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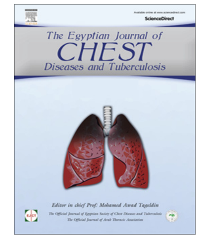

ORIGINAL ARTICLE

Breathing pattern in asthmatic patients during exercise

Nourane Y. Azab [a], Ibrahim I. El Mahalawy [a], Gehan A. Abd El Aal [a], Manar H. Taha [b,*]

[a] *Chest Department, Faculty of Medicine, Menoufia University, Egypt*
[b] *Giza Chest Hospital, Giza Governorate, Egypt*

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KEYWORDS

Cardiopulmonary exercise test (CPET);
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Abstract *Objectives:* To study the effect of exercise on asthmatic breathing pattern.

Background: Asthmatic patients have been reported to be breathless regardless of the degree of airway obstruction. Task performance may induce changes in breathing pattern and these in turn may mediate such a feeling. There is increasing interest in the use of breathing modification techniques in the treatment of asthma.

Methods: This study was conducted on 20 asthmatic patients in stable mild state, they were selected from the Chest Department of the Menoufia University Hospital from February 2014 to September 2014. All patients were subjected to clinical history and examination, plain chest-X-ray (postero-anterior and lateral views), ECG and echo if needed, pulmonary function tests and cardiopulmonary exercise testing.

Results: Breathing pattern parameters tidal volume (VT), respiratory rate (RR), minute ventilation (VE), mean inspiratory flow (VT/TI) increased during exercise then decreased during the recovery period while inspiratory time (TI) and total breath duration (Ttot) decreased during exercise then decreased during the recovery period.

There was an increase in forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow (PEF). Forced expiratory volume in one second/forced vital capacity (FEV1/FVC) during exercise and a decrease during the recovery period while forced expiratory time (FET100%) showed an opposite change.

Conclusion: Breathing pattern was altered significantly during exercise in asthmatic patients.

Introduction

Bronchial asthma is a common chronic inflammatory disease of the airways characterized by variable and recurring symptoms, reversible airflow obstruction, and bronchospasm and

* Corresponding author.

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its common symptoms include wheezing, coughing, chest tightness, and shortness of breath [1].

Breathing pattern is an oscillatory event approximating a sinusoidal function, of which the amplitude is tidal volume (VT) and the period is the total breath duration (Ttot) [2].

Early studies of exercise performance in patients with respiratory disorders identified reductions in ventilatory capacity and gas-exchange as the main causes of reductions in exercise capacity. Whether or not the breathing pattern of asthmatic patients change with exercise and whether it influences exercise outcome remains to be elucidated [3].

Aim of the study

The aim of this study was to evaluate the effect of exercise on the breathing pattern of asthmatic patients.

Methods

A written consent was obtained from all patients prior to inclusion and the regional ethics committee of the Menoufia University Hospital approved the study. The study was conducted in the Chest Department of the Menoufia University Hospital from February 2014 to September 2014. All patients underwent history taking, clinical examination, routine laboratory investigations, chest X-ray (postero-anterior and lateral views). ECG and echocardiography if needed. They also underwent pulmonary function tests before and after bronchodilatation using salbutamol (200–400 μg) to assess reversibility. Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), forced expiratory volume in one second/forced vital capacity (FEV_1/FVC), peak expiratory flow (PEF), forced expiratory flow between 25% and 75% of FVC (FEF 25–75%) and forced expiratory time FET100% were measured before, during, immediately after exercise and 30 min after exercise (during the recovery period), cardiopulmonary exercise test was performed (using Quark CPET-Italy). Assessment of the breathing pattern of the patient [tidal volume (VT), respiratory rate (RR), Minute ventilation (VE), inspiratory time (TI), total breath duration (Ttot), fractional inspiratory time (TI/Ttot), mean inspiratory flow (VT/TI)] before, during, immediately after and 30 min after exercise were done. In this study incremental exercise testing protocol was used as a modification of Balk's Protocol [4].

