Using the Oxygen-Cost Diagram in Ramp-slope Selection for Dyspneic Patients

Ming-Lung Chuang¹, Chih-Hsin Lee²,³ and I-Feng Lin⁴

Abstract

Background  Maximal incremental exercise testing should be completed within 8-12 minutes. The ramp-slope influences the exercise duration. Oxygen-cost diagram (OCD) is a scoring scale for the capability of daily activity performed and therefore can be used to estimate the ramp-slope.

Methods  The OCD-algorithm and the reported-algorithm were used prospectively in random order for selecting optimal ramp-slope: Ramp-slope_{OCD} = Score_{OCD} x weight in kg/40 for men and weight/50 for women and Ramp-slope_{reported} = (Predicted VO2peak - VO2max unloaded)/100. Fifty-three dyspneic patients and 16 normal controls were enrolled to perform a ramp-pattern exercise. Fourteen patients not reaching maximum exercise levels were excluded. The exercise capacity, exercise time, and success rate of loaded exercise between 8 and 12 minutes were measured.

Results  Comparing the reported-algorithm to the OCD-algorithm in normal controls, the only difference was that the ramp-slope was higher in males; in patients, the ramp-slope was higher in males, the exercise time shorter and the success rate lower (8.6±3.3 vs. 9.4±2.1 min, 61.5% vs. 84.6%, both p<0.05); in obese patients, the ramp-slope was lower and the exercise time longer.

Conclusion  OCD score can predict the ramp-slope selection for exercise testing in normal controls and dyspneic patients. This may be affected by gender and body weight when using the reported-algorithm for dyspneic patients.

Key words: cardio-pulmonary exercise testing, oxygen uptake, exercise protocol

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Introduction

The incremental work rate (WR) exercise protocol for cardio-pulmonary exercise testing (CPET) is widely used for its convenience and robustness in differentiating underlying conditions (1, 2). Selecting the ramp-slope for the test is important because different slopes influence the total exercise duration, and exercise physiological responses (3-5). Incremental exercise should be completed within 6-12 minutes (4-6) or in approximately 10 minutes (5, 7, 8) or within 5-9 minutes for patients with severe COPD (6) because: (1) the test in which the loaded part is completed within 6-12 minutes gives the highest peak VO₂ (5, 7), and (2) the diagnostic criteria of CPET reported in literature are based on the suggested exercise duration (5, 9).

An algorithm for predicting ramp-slope using age, body weight and height has been reported. It is usually employed for normal sedentary adults (5) and the algorithm is not suitable for symptomatic patients because the modification of the reported algorithm has not yet been quantified. Since the oxygen-cost diagram (OCD) scale is a self-estimated functional classification and is related to VO₂max (10-12), this study hypothesizes that the OCD scale may forecast VO₂max, thereby predicting the ramp-slope for an appropriate exercise duration. This is the first study on ramp-slope selection for incremental exercise protocol using OCD as a predictor in dyspneic patients.
Subjects and Methods

Subjects

Fifty-three patients with dyspnea were enrolled as the study group. Most had respiratory diseases or obesity with sleep apneas. Sixteen normal subjects without any symptoms or diseases were enrolled as the control group. Because subjects were allowed to stop of their own volition, testing might have been terminated prematurely for non-physiological reasons. With the purpose of the study to reach a maximal or physiological limitation within appropriate exercise duration, it is not justified to deal with the exercise data involving physiological limitations or maximal efforts and sub-maximal efforts due to patients’ volition to terminate. Therefore, only subjects who performed at maximum effort or achieved physiologic limits were included in the analysis. Fourteen subjects were excluded based on this criterion. In the remaining 39 subjects, 18 subjects performed at maximum effort without ventilatory limits and another 21 subjects achieved ventilatory limits. In contrast, the entire control group reached the criteria of maximum exercise or the gradient of SPO2 between unloaded exercise and peak exercise involved cardio-vascular limitation plus ventilatory exchange ratio (RER) >1.09 at peak exercise (9, 13). Physiologic limitations included cardiac, ventilatory, and/or gas-exchange limitations (9, 14). Cardiac limitation with impairment was defined as the HR at peak exercise ≥85% of predicted maximum HR and \( \Delta \dot{V}_O_2 \) <80% predicted, anaerobic threshold (AT) <40% of predicted \( \dot{V}_O_2 \) max if determinate, \( \Delta \dot{V}_O_2 \)/\( \Delta \dot{V}_O_2 \)WR <8.6 mL/watt, maximum exercise criteria reached with an early plateau oxygen pulse (O.P = \( \dot{V}_O_2 / \dot{V}_H R \)) <80% of predicted maximum, or \( \dot{V}_H R / \Delta \dot{V}_O_2 \) higher than predicted.

