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Breathing patterns response to the incremental exercise test in young males

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ABSTRACT

Incremental exercise test contains three different metabolic regions, including aerobic region, partly anaerobic and anaerobic dominated region. The work load from warm up period to anaerobic threshold (AT) was accepted as aerobic region, workload above AT to respiratory compensation point (RCP) was accepted partly anaerobic region and above RCP was accepted as anaerobic region of incremental exercise test. We aimed to compare the ventilatory patterns during different metabolic sections of incremental exercise test. Fifteen healthy males performed an incremental exercise test (15 W/min) to exhaustion on a cycle ergometer. Metabolic and cardiopulmonary parameters were measured breath-by-breath using metabolic gas analyser system and turbine volume meter. AT and RCP were estimated using ventilator and pulmonary gas exchange parameters. Respiratory patterns, breathing frequency (Bf) and tidal volume (VT), showed great differences among the exercise regions. VT is the main factor increases minute ventilation (VE) during aerobic region. However, Bf becomes dominant factor increasing VE in anaerobic region of test. In the region between AT to RCP, Bf and VT showed similar effects on increase in VE. VT to inspiratory time ratio increased significantly in all region of test. However, work production capacity for each liter of VE decreased markedly when the exercise intensity changed from aerobic to anaerobic regions. Consequently, evaluation of breathing patterns for different metabolic regions of incremental exercise will provide information regarding individual's metabolic strength and ventilator response.

1. Introduction

Cardiopulmonary exercise test is an important tool that is widely used to evaluate functional capacity of body respiratory, metabolic and cardiac systems (Wasserman et al., 2012). Incremental ramp exercise protocols have become popular because they provide smooth and constantly increasing load stress to metabolic systems. Thus, increased metabolic demands from resting to maximal exercise should be associated with cardiorespiratory adjustment for maintaining homeostasis.

Incremental exercise test contains three important set point, including anaerobic threshold (AT), respiratory compensation point (RCP) and maximal exercise (Max) (Algul et al., 2017). During incremental exercise test, minute ventilation (VE) increases linearly with increasing workload and closely with increased CO_2 output (VCO_2) until the anaerobic threshold (AT) (Whipp et al., 1989). AT reflects highest workload without increase of blood lactate levels reflecting aerobic region of incremental exercise tests (Wasserman et al., 2012). Above AT, when work rate increased further VE increases proportion to with increased VCO_2 until the RCP. However, beyond RCP VE increases out of proportion to VCO_2 until the end of test (Whipp et al., 1989). It is known that increases of VE is the result of wide range of change in breathing patterns, i.e. tidal volume (VT) and breathing frequency (Bf) (Milic-Emili and Cajani, 1957). Since its first clinical description, VT, Bf and VE are widely used in medicine and sport science (Hey et al., 1966). The breathing pattern changes have been evaluated at maximal exercise values and normal responses has been presented in some studies (Hansen et al., 1984; Blackie et al., 1991; Neder et al., 2003). In addition breathing patterns has been evaluated in response to the incremental exercise with different work increments (Scheuermann and Kowalchuk, 1999) or sinusoidal exercise (Nicola et al., 2018). However, the response of breathing patterns at the anaerobic threshold, at respiratory compensation point and at maximal of the incremental exercise test will provide important information concerning VE, Bf and VT triangle.

In the present study, we aimed to evaluate contribution of VT and Bf for increasing VE during an incremental exercise test and to compare the values at three different metabolic set points from onset to anaerobic threshold, from anaerobic threshold to RCP and from RCP to end of exercise test.

2. Materials and methods

Fifteen heathy male subjects were participated to this study after giving signed informed consents, which were approved by the local ethical committee. Their (mean±SE) age, weight and height are 21.06±0.5 year, 77.2±1.9 kg and 184.9±1.7 cm, respectively. The subjects were free of any metabolic, cardiac and respiratory disease. The subject's age should was between 18 to 25. The body composition analysis was made using BIA and subjects with normal body composition was participated to study (Kaya and Ozçelik, 2009).

Each subject performed an incremental exercise test (Whipp et al., 1981). The exercise work protocol started with 20 W cycling as a warm-up period for four minutes until the steady state of respiratory parameters. This period was carefully controlled for prior hyperventilation in which results pseudo-threshold phenomenon (Ozcelik et al., 1999). The workload increased by a workload controlled 15 W/min until the subjects' limit of tolerance. Then the workload reduced to 20 W as a recovery period for couple of minutes. The subjects had 12 lead-EKG and during exercise all cardiac values were controlled beat-by-beat especially ST segment for any deprivation.

During exercise, the subjects were instructed to breathe into low resistance, low dead space turbine volume transducer to measure ventilatory parameters. The metabolic parameters were measured using metabolic gas analyser. The data was evaluated breath-by-breath.

