〈Original article〉

Associations of peak oxygen uptake with its decrease time and exercise intensity

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Summary Peak oxygen uptake (peak VO_2), which clinically quantitates peak exercise capacity, is widely used to predict prognosis in patients with heart failure. Peak VO_2 might be underestimated because of reduced patient motivation. This study investigated whether the time to reach 50% of the difference between peak VO_2 and rest VO_2 [T (1/2) VO_2] could be used as an alternative predictor of peak VO_2. The study was conducted on 20 healthy university students (10 men and 10 women; mean age, 21.0 ± 0.8 years; mean height, 163.4 ± 8.6 cm; mean weight, 55.1 ± 6.6 kg). All subjects performed upright ergometer exercise with respiratory gas analysis according to the ramp protocol. Exercise load intensity was gradually and linearly increased by 20 Watts per minutes after a 4- minutes rest and 4- minutes warm-up at 20 Watts. T (1/2) VO_2 at peak work rate (peak WR), 75% of peak WR (75% peak WR) and 50% of peak WR (50% peak WR) were individually obtained on three different days. Peak VO_2 was favorably and negatively correlated with T (1/2) VO_2 at peak WR (y = -0.61x + 86.52, r = -0.85), at 75% peak WR (y = -0.65x + 88.22, r = -0.82) and at 50% peak WR (y = -0.57x + 83.98, r = -0.76), respectively. T (1/2) VO_2, which was almost similar at different exercise intensity, revealed a favorable and negative correlation with peak VO_2. The result of this study suggested that T (1/2) VO_2 could be an alternative of peak VO_2.

Key words: Peak oxygen uptake, Anaerobic threshold, Oxygen deficit, Oxygen debt, T (1/2) VO_2

1. Introduction

Reduced exercise tolerance in chronic heart failure is closely associated with clinical findings, such as dyspnea and fatigue on effort, and its presence is regarded as a decrease in peak oxygen uptake (VO_2; peak VO_2) and an early appearance of anaerobic threshold (AT)[1]. Since the parameters obtained from the results of expired gas analyses present skeletal muscle metabolism and hemodynamics[2-4] and have close associations with exercise tolerance[1-5], these are widely used in the assessment of heart failure in clinical settings. Delayed recovery kinetics of VO_2 after exercise in patients with congestive heart failure has been reported[6], however, its association with exercise intensity has not been fully elucidated. Here, this study aimed to investigate whether the time to reach 50% of the difference between peak VO_2 and rest VO_2 [T (1/2) VO_2] could be used as an alternative predictor of peak VO_2.

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2. Subjects and Methods

1. Subjects

This study was conducted on 20 healthy students in Saitama Prefectural University (10 men and 10 women; mean age, 21.0 ± 0.8 years; mean height, 163.4 ± 8.6 cm; mean weight, 55.1 ± 6.6 kg) without significant medical history.

2. Methods

All subjects underwent cardiopulmonary exercise testing (CPX) using a sitting cycle ergometer. The expired gas analysis was performed throughout the test with CPX-1 (Inter Reha co., Japan). The obtained data were converted into 3-seconds time-series data; then, the results were averaged with a moving-average filter every 8 points. VO_2, carbon dioxide production (VCO_2) and minute ventilation (VE) were measured on a breath-by breath basis. A standard 12-lead electrocardiogram (ML-4500, Fukuda Denshi Co., Tokyo, Japan) was continuously recorded to monitor heart rate. According to the ramp protocol, exercise load intensity was gradually and linearly increased by 20 Watts per minutes after a 4- minutes rest and 4- minutes warm-up at 20 Watts. CPX was terminated by subject request when reaching volitional exhaustion; expired gases were collected 6 minutes after CPX termination without a cool-down period. T (1/2) VO_2 was calculated as follows: (peak VO_2 - rest VO_2) × 1/2 (Fig. 1)[7]. T (1/2) VO_2 at peak work rate (peak WR), 75% of peak WR (75% peak WR) and 50% of peak WR (50% peak WR) were individually obtained on three different days. This study was approved by the Ethical Committee of Saitama Prefectural University and was conducted according to the Guidelines of the Declaration of Helsinki.

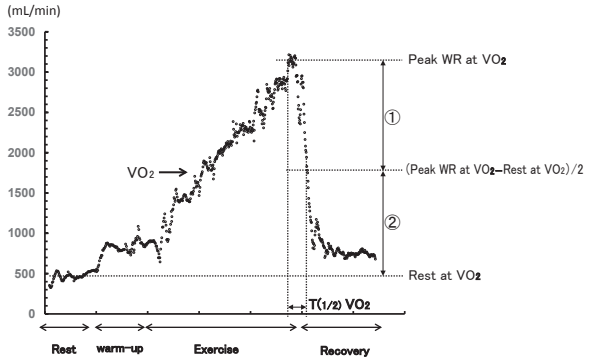

Fig. 1 The time to reach 50% of the difference between peak VO_2 and rest VO_2, T(1/2)VO_2.

3. Statistical analysis

The one-way analysis of variance was used to determine a significant difference between the 3 groups: the post-hoc test was also performed to identify the significant differences.

3. Results

T (1/2) VO_2 at peak WR, 75% peak WR and 50% peak WR

T (1/2) VO_2 at peak WR was 59.8 ± 5.1 seconds (52.5 - 68.5 seconds), T (1/2) VO_2 at 75%peak WR was 60.6 ± 5.4 seconds (50.5 - 69.5 seconds), and T (1/2) VO_2 at 50% peak WR was 60.7 ± 4.9 seconds (51.0 - 65.5 seconds). No significant differences were found between T (1/2) VO_2 at peak WR and 75% peak WR (p = 0.97), T (1/2) VO_2 at peak WR and 50% peak WR (p = 0.84), or T (1/2) VO_2 at 75% peak WR and 50% peak WR (p = 0.6, Fig. 2).