The test duration was 7 min which is divided into: 2 min for warming up, 4 min exercise and 1 min recovery. The speed starts by 1 km/h till 4 km/h during warming up stage, with a grade 3%, then the speed increases gradually to reach 5 km/h during exercise and grade increases till 7%. Finally, during recovery, speed and grade decrease till rest again.

Results

There was a statistically significant change between patients regarding tidal volume (VT), respiratory rate (RR), inspiratory time (TI), mean inspiratory flow (VT/TI) and fractional inspiratory time (TI/Ttot) before, during, immediately after and 30 min after exercise as there was an increase in tidal volume (VT), respiratory rate (RR), minute ventilation (VE), mean inspiratory flow (VT/TI) and fractional inspiratory time (TI/Ttot) during exercise and they decreased significantly during the recovery period while inspiratory time (TI) and total breath duration (Ttot) decreased during exercise then decreased during the recovery period (Table 1).

There was statistically significant differences regarding forced expiratory volume in one second (FEV1), forced expiratory flow between 25% and 75% of FVC (FEF 25–75%) and peak expiratory flow (PEF) before, during, immediately after and 30 min after exercise, as there was an increase in FVC, FEV_1, PEF, FEV_1/FVC during exercise and a significant decrease during the recovery period while forced expiratory time (FET100%) decreased during exercise then increased during the recovery period (Table 2).

During exercise, there was a positive correlation between VT and FVC, between RR and FEV1/FVC and FET100%, between TI and FET100% and between VE and FEF 25–75% (Table 3).

Before exercise, there was a positive correlation between both maximal rate of oxygen consumption (VO_2 max) and carbon dioxide volume (VCO_2) on one hand and FET100% on the other hand while 30 min after exercise, there was a positive correlation between FEV1 with VCO_2 (Tables 4–6).

Discussion

This study highlights the changes in breathing pattern during quiet breathing and incremental exercise in asthmatic patients. Tidal volume (VT), respiratory rate (RR), minute ventilation (VE), mean inspiratory flow (VT/TI) increased during exercise then decreased during the recovery period while inspiratory time (TI) and total breath duration (Ttot) decreased during exercise then decreased during the recovery period (Table 1).

The results coincide with Kassabian et al., who reported an increase in VT, VE, VT/TI and RR [5].

Gallagher et al., reported that during progressive exercise ventilation increases initially through an increase in VT and RR but at high levels of exercise further increase in ventilation is almost completely a result of increase in RR and VT plateaus is seen [6].

They reported that an early elevation of VE is a normal respiratory response to exercise by increasing the depth of breathing (increased VT) as the workload further increases by increasing RR.

Margaret et al., reported an increase in RR with incremental exercise, modest change in VT, shortened expiratory time and doubling of flow rates [7].

Wilkens et al., reported a decrease in duty cycle (TI/Ttot) at rest and at maximal exercise in asthmatic patients with a high inspiratory flow rate and high minute ventilation [8].

Also, Martin et al., measured breathing pattern in 15 asthmatic patients and reported increase in VT and VE with increased exercise [9].

This study agrees with Romer et al., who reported a decrease in RR and VE after exercise in asthmatic patients but they found an increase in VT and TI [10]. As did McMahon et al. [11].

Eastwood et al., found that there is an initial increase in VT than RR in asthmatic patients as exercise increases then the continued increase in RR compromises VT such that VT plateau increases or even decreases slightly resulting in tachypneic shift [12].

Table 1 Effect of exercise on the breathing pattern.

