ABSTRACT

Background
The thoraco-abdominal coordination and the ventilatory pattern are two decisive factors for the ventilatory efficiency. A greater coordination between the rib cage and abdomen motions as well as a deep and slow ventilatory pattern corresponds to a higher efficiency in terms of gas exchange. Despite this fact few studies have investigated the breathing pattern and the thoraco-abdominal synchrony both at rest and during exercise in physiological and pathological conditions.

Aims
We present two research. In the first, we investigate the role of thoraco-abdominal coordination on breathing pattern, gas exchange and endurance performance during an heavy-intensity exercise at altitude in elite sky runners (SKY) (Study 1). In the second, we describe the breathing pattern in healthy and asthmatics subjects with different BMI to identify the influence of bronchial obstruction and obesity on ventilation (VE) and exercise capacity (Study 2).

Materials and methods
In Study 1, 15 endurance-trained elite SKY (13M) were equipped with an inductive pletysmography (Lifeshirt), a pulse-oxymeter and a GPS. VE, tidal volume (VT), VE/VT, phase angle (PhA), SpO2 were recorded during simulated race from 2030m to 2804m.

The Study 2 has two components. The first is a an observational study analysing anthropometric and spirometric data of 280 asthmatics (126M) regularly visited at the Asthma Center of the University Hospital in Ferrara. In the second part of the study we compared two groups of 55 asthmatics (19M) and 37 non-asthmatics volunteers (21M). Subjects were classified in normal weight (NW), overweight (OW), obese (OB) following the BMI classification. We assessed: anthropometric characteristics, pulmonary function values, quality of life (AQLQ and SF-12 questionnaires), daily physical activity (SenseWear), dyspnea score (MMRC) and exercise capacity (6MWT). Ventilatory parameters (VE, VT, Respiratory Rate) were measured at rest and during exercise (Spiropalm).

Results
In the Study 1 SKY run 6.0±1.3 Km (ascent). During the race we observe a significantly reduced thoraco-abdominal coordination, as shown by the
increase in PhA. This is related to an increase in VE/VT (r=0.19*) and to a decrease in SpO₂ (r=-0.26*). These results are evident for ground slopes (S) between 20% and 40% (r=0.34*). A higher fall of SpO₂ is associated to a higher ratio of VE/VT (r=-0.69*). The low SpO₂ is associated to a lower race speed (r= 0.4*).

**Study 2**, first part. We find that the severity of bronchial obstruction (FEV₁%) is lower in subjects with BMI≥25 (82.6±19 vs 87.5±16.7*).

**Study 2**, second part. We find that OB asthmatics and non-asthmatics have a higher dyspnea score (MMRC) than NW (asthmatics OB: 1.4±0.8 vs NW 0.8±0.5, non-asthmatics OB 0.7±0.4 vs NW 0.1±0.3*) but the score is higher in asthmatics. The physical activity level is lower in OB than NW in both groups. There is a significant inverse correlation between BMI and the distance covered during the 6MWT in both groups (asthmatics r=-0.4, non-asthmatics r=-0.6*) but the exercise capacity (6MWdistance) is lower in asthmatics than in non-asthmatics in the same BMI category (462.2±85.4 vs 554.2±59*). As regard ventilation, OB have a higher increase in VE than NW, only in the asthmatics group (106.7±38.5 vs 72±12.1*), independently from the level of obstruction and as a consequence they show a lower ventilatory reserve (35.8±19.1 vs 63.5±24.3 *). In all subjects the increase in VE is always due to an increase in Vₜ. *p<0.05

**Conclusion**
The main finding of the first study on SKY is that during heavy endurance exercise at moderate altitude, the ground slope negatively influences the thoraco-abdominal coordination which corresponds to a less efficient ventilatory pattern and to a reduction of oxygen saturation. This reduction in SpO₂ seems to a have a significant role in race performance. The decrease of thoraco-abdominal synchrony could depend on a change in posture, more evident in higher slope, with a displacement of barycentre that causes disequilibrium of the two compartments, as reported in few studies on thoraco-abdominal kinematics.

The second study shows that obesity is associated to a lower exercise capacity and higher dyspnea score both in asthmatics and non-asthmatics. The presence of asthma is an additional limitation. The influence of asthma on ventilation during exercise seems to be relevant only if associated to obesity: only OB asthmatics have a significantly greater increase in VE and a smaller ventilatory reserve than NW.