Breathing pattern in highly competitive cyclists during incremental exercise

Abstract The purpose of our investigation was to analyse the breathing patterns of professional cyclists during incremental exercise from submaximal to maximal intensities. A group of 11 elite amateur male road cyclists [E, mean age 23 (SD 2) years, peak oxygen uptake (\(\dot{V'O_{2\text{peak}}\)) 73.8 (SD 5.0) ml · kg\(^{-1}\) · min\(^{-1}\)] and 14 professional male road cyclists [P, mean age 26 (SD 2) years, (\(\dot{V'O_{2\text{peak}}\)) 73.2 (SD 6.6) ml · kg\(^{-1}\) · min\(^{-1}\)] participated in this study. Each of the subjects performed an exercise test on a cycle ergometer following a ramp protocol (exercise intensity increases of 25 W · min\(^{-1}\)) until the subject was exhausted. For each subject, the following parameters were recorded during the tests: oxygen consumption (\(\dot{V'O_2}\)), carbon dioxide output (\(\dot{V'CO_2}\)), pulmonary ventilation (\(\dot{V'E}\)), tidal volume (\(V_T\)), breathing frequency (\(f_b\)), ventilatory equivalents for oxygen (\(\dot{V'E}/\dot{V'O_2}\)) and carbon dioxide (\(\dot{V'E}/\dot{V'CO_2}\)), end-tidal partial pressure of oxygen and partial pressure of carbon dioxide, inspiratory (\(t_i\)) and expiratory (\(t_E\)) times, inspiratory duty cycle (\(t_i/T\TOT\), where \(T\TOT\) is the time for one respiratory cycle), and mean inspiratory flow rate (\(V_T/t_i\)). Mean values of \(\dot{V'E}\) were significantly higher in E at 300, 350 and 400 W (\(P < 0.05\), \(P < 0.05\) and \(P < 0.01\), respectively); \(f_b\) was also higher in E in most moderate-to-maximal intensities. On the other hand, \(V_T\) showed a different pattern in both groups at near-to-maximal intensities, since no plateau was observed in P. The response of \(t_i\) and \(t_E\) was also different. Finally, \(V_T/t_i\) and \(t_i/T\TOT\) showed a similar response in both P and E.

It was concluded that the breathing pattern of the two groups differed mainly in two aspects: in the professional cyclists, \(\dot{V'E}\) increased at any exercise intensity as a result of increases in both \(V_T\) and \(f_b\), with no evidence of tachypnoeic shift, and \(t_E\) was prolonged in this group at high exercise intensities. In contrast, neither the central drive nor the timing component of respiration seem to have been significantly altered by the training demands of professional cycling.

Key words Ventilation · Exercise · Cycling

Introduction

Several authors have documented the breathing pattern adopted by healthy humans during incremental exercise (Gallagher et al. 1987; McParland et al. 1991). Whereas it has been shown that at low exercise intensities increases in pulmonary ventilation (\(\dot{V'E}\)) are due to both increases in tidal volume (\(V_T\)) and breathing frequency (\(f_b\)), at high exercise intensities a tachypnoeic breathing pattern develops, such that further increases in \(\dot{V'E}\) are largely caused by increasing \(f_b\) with \(V_T\) showing a plateau (Gallagher et al. 1987). This general pattern of breathing during progressive exercise has been demonstrated in subjects with a wide range of fitness levels (from sedentary individuals to elite athletes; Hey et al. 1966; Martin and Weil 1979; Clark et al. 1983; Folinsbee et al. 1983; Gallagher et al. 1987; McParland et al. 1991).

On the other hand, several cross-sectional studies have compared the breathing patterns in athletes of different fitness levels during exercise (Ramonatxo et al. 1989), while other cross-sectional reports have compared athletes to sedentary subjects (Yamaji and Miyashita 1978; Folinsbee et al. 1983; Mahler et al. 1991). From some of these data, it has appeared that larger \(V_T\) and lower \(f_b\) might be adopted at submaximal exercise intensities in response to physical conditioning. For ex-
ample, it has been found that extremely fit oarswomen exhibit a slower, deeper breathing pattern than less fit oarswomen or sedentary subjects (Mahler et al. 1991). Some authors, however, have reported no significant influence of increased fitness levels on breathing pattern (Yamaji and Miyashita 1978; Folinsbee et al. 1983; Ramonatxo et al. 1989; McParland et al. 1992) or ventilatory efficiency (Clark et al. 1994).

