Changes of Incremental Exercise $\dot{V}O_2$ Kinetics between Different Fitness Levels

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ABSTRACT

The analysis of $\dot{V}O_2$ kinetics in the previous studies focused more often in continuous exercise test. However, incremental exercise as a evaluation test or prescription raised clinical attention recently, but research evidence is still scant.
PURPOSE: The purpose of this study was to investigate the changes of incremental exercise $\dot{V}O_2$ kinetics between people with different fitness level.
METHOD:
Physically active college male students were recruited into this study. There were two groups of subjects, high-fitness (HF: 20.22 ± 2.11 yr, 177.89 ± 4.48cm, 72.06 ± 10.88 kg, $\dot{V}O_{2max}$: 58.87 ± 1.62 ml/kg/min; n=9) and low-fitness (LF: 19.33 ± 1.12 yr, 177.78 ± 5.95 cm, 79.82 ± 13.34 kg, $\dot{V}O_{2max}$: 44.10 ± 2.31 ml/kg/min; n=9).
All subjects completed two 6-min bouts of moderate-intensity (63%$\dot{V}O_{2max}$)and severe-intensity(95%$\dot{V}O_{2max}$) running incremental exercise test (separated by 10 min of rest). Breath-by-breath pulmonary gas exchange (SensorMedics, Vmax 29) and HR were measured. One-way repeated-measure ANOVA was used to compare the $\Delta\dot{V}O_2$ of each minutes between the 2 groups under different intensity.
RESULT:
The $\Delta\dot{V}O_2$ during SI exercise [HF: $\Delta\dot{V}O_{2(2\text{-}1),\ (3\text{-}2),\ (4\text{-}3),\ (5\text{-}4),\ (6\text{-}5)}$:11.48, 6.65, 0.49, 0.73, -0.73ml·kg^{-1}·min^{-1}; LF: $\Delta\dot{V}O_{2(2\text{-}1),\ (3\text{-}2),\ (4\text{-}3),\ (5\text{-}4),\ (6\text{-}5)}$: 6.0, 6.49, 1.31, 0.54, -0.54 ml · kg^{-1} · min^{-1}, respectively] was plateaued at third minute for both groups ($\dot{V}O_2$ between 3 and 4 min, HF: p = .15, LF: p = .26). The $\Delta\dot{V}O_2$ during MI exercise [HF: $\Delta\dot{V}O_{2(2\text{-}1),\ (3\text{-}2),\ (4\text{-}3),\ (5\text{-}4),\ (6\text{-}5)}$: 9.51, 3.11, 0.48, -0.30, 0.30 ml · kg^{-1} · min^{-1}; LF: $\Delta\dot{V}O_{2(2\text{-}1),\ (3\text{-}2),\ (4\text{-}3),\ (5\text{-}4),\ (6\text{-}5)}$: 6.41, 3.4, 0.98, 0.27, -0.27 ml·kg^{-1}·min^{-1}, respectively] was plateaued at third minute for LF groups ($\dot{V}O_2$ between 3 and 4 min, p = .87), but at second minute for the HF group ($\dot{V}O_2$ between 2 and 3 min, p = 1.5).
CONCLUSION:
Under moderate-intensity exercise, subjects at different fitness level achieved stages of stable $\dot{V}O_2$ at different timing. HF participants can reach stable $\dot{V}O_2$ earlier then participants in LF.

Keywords: oxygen uptake, $\dot{V}O_2$, incremental exercise

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RESULT: The $\Delta\dot{V}O_2$ during SI exercise [HF: $\Delta\dot{V}O_{2(2\text{-}1),(3\text{-}2),(4\text{-}3),(5\text{-}4),(6\text{-}5)}$:11.48, 6.65, 0.49, 0.73, -0.73ml · kg^{-1} · min^{-1}; LF: $\Delta\dot{V}O_{2(2\text{-}1),(3\text{-}2),(4\text{-}3),(5\text{-}4),(6\text{-}5)}$: 6.0, 6.49, 1.31, 0.54, -0.54 ml · kg^{-1} · min^{-1}, respectively] was plateaued at third minute for both groups ($\dot{V}O_2$ between 3 and 4 min, HF: $p = .15$, LF: $p = .26$). The $\Delta\dot{V}O_2$ during MI exercise [HF: $\Delta\dot{V}O_{2(2\text{-}1),(3\text{-}2),(4\text{-}3),(5\text{-}4),(6\text{-}5)}$: 9.51, 3.11, 0.48, -0.30, 0.30 ml · kg^{-1} · min^{-1}; LF: $\Delta\dot{V}O_{2(2\text{-}1),(3\text{-}2),(4\text{-}3),(5\text{-}4),(6\text{-}5)}$: 6.41, 3.4, 0.98, 0.27, -0.27 ml · kg^{-1} · min^{-1}, respectively] was plateaued at third minute for LF groups ($\dot{V}O_2$ between 3 and 4 min, $p = .87$), but at second minute for the HF group ($\dot{V}O_2$ between 2 and 3 min, $p = 1.5$).