Ventilatory limitation was defined as breathing reserve (BR) ≤30%, where BR = \( 1 - \dot{V}_{\text{peak}} / \dot{V}_{\text{MVV}} \). \( \dot{V}_{\text{peak}} \) indicated minute ventilation at peak exercise and MVV was direct maximum voluntary ventilation. Lung gas-exchange limitation at peak exercise involved cardio-vascular limitation plus \( \dot{V}_{\text{E}} / \dot{V}_{\text{CO}_2 \text{nadir}} >34 \), or \( \dot{V}_{\text{E}} / \dot{V}_{\text{CO}_2 \text{nadir}} >31 \) or oxyhemoglobin (HbO2) desaturation as measured by pulse oximetry (S2O2). HbO2 desaturation was defined as \( \Delta S_O_2 <90\% \) at peak exercise or the gradient of \( S_O_2 \) before unloaded exercise and peak exercise ≥3% (15).

Study design

This was a prospective study designed to select ramp-slopes for each subject to perform two symptom-limited exercise tests according to (A) the OCD-related algorithm and (B) the formula-reported algorithm. The order of the selected algorithm was random to prevent the learning segment from interfering with either algorithm: order (A)-(B)
Figure 1. Oxygen-cost diagram (OCD) was a 100-mm long vertical line with everyday activities and the associated oxygen requirements in performing each task, to which the subjects thought their breathlessness limited them (12). The distance from point zero was measured and scored (centimeters).

Protocol and measurements

Oxygen-cost diagram

OCD was used as a scale for daily activities as assessed by the patients themselves (Fig. 1). They were asked to indicate a point on an OCD, a 100-mm long vertical line with everyday activities along which was the associated oxygen requirement for performing each task for which they thought their breathlessness limited them (12). The distance in cm from point zero was measured.

Modified Medical Research Council

The MMRC is a dyspnea scale assessed by patients themselves and ranges from 0 (dyspnea only with intense physical activity) to 4 (dyspnea with minimal activity, such as getting dressed). The patients were asked to grade their exercise capabilities from zero to four according to the point at which their breathlessness limited them (17). For normal subjects, the MMRC score was not measured because it was intended for use of chronic dyspneic patients.

Maximum CPET

After attaining stable exercise gas exchange while the subject sat on the cycle ergometer (Corival, Groningen, The Netherlands), data were collected during a 2-min period of rest followed by a 2-min period of unloaded cycling, followed by a ramp-pattern exercise test to exhaustion. The WR was increased at a rate of 5-25 watt/min according to the algorithm, using the following formula:

The OCD-related algorithm:

\[ \text{Ramp-slope}_{\text{OCD}} = \frac{\text{Score}_{\text{OCD}} \times \text{BW}}{40} \]  
\[ \text{Ramp-slope}_{\text{OCD}} = \frac{\text{Score}_{\text{OCD}} \times \text{BW}}{50} \]

where BW was body weight in kg. Please see Appendix for derivation.