Other respiratory variables that characterize the neural regulation of respiration have also been measured during incremental exercise (Jensen et al. 1980; Clark et al. 1983). These variables can be obtained without the requirement for recording respiratory neural activity by measuring $V_T$ and the durations of the inspiratory ($t_I$) and expiratory ($t_E$) phases of the breathing cycle (Clark and von Euler 1972). Moreover, it has been suggested that the ratio of $V_T$ to $t_I$ or mean inspiratory flow rate ($V_T/t_I$), and the ratio of inspiratory to total respiratory cycle duration ($t_I/t_{TOT}$) might be used as indices of central inspiratory “drive” and respiratory “timing”, respectively (Milic-Emili and Grunstein 1976).

On the other hand, numerous studies have analysed the physiological responses of “elite”, amateur road cyclists during physical exertion (Hagberg et al. 1979; Burke 1980; Coyle et al. 1988, 1991; Faria et al. 1989; Tanaka et al. 1993), and some data are available concerning their breathing patterns during incremental protocols (Folinsbee et al. 1983). Little information exists, however, concerning the physiological responses of real elite endurance cyclists, that is to say, professional road cyclists. To our knowledge, a previous study conducted in our laboratory has been the only attempt to identify what physiological adaptations distinguish professional cyclists (i.e. able to complete extremely demanding events such as the Tour de France) from amateur, elite ones (i.e. with a lower fitness level, similar to those of the elite cyclists selected as subjects in that study) (Lucía et al. 1998). It has been concluded that professional riders exhibit a considerable reliance on fat metabolism at high exercise intensities as well as some neuromuscular adaptations. To date, however, no investigation has analysed the breathing pattern of these subjects. In this perspective, it would be interesting to assess if the aforementioned breathing parameters ($V_T$, $f_b$, $V_T/t_I$, etc.) might also be altered by the extreme demands of training and competing in the professional category.

The purpose of our investigation was to analyse the breathing patterns of professional cyclists during incremental exercise from submaximal to maximal intensities. A group of cyclists at an amateur level was also studied.

### Methods

#### Selection of subject

A group of 11 elite (amateur category) male road cyclists (E) and 14 professional male road cyclists (P) participated in this study. To be included in group E, the subjects were required to meet the following criteria at the time of the study:

1. Age 20–30 years
2. Competition experience of at least 2 years in the “sub23-elite” category of the International Cycling Union (former “amateur” category)
3. Being enrolled in a licensed amateur team.

The subjects in group P were selected if they met the following criteria at the time of the study:

1. Age 20–30 years
2. Competition experience of at least 2 years in the professional category of the International Cycling Union
3. Being enrolled in a licensed professional team
4. Having participated in at least one of the main 3-week stage races (“Vuelta a España”, “Giro d’Italia”, or “Tour de France”).

All the subjects were in good health, as determined by a physical examination (including electrocardiogram) within the previous year.

#### History of racing performance of the subjects

The E group had a mean competition experience of 3 (SD 1) years in the “sub23-elite” category and they had covered an average of 25,000 (SD 2,300) km (including training and competition) during the previous season. Each of them was enrolled in one the better Spanish amateur teams.

The P group had a mean competition experience of 4 (SD 2) years in the professional category and they had covered an average of 32,000 (SD 4,000) km (including training and competition) during the previous season. Among the most notable performances of the subjects in the professional races were the following: 1st in 1995 World Championships (road race), 2nd in 1995 Time Trial World Championships, 2nd in 1996 Olympic Games (Time Trial), 2nd in 1995 Vuelta a España, 3rd in 1996 Giro d’Italia, 4th and 8th in 1997 Tour de France, 6th in 1997 Vuelta a España, 1st in several stages (including Time Trials) of Tour de France and Vuelta a España.

#### Study protocol

Informed consent was obtained from each subject in accordance with the regulations of the Complutense University. Prior to each exercise test, the subjects were familiarized with the equipment and procedures used in this investigation. In addition, they were instructed to refrain from intense training during the day before the test. Before the exercise protocols, forced vital capacity (FVC) and maximal voluntary ventilation (MVV) were measured while the subjects were standing, using a standard automatic system (CPX; Medical Graphics; St. Paul, Minn).

The subjects exercised once on a cycle ergometer (Ergometrics 900; Ergo-line; Barcelona, Spain) following a ramp protocol until they were exhausted. Starting at 0 W, the exercise intensity was increased by 25 W·min⁻¹ and pedalling cadence was kept between 70–90 rpm. The subjects maintained this cadence by watching a pedal-frequency meter. In all cases, the exercise tests were ended either

1. Voluntarily by the subjects
2. When the pedalling cadence could not be kept at least at 70 rpm or,
3. When established criteria for the ending of a test were met (American College of Sports Medicine 1986).

During the tests, all the subjects adopted the conventional (upright) cycling posture. This posture was characterized by a trunk inclination of approximately 75° and by the subjects placing their hands...