CONCLUSION: Under moderate-intensity exercise, subjects at different fitness level achieved stages of stable $\dot{V}O_2$ at different timing. HF participants can reach stable $\dot{V}O_2$ earlier then participants in LF.

Keywords: oxygen uptake, $\dot{V}O_2$, incremental exercise

Introduction

As both aerobic power and economy are related to $\dot{V}O_2$ kinetics，these parameters may be useful indices of performance. It is known that endurance training has important effects on the fundamental component of the $\dot{V}O_2$ kinetics. A reduction in the amplitude of the response would signify an improved exercise economy/efficiency, but effects on the time constant of the response are even more profound. In addition, decrease in the amplitude of the slow component leads to a proportional increase in economy. This might be particularly important for exercise above the critical power.(Burnley, & Jones, 2007) Furthermore, the enhanced exercise tolerance after endurance training was related to changes in both the "fast" and "slow" components of the $\dot{V}O_2$ kinetics response. (Koppo, Bouckaert, & Jones, 2004; Burnley, & Jones, 2007)

Methods

Subjects.

Thirty-seven healthy, physically active college male students were allocated into two groups according to their fitness level: high-fitness group (HFG) (20.22 ± 2.11 yr, 177.89 ± 4.48cm, 72.06 ± 10.88 kg, $\dot{V}O_{2max}$: 58.87 ± 1.62 ml/kg/min; n=9) and low-fitness group (LFG) (19.33 ± 1.12 yr, 177.78 ± 5.95 cm, 79.82 ± 13.34 kg, VO2max: 44.10 ± 2.31 ml/kg/min; n=9).

During all tests, pulmonary gas exchange and ventilation were measured continuously using a metabolic measurement system (SensorMedics, Vmax 29). Heart rate (HR; beat · min^{-1}) was measured during all tests using a 12-lead electrocardiograph (SensorMedics, CardioSoft V4 (37/38) ECG). The breath-by-breath pulmonary gas-exchange data were collected continuously during incremental test and were averaged over consecutive 10-s periods. All subjects completed two 6-min bouts of moderate-intensity (63%$\dot{V}O_{2max}$) and severe-intensity (95%$\dot{V}O_{2max}$) incremental treadmill exercise test (separated by 10 min of rest). Blood samples were also collected during pre and post exercise test.

Exercise tests.

Subjects initially completed a preliminary incremental treadmill test for determination of $\dot{V}O2_{max}$ followed by "step" running tests over 2 consecutive days.

All treadmill exercise testing sessions were carried out in a well-ventilated laboratory on a treadmill (Cosmed Programmable Sport treadmill Model T150E, Cosmed, USA). On the first laboratory visit, the subjects completed a ramp incremental exercise test for determination of the $\dot{V}O2_{max}$ and gas exchange threshold (GET). After the warm-up, GXT was administered until the subjects reached volitional fatigue. The protocol began with subjects walking at 7 km/h for 6 min; then the speed was increased by 1 km/h every minute until volitional exhaustion. The breath-by-breath pulmonary gas exchange data were collected continuously during the incremental test and averaged over consecutive 10-s periods.The GET was determined according to the previously references (Bailey, Winyard, Vanhatalo, Blackwell, Dimenna, Wilkerson, Tarr, Benjamin, & Jones, 2009; Beaver, Wasserman, & Whipp, 1986).

Subsequently, the treadmill speeds that matched 80% of the GET (moderate-intensity exercise) and 75% [75% of the difference between the speed at the GET and $\dot{V}O2_{max}$ + the speed at GET (severe-intensity exercise)] were calculated, taking account the mean response time for $\dot{V}O2$ during ramp exercise (i.e., two-thirds of the ramp rate was deducted from the running speeds at GET and $\dot{V}O2_{max}$) (Whipp, Davis, Torres, & Wassserman, 1981).

All exercise bouts involved a transition to the target speed initiated from a walking stage (4 km/h), and exercise bouts were separated by 10 min of walking at 4 km/h.