The formula-reported algorithm was as follows (5):

\[ \text{Ramp slope}= \frac{\text{Predicted peak } \dot{V}O_2-\text{unloaded }}{100} \]

where Predicted peak \( \dot{V}O_2= (\text{Height in cm-} \text{age}) \times 20 \) for men and 14 for women

and unloaded \( \dot{V}O_2=150+6\times\text{BW} \) in kg

and 100: please see Appendix.

During each test, subjects were encouraged to maintain a pedaling frequency of 60 rpm with the aid of a visual pedal rate indicator. \( \dot{V}O_2 \) (L/min), \( \dot{V}CO_2 \) (L/min), and \( \dot{V}e \) (L/min) were computed breath-by-breath and the data were displayed every 15 seconds using an on-line computer (CardiO₂™, Medical Graphics, St. Paul, MN, U.S.A.). Twelve lead EKG, heart rate and \( S_O2 \) using a pulse oximetry (Ohmeda 3,740, BOC Health Care Company, Louisville, CO, U.S.A.) were measured continuously. Calibration of the preVent™ pneumotachography (CardiO₂™, Medical Graphics) was performed with a 3-L syringe before each test. The Zirconia
Table 2. Data of Exercise Test Using Two Algorithms in the Patient and Normal Control Groups

<table>
<thead>
<tr>
<th></th>
<th>Dyspneic patients (n=39)</th>
<th>Normal control (n=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men (n=28)</td>
<td>Women (n=11)</td>
</tr>
<tr>
<td><strong>WR increment</strong> (watts/min)</td>
<td>14 ± 5</td>
<td>17 ± 3 *</td>
</tr>
<tr>
<td><strong>WRmax</strong> (watts)</td>
<td>135 ± 60</td>
<td>136 ± 59</td>
</tr>
<tr>
<td><strong>V̇O₂max</strong> (L/min)</td>
<td>93 ± 29</td>
<td>94 ± 29</td>
</tr>
<tr>
<td><strong>V̇O₂%max</strong></td>
<td>1.53 ± 0.56</td>
<td>1.39 ± 0.6</td>
</tr>
<tr>
<td><strong>success rate 8-12, %</strong></td>
<td>77 ± 18</td>
<td>75 ± 18</td>
</tr>
</tbody>
</table>

WR: work rate. Reported algorithm was to calculate the ramp-slope using formulae [3]–[5] (5). For the formulae, please refer to text. Between-algorithm comparisons: *p<0.05, †p<0.01; Between-sex comparisons: **p<0.05, ††p<0.01, ¶¶p<0.001, †††p<0.001; Between-group comparisons: **p<0.05, ††p<0.01, ¶¶p<0.001, †††p<0.001.

Table 3. Comparison of Exercise Duration and Success Rate in Selection Work-rate Increments between Two Algorithms and between the Two Groups of Subjects

<table>
<thead>
<tr>
<th></th>
<th>Dyspneic patients (n=39)</th>
<th>Normal control (n=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time of exercise, min</strong></td>
<td>9.4 ± 2.1</td>
<td>8.6 ± 3.3 *</td>
</tr>
<tr>
<td><strong>Success, no.</strong></td>
<td>33</td>
<td>24 *</td>
</tr>
<tr>
<td><strong>Success rate 8-12, %</strong></td>
<td>84.6</td>
<td>61.5 *</td>
</tr>
</tbody>
</table>

Reported algorithm was to calculate the ramp-slope using formulae [3]–[5] (5). For the formulae, please refer to the text. Success means patients whose loaded exercise time is between 8 and 12 minutes. Between-algorithm comparisons: *p<0.05, †p<0.01; Between-group comparisons: **p<0.05, ††p<0.01, ¶¶p<0.001, †††p<0.001.

Results

Comparing the two algorithms in the normal control group, the ramp-slope was higher in the reported algorithm than in the OCD-algorithm (p<0.05) in males but not in females (p=NS) (Table 2). These results were the same in the study group. There were no differences in exercise capacities between these two algorithms in the patient and control groups.