Anaerobic threshold was estimated using standard V-sloe method (Beaver et al., 1986). The other conventional methods including increases of ventilatory equivalent for VO_2 (VE/VO_2) and end-tidal partial pressure of O_2 ($PETO_2$ mmHg) also used to estimate AT (Whipp et al., 1986). Respiratory compensation point was estimated using increase of ventilatory equivalent for CO_2 (VE/VCO_2) and decrease in end-tidal partial pressure of CO_2 ($PETCO_2$ mmHg) (Algul et al., 2017). Anova test was used to analyse data for significant differences between three different regions. A Pearson correlation analysis was used to evaluate data between breathing patterns and respiratory time. $P<0.05$ was accepted as statistically significant.

3. Results

The subjects (mean±SE) work rate at the AT, RCP and maximal exercise were found to be 143.6±6 W, 171.3±7 W and 226.6±6 W, respectively. The AT and RCP were occurred at 63% and 75% of the maximal exercise capacity. The work production capacity and O^2 uptake for each kg of body weight at maximal exercise were found to be 2.94±0.08 W/min/kg and 39.9±1.2 ml/min/kg, respectively.

Ventilatory patterns response to incremental exercise test is shown in Fig. 1. The percent change of VE, Bf and VT from warm up to AT, from At to the RCP and RCP to maximal exercise test are shown in Fig. 2. Minute ventilation at the 20 W warm up period was found to be 16.73±0.48 L/min. VE increased to 49.4±2.0 L/min at the AT. The marked increase of VE in the aerobic region of exercise test occurred as 197%. Above the AT VE, continued to increase and it reached to 64.4±2.9 L/min at the RCP (i.e. 30% of increase). VE at maximal exercise was found to be 103.7±4.3 L/min (i.e. 62% of increase). Breathing frequency at the 20 W warm up period was found to be 19.4±0.6 br/min. Bf increased to 24.3±1.3 L/min at the AT. The increase of Bf in the aerobic region of exercise test was occurred as 25%. Above the AT, Bf increased slightly and it reached to 28.8±2.0 br/min At the RCP (i.e. 18% of increase). Bf at maximal exercise was found to be 42.1±2.2 br/min (i.e. 50% of increase). VT at the 20 W warm up period was found to be 0.87±0.03 Ln. VT increased to 2.10±0.13 L at the AT. The increase of VT in the aerobic region of exercise test was occurred as 142%. Above the AT, VT increased slightly and it reached to 2.343±0.16 L At the RCP (i.e. 11% of increase). VT at maximal exercise was found to be 2.538±0.15 L (i.e. 10% of increase).

The amount of workload for each litter of VE (WR/VE) in aerobic region of incremental exercise test was 3.875±0.16 (L/min/W). However, above the

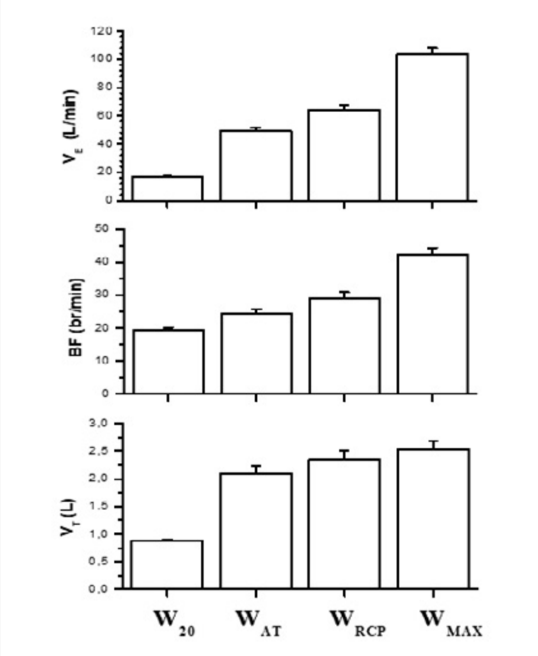

Fig. 1. The (mean±SE) values of minute ventilation (VE), breathing frequency (Bf) and tidal volume (VT) in response to the incremental exercise at the warm up (W20), at anaerobic threshold (WAT), at respiratory compensation point (WRCP) and at maximal exercise (WMAX).

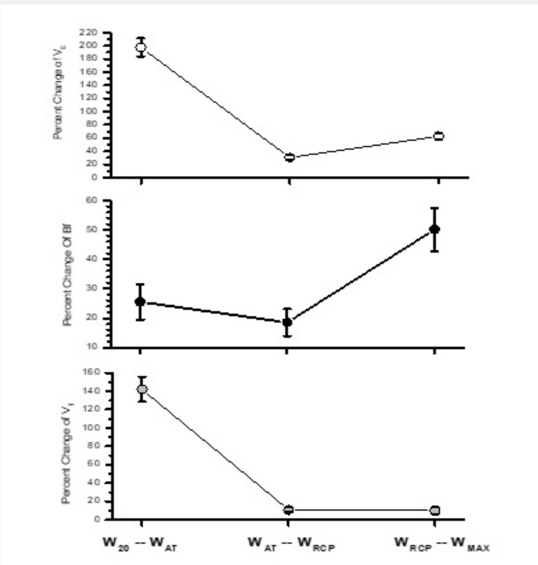

Fig. 2. The (mean±SE) percent change of minute ventilation (VE), breathing frequency (Bf) and tidal volume (VT) in response to the incremental exercise tests: from warm-up to anaerobic threshold (W20-- WAT), from anaerobic threshold to respiratory compensation point (WAT -- WRCP) and from respiratory compensation point to maximal exercise (WRCP --WMAX).