The protocol consisted of two 6-min bouts of moderate-intensity running (80% GET) and one exhaustive bout of severe-intensity running (75% Δ) as a measure of exercise tolerance. (Fig. 1) Changes in physiological responses to walking and moderate- and severe-intensity running were investigated.

Statistical analysis.

Data are expressed as the mean $\pm$ SD or median (range) as appropriate after testing the normality of distribution. All statistical analysis was completed using the software package SPSS, version 18.0 (SPSS, Inc., Chicago, IL). One-way repeated-measure ANOVA was used to compare the $\Delta\dot{V}O_2$ of each minutes between the 2 groups under different intensity. Statistical significance was set at $p < .05$.

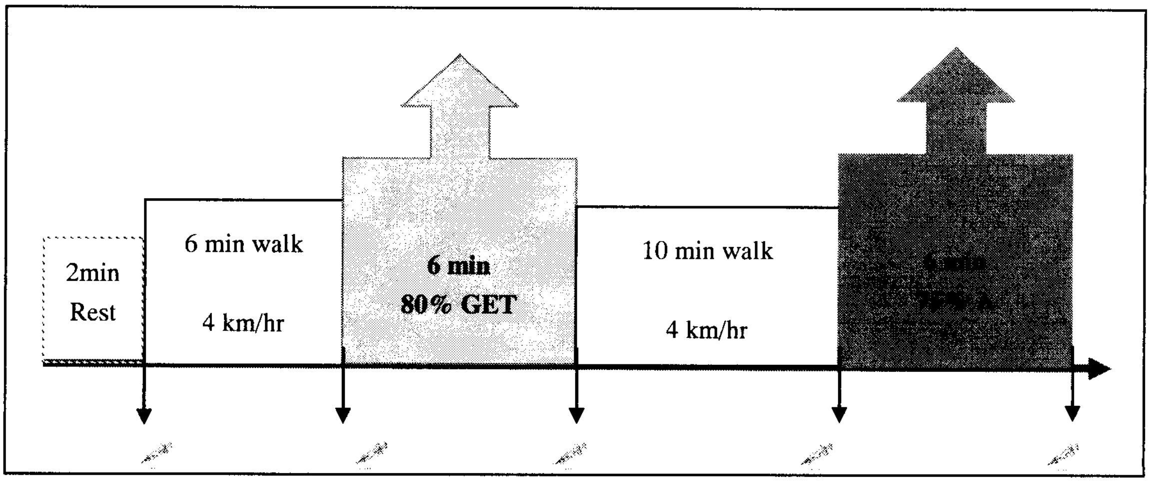

Fig. 1. Schematic illustration of exercise test protocol.
GET: get exchange threshold. : capillary blood sample.

Results

All 18 subjects undertook the test battery and none reported any injury that may have affected their performance. Participant characteristics are shown in Table 1.

Pulmonary $\dot{V}$O2 responses across the ramp incremental exercise test are presented in Table 2. Pulmonary$\dot{V}O_{2max}$ was significant among the groups (58.87 ± 1.62 vs. 44.10 ± 2.31 $ml^{-1} \cdot kg^{-1} \cdot min^{-1}$, $p < .05$) The plasma lactate responses during moderate – intensity and severe – intensity are show in Table.3.

The changes of oxygen comsumption($\Delta\dot{V}O_2$) compared to the previous minutes during MI exercise [HF: $\Delta\dot{V}O_{2(2\text{-}1),(3\text{-}2),(4\text{-}3),(5\text{-}4),(6\text{-}5)}$: 9.51, 3.11, 0.48, -0.30, 0.30 $ml \cdot kg^{-1} \cdot min^{-1}$; LF: $\Delta\dot{V}O_{2(2\text{-}1),(3\text{-}2),(4\text{-}3),(5\text{-}4),(6\text{-}5)}$: 6.41, 3.4, 0.98, 0.27, -0.27 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively] was plateaued at the third minute for LF groups ($\dot{V}O_2$ between 3 and 4 min, p = .87), but at the second minute for the HF group ($\dot{V}O_2$ between 2 and 3 min, p = 1.5). (Fig.2) The $\Delta\dot{V}O_2$ compared to the previous minutes during SI exercise [HF: $\Delta\dot{V}O_{2(2\text{-}1),(3\text{-}2),(4\text{-}3),(5\text{-}4),(6\text{-}5)}$:11.48, 6.65, 0.49, 0.73, -0.73$ml \cdot kg^{-1} \cdot min^{-1}$; LF: $\Delta\dot{V}O_{2(2\text{-}1),(3\text{-}2),(4\text{-}3),(5\text{-}4),(6\text{-}5)}$: 6.0, 6.49, 1.31, 0.54, -0.54 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively] was plateaued at third minute for both groups ($\dot{V}O_2$ between 3 and 4 min, HF: p = .15, LF:

p = .26). (Fig.3)

Table. 1 Participant characteristics.