Table 3 reveals that in the normal control group, differences in exercise duration and success rate in ramp-slope selection were not significant between the two algorithms. In contrast, in the patient group, exercise time was longer and the successful exercise time was higher using the OCD-algorithm than when using the reported algorithm (9.4±2.1 vs. 8.6±3.3 min; 84.6% vs. 61.5%, both p<0.05). Figure 2 shows that the WRmax, V̇O₂max and exercise duration in minutes using the OCD-related algorithm were significantly related to the OCD scores (R²=0.61, p<0.0001; R²=0.59, p<0.0001, and R²=0.20, p=0.003, respectively).

Table 4 shows that in non-obese patients, the ramp-slope was higher, exercise capacity lower and exercise duration shorter when using the reported algorithm as compared to the OCD-algorithm. In contrast, the ramp-slope was lower and exercise duration longer when using the reported algo-

cell O₂ and single-beam infrared CO₂ analyzer (CardiO₂TM, Medical Graphics) were calibrated with 12%O₂ and 5%CO₂, and 20.93%O₂ and 0%CO₂ gases, respectively.

Measurements

Anthropometric data, underlying diseases, if present, and OCD and MMRC scores were recorded before exercise testing. Ramp-slope, peak workload, V̇O₂, and the time of loaded exercise were measured during the exercise. The frequency of exercise time between 8 and 12 minutes was calculated. The V̇O₂max was designated as the peak or maximum V̇O₂ achieved.

Statistics

The mean (SD) of each variable and the frequency for categorical variables were shown. Paired or unpaired t-test, Chi², or Fisher exact tests were used when indicated. The relationship between exercise variables and OCD scores were quantified using Pearson’s correlation coefficients. All tests were two-sided and a p value <0.05 was considered statistically significant. These procedures were performed using statistical software packages (SAS, version 8.2; SAS Institute Inc; Cary, NC; and Microcal Origin, version 4.0; Microcal Software Inc; Northampton, MA).
Figure 2. Work rate (watts) (Panel A), \( V_{O_2} \) in mL/min (Panel B), and exercise duration (minutes) using the OCD-algorithm (Panel C) and using the reported algorithm (Panel D) as a function of oxygen-cost diagram score (centimeters) for a ramp-pattern maximum exercise test. Each symbol of each panel represented a specific subject. The solid line indicated the linear regression line; curved lines indicated 95% confidence interval; and dotted lines delineated exercise duration at 8 and 12 minutes, respectively.

Table 4. Comparison of Work Rate (WR) Increment, Exercise Duration, and Success Rate between Obese and Non-obese Patients

<table>
<thead>
<tr>
<th>Dyspneic patients (n=39)</th>
<th>Non-obese (n=23)</th>
<th>Obese (n=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>57.2 (16)</td>
<td>43.9 (9.9)††</td>
</tr>
<tr>
<td>M:F</td>
<td>19:4</td>
<td>10:6</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22(3.2)</td>
<td>31(2.9)*</td>
</tr>
</tbody>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>WR increment (watts/min)</td>
<td>11(4)</td>
<td>16(3)*</td>
<td>17(4)**</td>
<td>15(4)*</td>
</tr>
<tr>
<td>WR(_{max}) (watts)</td>
<td>107(52)</td>
<td>108(51)</td>
<td>161(38)**</td>
<td>163(39)**</td>
</tr>
<tr>
<td>WR(_{max}), %</td>
<td>91(31)</td>
<td>92(32)</td>
<td>113(29)**</td>
<td>114(30)**</td>
</tr>
<tr>
<td>VO(_{2 max}) (L/min)</td>
<td>1.28(0.5)</td>
<td>1.24(0.5)*</td>
<td>1.78(0.32)**</td>
<td>1.75(0.38)**</td>
</tr>
<tr>
<td>VO(_{2 max}), %</td>
<td>77(20)</td>
<td>74(20)*</td>
<td>85(15)</td>
<td>82(14)</td>
</tr>
<tr>
<td>Time of exercise, min</td>
<td>9(2.6)</td>
<td>6.8(2.9)†</td>
<td>9.9(1.1)</td>
<td>11.1(2)***</td>
</tr>
<tr>
<td>Success, no.</td>
<td>17</td>
<td>11</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Success rate, %</td>
<td>73.9</td>
<td>47.8*</td>
<td>100*</td>
<td>68.8*</td>
</tr>
</tbody>
</table>