Pattern of breathing	Before	During	After	After 30 min	Post hoc (Scheffe's test)
VT	0.67 ± 0.32	0.96 ± 0.45	1.12 ± 0.46	0.60 ± 0.32	P1 > 0.05 P2 < 0.05 P3 > 0.05 P4 > 0.05 P5 > 0.05 P6 < 0.05
RR	21.37 ± 5.74	31.97 ± 8.51	29.93 ± 8.91	20.30 ± 5.88	P1 < 0.001 P2 < 0.05 P3 > 0.05 P4 > 0.05 P5 < 0.001 P6 < 0.05
VE	13.13 ± 3.54	34.75 ± 19.05	34.74 ± 15.26	11.88 ± 3.88	P1 < 0.001 P2 < 0.001 P3 < 0.001 P4 > 0.05 P5 > 0.05 P6 > 0.05
TI	0.87 ± 0.21	0.72 ± 0.16	0.762 ± 0.24	0.81 ± 0.18	P1 < 0.001 P2 < 0.001 P3 < 0.001 P4 < 0.001 P5 > 0.05 P6 < 0.001
T total	3.05 ± 1.06	1.78 ± 0.46	2.02 ± 0.52	3.27 ± 1.22	P1 > 0.05 P2 > 0.05 P3 > 0.05 P4 > 0.05 P5 < 0.05 P6 < 0.05
TI/T total	0.78 ± 0.37	0.41 ± 0.04	0.38 ± 0.048	0.31 ± 0.19	P1 < 0.001 P2 < 0.001 P3 < 0.05 P4 > 0.05 P5 < 0.05 P6 < 0.001
VT /TI	0.30 ± 0.06	1.36 ± 0.68	1.49 ± 0.62	0.70 ± 0.41	P1 < 0.05 P2 < 0.05 P3 < 0.001 P4 > 0.05 P5 > 0.05 P6 > 0.05

Scheuermann and Kowalchuk also found that VT and RR increase as exercise increases then decrease after rest in asthmatic patients [13].

Folinsbee et al., who found an increase in RR in asthmatic patients, reported that the decrease in expiratory time (TE) rather TI reverses normal inspiratory time:expiratory time (I/E) ratio which may ultimately decrease exercise performance [14].

Lucia et al., explained that TI decreases in asthmatic patients with increased exercise intensity with prolongation of TE as an important adaptation during high exercise [15].

They reported that changes in RR and VT coupled with an unchanged VE in asthmatic patients prevent the occurrence of a tachypneic shift which is one of the major differences in breathing pattern.

Johnson et al., said that for good exercise performance there should be a decrease in the work of breathing, decrease in respiratory muscle fatigue and at high workload decrease in blood stealing [16].

This study agrees with Harms et al. [17], Sheel et al. [18] and Shephard [19] who described an increase in VE with increased exercise intensity in asthmatic patients. Bradley et al., explained that this pattern achieves a breathing pattern that enables the ventilatory demand of high intensity exercise to be met and usually causes respiratory pattern shift from diaphragmatic via the nose to apical via the mouth in an attempt to shift larger volumes of air faster [20].

Meyer et al. also showed the increase in VE by increasing RR and VT but did not specify whether the shift from

Table 2 Effect of exercise on pulmonary functions.

Pulmonary functions	Before	During	After	After 30 min	Post hoc (Scheffe's test)
FVC	77.01 ± 19.79	78.54 ± 12.69	76.45 ± 13.09	73.46 ± 13.64	–
FEV1	79.66 ± 17.62	74.35 ± 15.85	70.74 ± 18.41	61.71 ± 20.13	P1 > 0.05 P2 > 0.05 P3 < 0.05 P4 > 0.05 P5 > 0.05 P6 > 0.05
PEF	59.13 ± 20.69	55.03 ± 18.08	50.33 ± 22.03	45.37 ± 19.42	P1 > 0.05 P2 < 0.05 P3 < 0.05 P4 > 0.05 P5 < 0.05 P6 > 0.05
PEV1/FVC	81.98 ± 11.29	80.71 ± 10.92	76.89 ± 18.21	77.02 ± 15.60	–
FEF 25–75	63.13 ± 32.10	62.80 ± 25.99	61.62 ± 29.80	53.95 ± 23.37	P1 > 0.05 P2 > 0.05 P3 < 0.05 P4 > 0.05 P5 < 0.05 P6 > 0.05
FET100%	2.42 ± 1.06	2.52 ± 0.87	2.44 ± 1.13	2.38 ± 1.01	–

Table 3 Correlations between the pattern of breathing and pulmonary functions during exercise.

