (13,28). The present study is the first report of the use of OCD in a follow-up study of patients treated by NIHV. As in patients with COPD (13,16,17,29), OCD ratings were very significantly correlated with the distance walked during a 6 min walk test, suggesting that patients reliably report their tolerance to physical activity with the OCD. However, this observation is misleading: because of the large variability around the regression line (Fig. 1), effort tolerance could not adequately be predicted from OCD scores on an individual basis. More importantly, our results suggest that the OCD may not correctly reflect changes in physical performances in follow-up studies: indeed, objective changes in capacity of ambulation—as assessed by a 6' walk test—could not be extrapolated from changes in OCD scores, either quantitatively or qualitatively.

As previously mentioned, the OCD has been widely used in clinical trials, as a clinical endpoint in evaluating the efficacy of bronchodilators, inhaled corticosteroids, theophylline, ACE inhibitors or other treatments for dyspnoea in patients with asthma, COPD or chronic heart failure.

**Table 2. Correlations between changes in oxygen cost diagram ratings and changes in functional parameters or resting dyspnoea**

<table>
<thead>
<tr>
<th>Functional parameters</th>
<th>n</th>
<th>Rho (*)</th>
<th>P (*)</th>
<th>P value (McNemar's test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔFEV₁ (% of predicted)</td>
<td>45</td>
<td>−0.03</td>
<td>0.85</td>
<td>0.84</td>
</tr>
<tr>
<td>AFVC (% of predicted)</td>
<td>45</td>
<td>−0.03</td>
<td>0.81</td>
<td>1</td>
</tr>
<tr>
<td>ΔPaO₂ (kPa)</td>
<td>45</td>
<td>−0.004</td>
<td>0.98</td>
<td>0.83</td>
</tr>
<tr>
<td>ΔPaCO₂ (kPa)</td>
<td>45</td>
<td>0.03</td>
<td>0.94</td>
<td>0.99</td>
</tr>
<tr>
<td>Δ6 min walking distance (m)</td>
<td>45</td>
<td>−0.046</td>
<td>0.77</td>
<td>0.17</td>
</tr>
<tr>
<td>Resting dyspnoea (ΔBorg score)</td>
<td>45</td>
<td>−0.13</td>
<td>0.43</td>
<td>0.030</td>
</tr>
<tr>
<td>Hospital Anxiety and Depression scale</td>
<td>scores for anxiety</td>
<td>45</td>
<td>−0.08</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>scores for depression</td>
<td>45</td>
<td>−0.12</td>
<td>0.43</td>
</tr>
</tbody>
</table>

* Spearman's rank correlation. For abbreviations see text.
(3-11). The OCD has also been used to compare levels of breathlessness and effort tolerance between specific groups of patients, i.e. 'pink puffers' vs. blue 'bloaters' (14), or COPD vs. patients with restrictive lung disease (13). In patients with terminal cancer, Farncombe reported that OCD was more sensitive than the Borg scale or a VAS scale in identifying subjects with a shortness of breath interfering with their quality of life (30). Results of OCD scores are well correlated with other clinical scales such as the Medical Research Council scale (MRC) and the Baseline Dyspnoea Index (BDI). Significant relationships have been documented between the OCD and specific domains of HRQL questionnaires such as the SF-36, the St George Respiratory Questionnaire (SGRQ) and the Chronic Respiratory Questionnaire (CRQ)(12,16,18,31). In fact, Hajiro et al. recently described the OCD as performing identically to the BDI, the MRC scale, and the dyspnoea scales of the CRQ or the SGRQ in evaluating dyspnoea in patients with COPD (18).

Noseda et al. suggested that the OCD is responsive to therapy (32). However, the validity of the OCD as an endpoint in clinical trials or as an indicator of objective exercise tolerance in follow-up studies should be questioned. Indeed, Woodcock et al. (10) used the OCD in a study of the effect of promethazine and diazepam on dyspnoea in COPD patients: promethazine was associated with lower dyspnoea scores and higher walking distance in 12 min than placebo; conversely, diazepam was associated with decreased walking distance in 12 min; however, OCD ratings did not differ between patients under placebo, diazepam or promethazine. Guyatt et al. (19) studied the effect of pulmonary rehabilitation on dyspnoea in 28 patients with chronic lung disease: impact was highly significant using the Chronic Respiratory Disease Questionnaire (CRQ) or the Transition Dyspnoea Index—an elaborate scale for scoring dyspnoea—but did not reach statistical significance when using the OCD. Guyatt et al. (7) also showed, in a randomized control trial of inhaled salbutamol and oral theophylline in COPD, that OCD failed to detect a clinical effect of theophylline on dyspnoea clearly detected by the CRQ, by a modified MRC category scale, and by an increase in 6 min walking distance. OCD changes were however significant for salbutamol. The conclusions of Guyatt et al. (7,19) were essentially that the OCD was less responsive than the CRQ or the TDI. The results of the present study—the largest follow-up study using the OCD published—question the usability of the OCD in follow-up studies in as much as changes in OCD did not even correctly identify the trends in changes of physical autonomy, in patients either increasing or decreasing significantly there results on a 6' W test. This observation does not seem to be related to the population studied (patients with NIHV): in a previous study, we analysed the physical activity of patients under long-term oxygen therapy using a pedometer over a 1-week period: 32 patients were re-assessed after 1 yr; although OCD ratings were initially significantly correlated with average daily distance walked (rho = 0.45, P = 0.0003), there was no correlation between OCD and changes in ambulation; as in the present study, OCD did not accurately describe quantitatively or qualitatively the changes in physical activity over the 1 yr follow-up period (12).

Conclusion

The oxygen cost diagram is a simple tool for quantifying a patient's perception of his tolerance to exercise and has been shown to be well correlated with objective measures of capacity of ambulation such as the 6' or 12' walk test, or measures by pedometer. These correlations however show a large variability around the regression line, and, as such, individual performances cannot be extrapolated from OCD ratings. Furthermore, the present study shows that the OCD does not accurately depict objective changes in capacity of ambulation—as assessed by 6 min walk test performances—either quantitatively or qualitatively. This study suggests that OCD does not appear appropriate to describe or even approximate changes in physical performance in clinical trials or follow up studies: rather, it should be used only as a HRQL tool (i.e. a reflection of the patient's perception), with the awareness of a possible discrepancy between objective changes in performance and OCD ratings.

References