Reported algorithm was to calculate the ramp-slope using formulae [3]–[5] (5). For the formulae, please refer to text. Success means patients whose loaded exercise time is between 8 and 12 minutes. Between-algorithm comparisons: †p=0.07, *p<0.05, ††p=0.01, ‡p<0.001; Between-group comparisons: †p=0.06, **p<0.05, ††p=0.01, ‡‡p<0.001, §p<0.001.
Discussion

This study demonstrated that the OCD score allows for the selection of a ramp-slope for incremental exercise testing for normal subjects and patients with dyspnea. The OCD score algorithm yielded an 84.6-93.8% success rate of loaded exercise time between 8 and 12 minutes, as previously suggested (5, 7, 8, 16).

Ramp slopes

There are some drawbacks in a rapid ramp-slope exercise protocol. First, there is insufficient time for data collection. Second, there is insufficient time for carotid bodies to respond to lactic acidosis, which makes dyspnea difficult to evaluate and makes the breaking point of the lactic acidosis threshold indeterminate (7). In contrast, there are equivocal results that the steeper the ramp-slope, the higher the frequency of identification of AT (18). The disagreement may be due to: 1) the small patient number, which may lead to type II errors of comparison analysis, and 2) the different techniques used to measure AT. Buchfuhrer et al (7) used \( \dot{V}_{O2} / \dot{VCO2} \), \( \dot{VCO2} \), \( P_{ETO2} \) and \( P_{ETCO2} \) to measure AT while Miyahara et al (18) used the modified V-slope method (19).

The drawbacks of a slow ramp-slope exercise protocol are as follows: the subject is too bored and uncomfortable with the seat; the test is prematurely terminated; and core temperature is elevated if the exercise is longer than 10 minutes (20). While the \( \dot{V}_{O2} \), HR, minute ventilation, and lactate concentration at peak exercise, and AT are commensurate in response to different ramp-slope exercise protocols, the WR, \( \dot{V}_{O2} / \dot{VCO2} \), \( \dot{VCO2} \) versus WR, especially the second portion of \( \dot{VCO2} - \text{versus-WR relationship, and Borg rating score during exercise are different (3, 4, 6). A recent study challenged the standard 8-12 minutes of incremental exercise duration and reported that to elicit valid \( \dot{V}_{O2\text{max}} \) values, cycle ergometer tests should last between 7 and 26 minutes (21). To be noted, they focused on eliciting \( \dot{V}_{O2\text{max}} \) values and did not consider the other variables. Nevertheless, the 8-12 minute exercise duration time of the present study was within 7-26 minutes of exercise duration.

Oxygen-Cost Diagram

The OCD was first collected by Durnin and Passmore (11) to correspond to the metabolic equivalents required to carry out activities (22) and was first used in patients with respiratory diseases by McGavin et al (12) and widely applied thereafter in patients with similar disease entities. The OCD scale has been used in subjects with obesity and in patients with advanced cancer, chronic heart disease and in healthy elderly people (23-25). We therefore expected that the OCD might be extrapolated to the patients with obesity and/or sleep apneas.