Variable	High-fitness group (n=9)	Low-fitness group (n=9)
Age (yr)	20.22 ± 2.11	19.33 ± 1.12
Height (cm)	177.89 ± 4.48	177.78 ± 5.95
Weight (kg)	72.06 ± 10.88	79.82 ± 13.34
BMI	22.72 ± 2.85	25.21 ± 3.64

Values are mean ± SD.

Table 2. Heart rate and blood lactate responses during ramp incremental exercise test.

	HFG (n=9)	LFG (n=9)
$\dot{V}O_{2max}$ ($ml^{-1} \cdot kg^{-1} \cdot min^{-1}$)	58.87 ± 1.62	44.10 ± 2.31
$HR_{baseline}$ (beats · min)	82.11 ± 11.95	88.67 ± 6.00
HR_{max} (beats · min)	201.33 ± 8.69	195.22 ± 6.53
Blood [lactate]		
Pre-	3.16 ± 1.08	3.15 ± 1.36
Post-	11.35 ± 2.55	12.73 ± 3.70

Values are mean ± SD, HR: Heart rate, [Lactate]: lactate concentration, Pre-: pre-exercise, Post- post exercise, HFG: high fitness group, LFG: low fitness group.

Table 3. Blood lactate responses to moderate- and severe –intensity exercise following the HFG and LFG.

	HFG (n=9)	LFG (n=9)
	Moderate - intensity exercise	
Blood [lactate]		
Walking baseline, mM	2.21 ± 0.53	2.99 ± 1.47
End, mM	5.10 ± 1.56	4.74 ± 1.38
	Severe - intensity exercise	
Blood [lactate]		
Walking baseline, mM	3.25 ± 1.09	3.76 ± 1.49
End, mM	10.64 ± 1.31	10.61 ± 2.20

Values are means ± SD. [Lactate]: lactate concentration, HFG: high fitness group, LFG: low fitness group.