During		FVC	FEV1	PEF	FEV1/FVC	FEF25-75	FET100
VT	*r*	.502*	.380	.147	−.031	.413	.147
	P value	.024	.098	.535	.898	.070	.536
RR	*r*	−.018	.287	.284	.458*	.328	−.445*
	P value	.940	.219	.225	.042	.158	.050
TI	*r*	.240	−.087−	−.156-	−.384-	−.086	.613**
	P value	.308	.715	.510	.095	.719	.004
VE	*r*	.412	.399	.236	.147	.468*	−.094
	P value	.071	.081	.317	.537	.038	.694
Ttot	*r*	.130	−.037	.023	−.266	−.101	.367
	P value	.586	.878	.923	.256	.672	.112
VT/TI	*r*	.385	.378	.194	.108	.419	−.091
	P value	.094	.101	.412	.651	.066	.704
TI/Ttot	*r*	.357	.207	.246	.098	.377	.083
	P value	.123	.382	.296	.682	.101	.728

P1 between before and during exercise.
P2 between before and immediately after exercise.
P3 between before and 30 min after exercise.
P4 between during and immediately after exercise.
P5 between during and 30 min after exercise.
P6 between immediately after and 30 min after exercise.
R = co-efficient of variation.
Level of significance was set at p value < 0.05, p value < 0.05 is considered significant.

diaphragmatic to apical breathing is a physiological necessity or a learned habit [21] Clark et al. [22], Hey et al. [23] and Spengler et al. [24] added that VT will either plateau at 50–60% of vital capacity or start to decrease.

Folinsbee et al., found that at high RR the reduction of expiratory time (TE) makes a significantly greater contribution to the rise in RR than the decrease in TI resulting in reversing TI/TE ratio of 2:1 and leads to "breath stacking" a

Table 4 Correlations of pulmonary functions before exercise with gas exchange.

Pulmonary functions	Pearson correlation	VO_2max	VCO_2	$PETCO_2$
FVC before	*R*	−.180	−.024	.055
	P value	.448	.919	.818
FEv1 before	*r*	.248	.365	.084
	P value	.293	.113	.726
PEF before	*r*	.077	.087	.020
	P value	.748	.717	.934
FEV1/FVC before	*r*	−.253	−.179	−.100
	P value	.283	.450	.675
FEF 25–75 before	*r*	.313	.337	.109
	P value	.179	.146	.646
FET100 before	*r*	.483*	.506*	.140
	P value	.031	.023	.557

Table 5 Correlations of pulmonary functions during exercise with gas exchange.

	Pearson correlation	VO_2	VCO_2	$PETCO_2$
FVC	*R*	.396	.509*	.086
	P value	.084	.022	.718
FEV1	*R*	.259	.322	.012
	P value	.271	.166	.960
PEF	*R*	.049	.046	−.095
	P value	.836	.846	.691
FEV1/FVC	*R*	−.086	−.022	−.068
	P value	.719	.926	.777
FEF 25–75	*R*	.320	.340	.109
	P value	.169	.143	.648
FET100	*R*	.272	.266	.206
	P value	.245	.257	.385

Table 6 Correlations of pulmonary functions after 30 min of exercise with gas exchange.

	Pearson correlation	VO_2	VCO_2	$PETCO_2$
FVC 30	*R*	.123	.345	.088
	P value	.606	.136	.712
FEV1 30	*R*	.405	.488*	−.158
	P value	.076	.029	.505
PEF 30	*R*	−.187	−.123	−.317
	P value	.430	.606	.174
FEV1/FVC30	*R*	−.086	.047	−.305
	P value	.719	.844	.191
FEF 25–75 30	*R*	.386	.363	.189
	P value	.093	.115	.426
FET100 30	*R*	.050	−.051	.299
	P value	.833	.832	.200

phenomenon where a subsequent inspiration is taken prior to the full exhalation of the previous breath resulting in tidal breathing occurring closer to total lung capacity [14].