The OCD scores reflect patients’ symptom-limited maximum workload in daily activities rather than dyspnea ratings (11, 12), thereby closely relating to work rate (r=0.78, p<0.0001) and \( \dot{V}_{O2} \) (r=0.77, p<0.0001) at peak exercise in the study (Fig. 2) and in previous reports (r=0.56, p<0.01) (26). This is also supported by previous reports that OCD scores are more closely related to the medical research council (MRC) scores than the visual analog scale (VAS) scores or Borg scores (27). The MRC score is a score for rating daily exercise capability while the VAS or Borg scale is a scale for rating dyspnea rather than rating functional capability.

The usefulness of the OCD scale might be questioned since the correlation of MRC and baseline dyspnea index (BDI) with FEV1 is more significant than that of OCD with FEV1 in patients with COPD (27). However, Hajiro et al recommended to arbitrarily choose OCD, MRC, BDI, Activity of Saint George’s Respiratory Questionnaire (SGRQ), and Dyspnea of the Chronic Respiratory Questionnaire (CRQ) (26). Oga et al reported that the OCD score can forecast exercise capacity (28). The OCD and BDI scores have significant associations with parameters of physiological impairment, while the MRC score does not (29). Although our patients had high mean OCD scores, one-third of our study group patients could only briskly walk on the level (OCD approximately 7.1) or less. Approximately 20% of our patients were at stage 3 or 4 COPD. The aforementioned findings indicate that the OCD-algorithm is useful in selecting ramp-slope for a CPET for patients with a wide range of dyspnea sensation.

The OCD-algorithm and the reported-formula algorithm

In predicting equations for ramp-slope using the OCD algorithm, 25 and 20 watt/min have been arbitrarily delineated as the steepest ramp-slopes for general healthy Chinese men and women, respectively, aged between 22 and 78 years, who are not engaged in exercise training, as suggested previously (30). The OCD score of 10 is considered the highest score for an average healthy subject. For age as graded every 10 years from 20 to 59 years, 10 METs of exercise capacity can approximate the \( \dot{V}_{O2\text{max}} \) for men with average fitness (31). For subjects with age \( \geq 60 \) years, nine or lower METs of exercise capacity may appropriate the \( \dot{V}_{O2\text{max}} \). For simplicity to predict the \( \dot{V}_{O2\text{max}} \), 10 METs of exercise capacity are used. On the other hand, brisk walking uphill may be an intense exercise for normal subjects but may not be an intense exercise for athletes. Therefore, the OCD-related algorithm is not recommended for athletes.

The previously reported algorithm is used for average healthy subjects but not for patients with dyspnea (5). In the normal control group, both the OCD-algorithm and the reported-algorithm allows for the selection of an optimal ramp-slope for a ramp-pattern exercise test. In contrast, in the patient group with dyspnea, the OCD-related ramp-slope is significantly lower than the reported-algorithm ramp-slope (13±5 vs. 15±4 watt/min in males and females as a whole group, p<0.01). Thus, the loaded exercise time is longer us-
ing the OCD-related algorithm (9.4±2.1 vs. 8.6±3.3 minutes, p<0.05). The success rate of timed exercise between 8 and 12 minutes is significantly higher using the OCD-related algorithm as compared to the formula-reported algorithm (84.6% vs. 61.5%, p<0.05, Table 3).

**Obesity**

Comparing the two algorithms, the ramp-slope is lower in obese patients using the reported-algorithm, thereby resulting in longer loaded exercise duration (Table 4). This may be due to 1) not considering body weight when calculating the predicted peak \( \dot{V}O_2 \), 2) the subtraction of unloaded \( \dot{V}O_2 \), which is 150 mL/min plus six multiplied by body weight from the predicted peak \( \dot{V}O_2 \) in calculating ramp-slope (please see formulae (3-5)). We speculate that performance of the reported formulae in predicting the ramp-slope may be improved by considering Table 7-2 of reference (32) to predict the peak \( \dot{V}O_2 \). From the study, we indirectly support that body weight might influence \( \dot{V}O_2 \) during the cycling exercise (32). Moreover, leg muscle mass is related to body weight (33) and must influence external work capacity on the cycle ergometer, which rejects that body weight alone does not influence external work capacity on the cycle ergometer (34).