AT, WR/VE significantly decreased to 2.147±0.26 L/min/W ($p<.005$). Beyond the RCP, WR/VE continued to decreased and averaged 1.524±0.13 L/min/W ($p<0.005$) at maximal exercise. During incremental exercise test, VT to inspiratory time and inspiratory time to total breathing time response to the AT, RCP and maximal exercise are shown in Table 1. There is linear significant correlation between increase in VT/Ti and VE (Fig. 3).

Table 1. Relationships between tidal volume to inspiratory time ratio (VT/Ti) and inspiratory time to total respiratory time ratio (Ti/Ttot) in response to the incremental exercise at the warm up, at anaerobic threshold (WAT), at respiratory compensation point (WRCP) and at maximal exercise (WMAX) (mean±SE).

	V_T/Ti	Ti/Ttot
Warm-up	0.668±0.02	41.9±0.9
W_{AT}	1.848±0.06	45.8±0.8
W_{RCP}	2.326±0.09	47.1±0.9
W_{MAX}	3.509±0.13	49.1±0.9

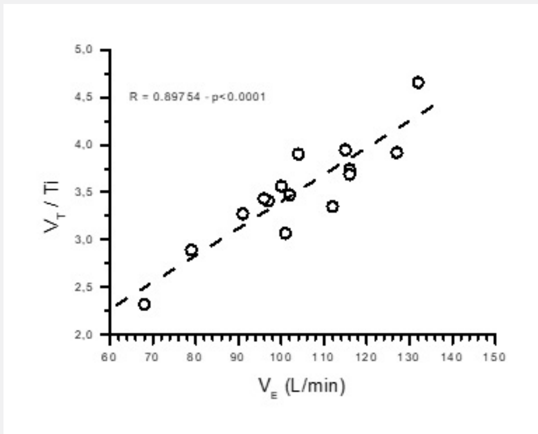

Fig. 3. The correlation between minute ventilation and tidal volume to inspiratory time ratio (VE/Ti at the end of the ramp test (n=15)).

4. Discussion

We have found different interaction in VT and Bf during each metabolic stage of incremental exercise test, i.e. aerobic region, isocapnic buffering period and anaerobic region. There was significant change in ventilator pattern regarding the exercise modality. Evaluating the differentiating between Bf and VT during different part of the incremental exercise test may improve our knowledge of exercise hyperpnoea, because Bf and VT seems to be regulated by different metabolic effects (Whipp and Ward, 1998).

AT describes the metabolic transition point from aerobic to anaerobic metabolism occurred at 63% of maximal exercise capacity, which is accepted as normal healthy range (Ozcelik et al., 2004; Wasserman et al., 2012). During an incremental exercise test, increased metabolic demands of exercising muscle in response to the progressively increasing work load (i.e. from 20 W to 143 W) accompanied by a marked increase of VE (Fig. 2). In the aerobic region of incremental, exercise test, VE increased mainly by a marked increase in VT (142%) and also small but significant increase in Bf (25%) (Figs.1, 2).

Breathing patterns response to the incremental exercise work rate between AT and RCP was different than aerobic region of exercise. VE increased due to the rise in both VT and Bf (Fig. 2). Workload above the RCP, VE increased significantly (62%). In contrast to the aerobic region of increment exercise test, Bf is the main factor stimulating VE (Fig. 2). Bf begins to increase workload above AT and becomes more rapidly above RCP to maximal exercise (Cross et al., 2012).

VT/Ti increased thought the incremental exercise test (Naranjo et al., 2005) and reflect switch off inspiration regulating the rate of VT and Bf. The work production capacity for each liter of VE decreased when the work rate increased further (Benito et al., 2006). A high level of Bf relative to given VT above the AT and RCP will result in a less effective ventilation. The study performed trained subjects showed different breathing pattern in treadmill exercise compared to cycle ergometer especially lower VT observation (Power et al., 2012). The disparate response of respiratory pattern to metabolic activity under the condition of progressively increasing exercise stress reveal close relationships between metabolic activity level and breathing patterns.

Evaluating of the relationships between Bf and VT for assessing ventilatory response during incremental exercise at the AT, RCP and maximal values will provide useful information in the assessment of the response to each part of exercise in healthy people.

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