Johnson et al., found that while initial increase in VT at the onset of exercise that may cause end expiration lung volume to decrease, increase in RR and the subsequent changes to respiratory timing may increase end expiration lung volume resulting in dynamic hyperinflation.

Holloway and Ram, reported a decrease in RR and VT during recovery from exercise in asthmatic patients [25].

In this study, there was an increase in forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow (PEF). Forced expiratory volume in one second/forced vital capacity (FEV_1/FVC) during exercise and a decrease during the recovery period while forced expiratory time (FET100%) showed an opposite change, also there was a significant difference in FEV_1 after 30 min of exercise, PEF (immediately after and 30 min after exercise) and FEF 25–75% 30 min after exercise.

This was attributed to the bronchospasm that occurs during exercise and affects mainly the large airways and to the mouth breathing adopted by the patients.

The fact that FEF 25–75% starts to drop 30 min after exercise more than during the immediate post exercise period might be due to the increase in the cytokines and inflammatory mediators during exercise that can lead to edema in the small airway after a period from starting effort. Also bronchospasm that occurs during exercise and affects large airway still manifests 30 min after completion of the exercise (Table 2).

El-Helaly et al., showed that there was a significant difference as regards FEV_1, PEF and FEF 25–75% at different times of exercise and recovery [26].

Arshi et al. [27] and Richa et al. [28] found no significant difference between spirometric measurements before and after exercise challenge in patients with asthma and rhinitis as they used mild intensity exercise that might not have reached an effect on the airways.

Reza et al., reported that FEV_1, FVC, PEF and FEF 25–75% were significantly higher than the pre-exercise measurement but they found no significant difference as regards FEV_1/FVC [29].

During exercise, there was a positive correlation between VT and FVC and between RR and both FEV_1/FVC, FET100%, TI and FET100%. Also there was no significant correlation between TI, RR and FEV_1 during exercise (Table 3).

Similar results were reported by Hillman et al. who reported that there was no relationship between FEV1 and RR or VT. However when VE was analyzed in the form of TI/Ttot and VT/TI, interesting relationship with FEV1 emerged. TI/Ttot decreases disproportionally with FEV_1. Above an FEV_1 of 25% this decrease was significantly correlated with an increase in VT/TI and below an FEV_1 of 25% VT/TI decreases [30].

There was a positive correlation between both maximal rate of oxygen consumption (VO_2 max) and carbon dioxide volume (VCO_2) with FET100% before exercise and with FVC during exercise. There was also a correlation between FEV_1 and VCO_2 30 min after exercise.

These results coincide with Counil et al., who reported no correlation between FEV_1 and VO_2 max before and immediately after exercise [31].

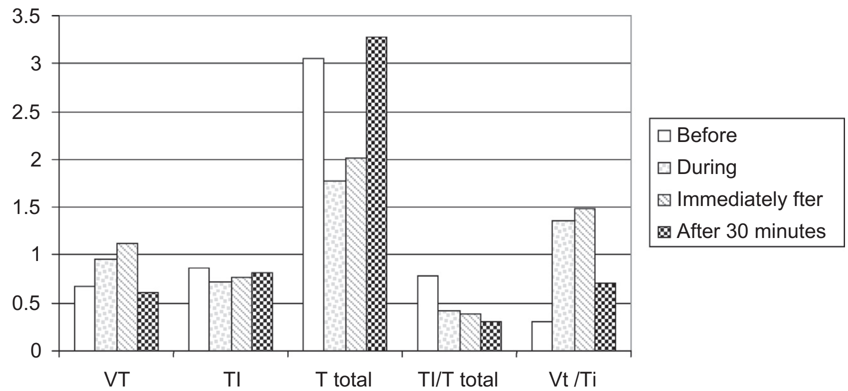

Figure 1 Illustrates the effect of exercise on the breathing pattern parameters before, during, immediately after and 30 min after exercise.