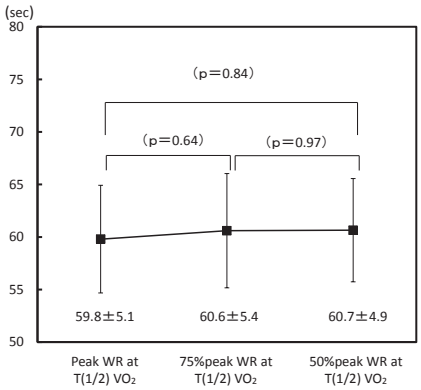

Fig. 2 T (1/2) VO_2 at different exercise intensity. No significant differences in T (1/2) VO_2 were found among peak WR, 75% peak WR and 50% peak WR.

Associations between peak VO_2 and T (1/2) VO_2 at each WR

Peak VO_2 was favorably and negatively correlated with T (1/2) VO_2 at peak WR (y = -0.61x +

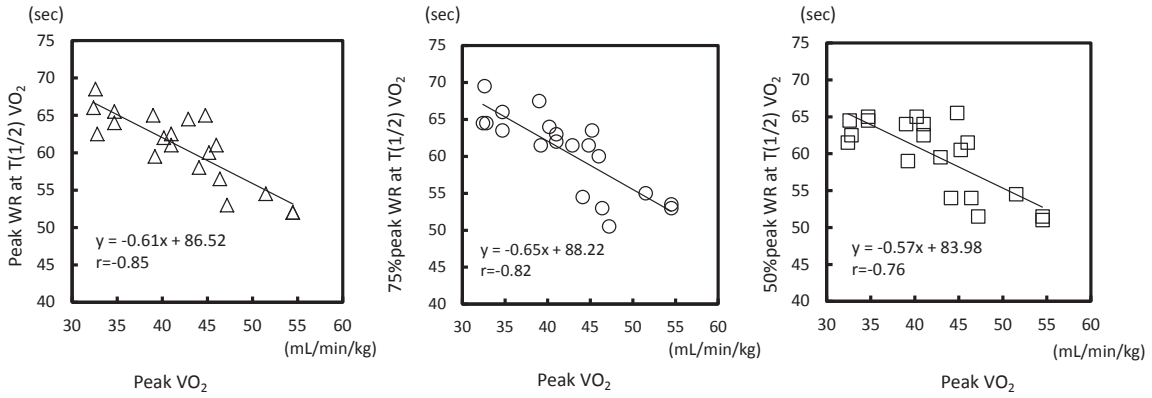

Fig. 3 Associations between peak VO_2 and T (1/2) VO_2 at peak WR, 75% peak WR and 50% peak WR. Peak VO_2 revealed favorable and negative correlations with T (1/2) VO_2 at peak WR (r = -0.85), 75% peak WR (r = -0.82), and 50% peak WR (r = -0.76), respectively.

86.52, r = -0.85), at 75% peak WR (y = -0.65x + 88.22, r = -0.82) and at 50% peak WR (y = -0.57x + 83.98, r = -0.76), respectively (Fig. 3).

4. Discussion

The analyses of VO_2 kinetics have presented two components, on-fast component in which VO_2 rapidly decreases after exercise and on-slow component appearing after on-fast component[8]. VO_2 in on-fast component resynthesizes phosphocreatine in the skeletal muscles. In this study, on-fast component was employed in the formula of T (1/2) VO_2. The result of this study demonstrated no significantly prolonged T (1/2) VO_2 in different exercise intensity in the same subject. Since similar T (1/2) VO_2 was observed even in the submaximal and maximal exercise tests, this parameter might have a possibility to assess patients with severe heart failure who may have difficulty performing maximal exercise. Tanabe et al.[9] demonstrated that T (1/2) VO_2 was prolonged in patients with advanced stages of heart failure, particularly in those with overshoot of cardiac output which was defined as a further increase in cardiac output at 1 minute of recovery above the cardiac output at peak exercise. Our previous study[10] also reported that VO_2 kinetics during recovery from exercise were delayed in patients with severe coronary artery disease. An oxygen deficit occurs when sufficient oxygen cannot be taken fast enough during exercise, leading to anoxic metabolism in the skeletal muscles. In such cases, the quantity of oxygen during recovery from exercise is increased and the time to reach VO_2 at rest takes longer. This is the mechanism of oxygen debt (O_2 debt). In advanced heart failure, O_2 debt increases during exercise, resulting in prolonged T (1/2) VO_2. Peak VO_2 is widely used in the assessment of exercise tolerance and the severity of heart failure. However, peak VO_2 might be underestimated because of reduced patient motivation; thus, this study employed T (1/2) VO_2. Since no significant differences in T (1/2) VO_2 at peak WR, 75% peak WR and 50% peak WR and a significant negative correlation between peak VO_2 and T (1/2) VO_2 at different exercise intensity were found, the result of this study suggested that T (1/2) VO_2 could be an alternative of peak VO_2.

In conclusion: Peak VO_2 had significant correlations with T (1/2) VO_2 at peak WR, 75% peak WR and 50% peak WR, respectively, suggesting that the parameters obtained during submaximal exercise should also provide an appropriate assessment of heart failure. Further studies with different gender and age groups are required for the establishment of new assessment method using T (1/2) VO_2.

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