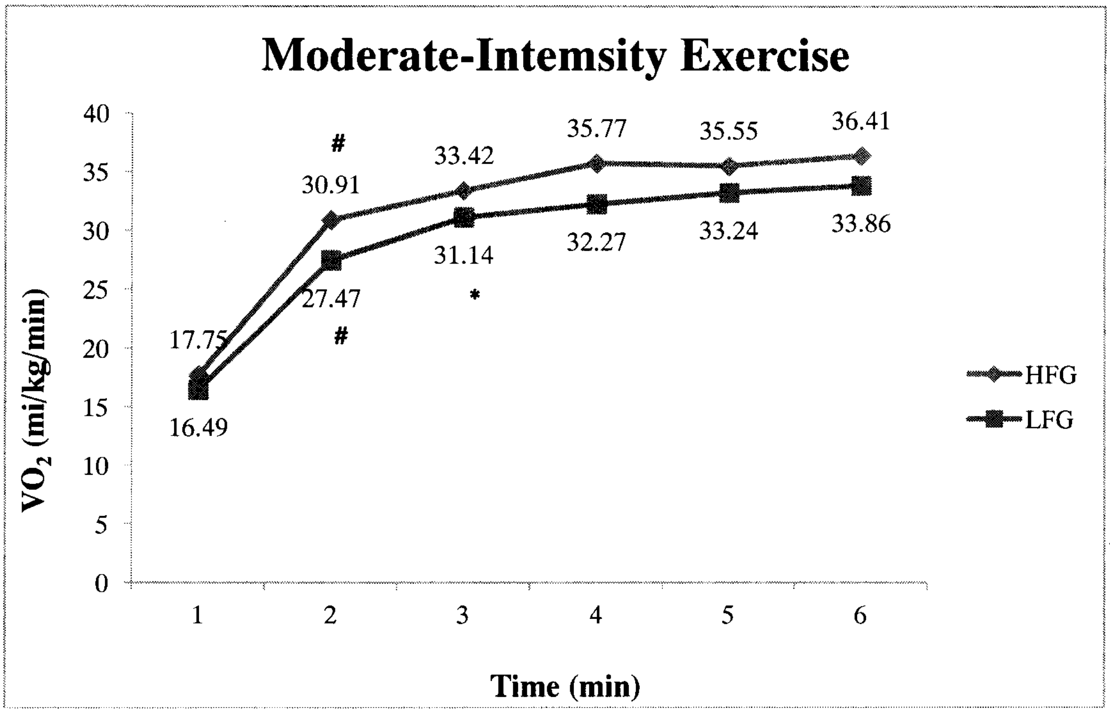

Fig. 2. Pulmonary O2 uptake responses during running test at moderate-intensity exercise. HFG: high – fitness group. LFG: low – fitness group.

*: $\dot{V}O_{2\ (\mathrm{third\ min})}$ significantly different from $\dot{V}O_{2\ (\mathrm{second\ min})}$, $p < .01$.

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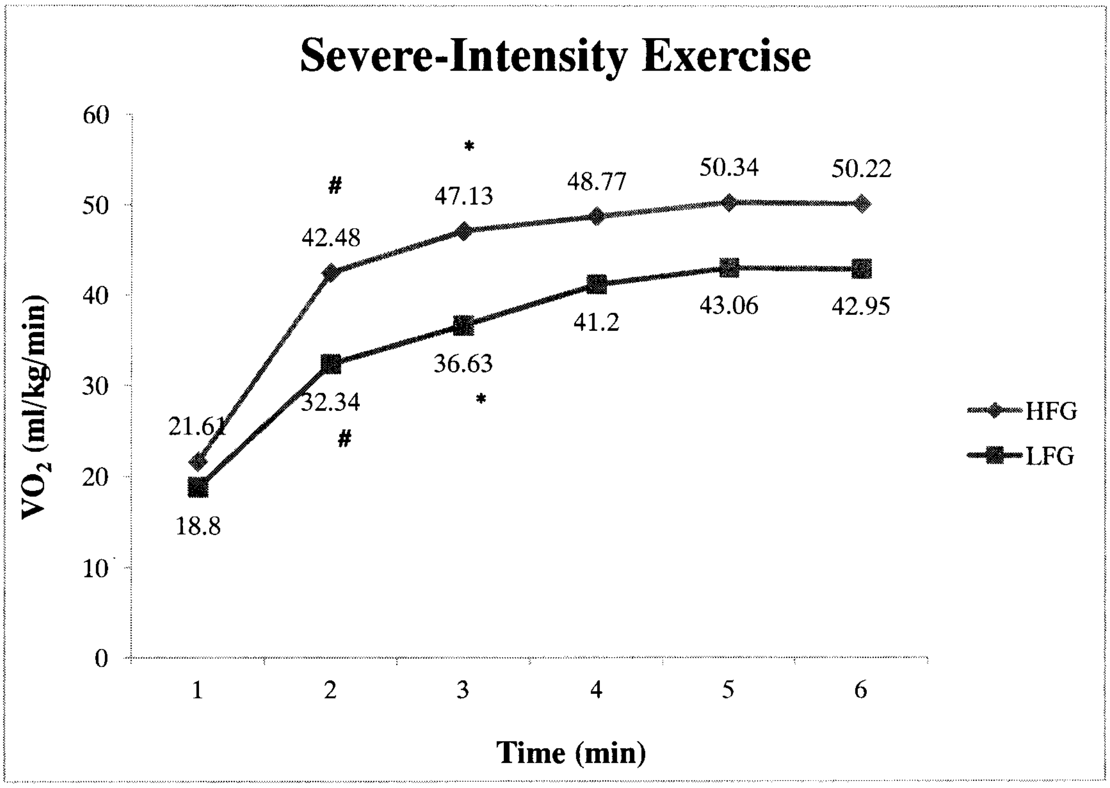

Fig. 3. Pulmonary O2 uptake responses during running test at severe-intensity exercise.

HFG: high – fitness group. LFG: low – fitness group.

*: $\dot{V}O_{2\,(\text{third min})}$ significantly different from $\dot{V}O_{2\,(\text{second min})}$, $p < .01$.

#: $\dot{V}O_{2\,(\text{second min})}$ significantly different from $\dot{V}O_{2\,(\text{firstt min})}$, $p < .01$.

Conclusions

Under moderate-intensity exercise, subjects at different fitness level achieved stages of stable $\dot{V}O_2$ at different timing. HF participants can reach stable $\dot{V}O_2$ earlier then participants in LF.

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