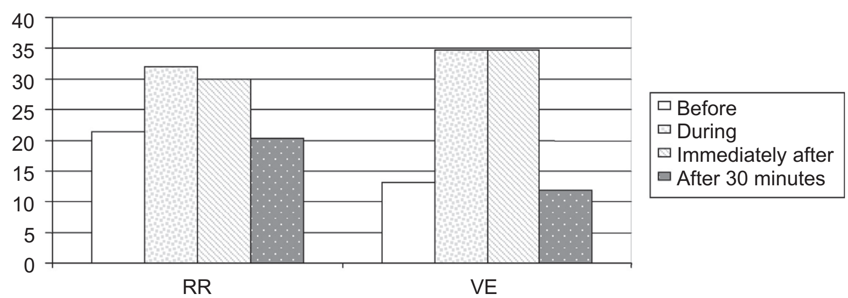

Figure 2 Illustrates the effect of exercise on the breathing pattern parameters before, during, immediately after and 30 min after exercise.

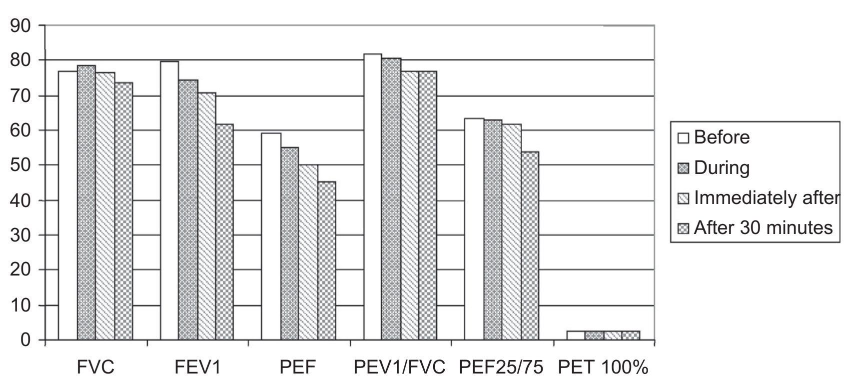

Figure 3 Illustrates the effect of exercise on pulmonary functions before, during, immediately after and 30 min after exercise.

Kinnula and Sovijarvi [32] and Hammo and Wienburger [33] reported no correlation between FEV_1 and VCO_2.

Ward, explained that VE responds more closely to demands for CO_2 clearance than for O_2 uptake [34]. Hanson et al., added that when tachypneic shift occurs, the dead space/tidal volume ratio increases and alveolar ventilation may decrease resulting in increased Pco_2 and to preserve alveolar ventilation VE may be increase by 10–30% [35].

The results of the present study also coincide with Pineda et al., who described that the correlation between maximum oxygen consumption and FEV_1 was not statistically significant in asthmatic patients. These patients utilize ventilation during exercise that corresponds to a greater fraction of their maximum voluntary ventilation (MVV). However, Pineda et al., described that maximum oxygen consumption in asthmatic patients correlated most strongly with indices of expiratory airflow (FEV_1, FEF 25–75%) [36].

A possible explanation of these findings is that pulmonary reserves are such great that normal blood gases can be achieved even in the face of moderate diffusion disturbances, but such disturbances will impair gas exchange when blood flows faster during exercise (see Figs. 1–3).

Conclusion

1. Exercise leads to large airway obstruction immediately and 30 min after exercise.

2. Exercise affects small airway functions during recovery but not immediately after the exercise.
3. Exercise alters the breathing pattern of asthmatic patients (in the form of changes in VE, VT, RR and TI) and modification of their pattern could improve their condition during exercise.
4. Mild exercise does not affect O_2 consumption in the asthmatic patient.

Conflict of interest

No conflict of interest.

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