Body weight is known to affect walking ability (10) and is expected to affect daily activities relating to OCD scores. Obese patients with higher OCD scores may be expected to have higher \( WR_{max} \) and ramp-slope. Obese patients with lower OCD scores may also be expected to have relatively lower \( WR_{max} \) and ramp-slope if the loaded exercise durations are within an appropriate duration (i.e., 8-12 minutes). The derived formula here contains OCD scores and body weight, which are important in predicting ramp-slope for patients with obesity to perform a maximum ramp-pattern exercise test.

**Study limitations**

First, the workload-related OCD score is obtained from memory (i.e., retrograde) but the process of the workload is estimated during the continuous exercise exertion (i.e., antegrade). This may cause inaccuracy of the ramp-slope prediction using the OCD score, as in the previous report using the Borg 6-20 rating of a perceived scale as relating to continuous exercise exertion (35). Secondly, as high as 26% of patients were excluded from the study, thus the generalization of the OCD-related algorithm is questioned. One previous study reported that \( \dot{V}O_{2max}, \dot{V}CO_{2max} \) and \( \dot{V}O_2 \)max of the first test were 20% lower than those of the repeated test in patients with heart failure (36). In contrast, we asked the subjects to perform a brief practice cycling some time before a study test but not to perform multiple symptom-limited tests. We considered that by performing at least two symptom-limited tests, the patients excluded from the study might be reduced. But, subjects who failed to reach a maximum effort or those with physiologic limitations have been lost to follow-up.

**Conclusions**

Oxygen-cost diagram subjectively indicated by patients was proportional to \( \dot{V}O_2 \) and WR at peak exercise. There was an 84.6% success rate of exercise time between 8 and 12 minutes using the OCD-algorithm to select ramp-slope exercise protocol in patients with dyspnea, and 93.8% in normal subjects. This study suggests using the OCD-algorithm in work-rate selection for a ramp-pattern exercise test in the general Chinese population and in patients with dyspnea or obesity.

**Appendix**

OCD-related algorithm:

**Ramp-slope for men**

\[
\frac{\dot{V}O_{2max}}{35} = \frac{3.5 \times \text{Score}_{OCD} \times \text{BW}}{10 \text{ mL/watt} \times 10 \text{ minutes}} + \frac{\text{BW}}{40} \text{ (a normal value of } \dot{V}O_2 - \text{WR Relationship) + (optimal duration of timed exercise)}
\]

**Ramp-slope for women**

\[
\frac{\dot{V}O_{2max}}{35} = \frac{3.5 \times \text{Score}_{OCD} \times \text{BW}}{10 \text{ mL/watt} \times 10 \text{ minutes}} + \frac{\text{BW}}{50} \text{ (a normal value of } \dot{V}O_2 - \text{WR Relationship) + (optimal duration of timed exercise)}
\]

where 3.5 mL/kg/min=1 MET and the highest OCD was assumed 10 in normal average men and women

And BW was body weight in kg

10 mL/watt=the normal ratio of increase in \( \dot{V}O_2 \) (\( \Delta \dot{V}O_2 \)) and increase in WR (\( \Delta \dot{W}R \)), considered as normal for healthy Chinese subjects as the ratio reflecting the reverse of work efficiency is not influenced by anthropometrics and ethnicity, but only by aerobic function of muscular and cardio-vascular systems (32).

10 min=a suggested duration of timed exercise (5, 7, 8, 16),

25 and 20 was assumed to be the normal maximum ramp-slope for normal average males and females, respectively.

And 35=3.5×10, which 10 is the maximum OCD score to weight the normal maximum ramp-slope for normal average males and females [4]

**Registration:** Site: Chang Gung Memorial Hospital, Taipei, Taiwan; Number: CMRP443

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