

## ORIGINAL ARTICLE

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# Pulmonary Function Parameters Changes at Different Altitudes in Healthy Athletes

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## ABSTRACT

Hypoxia and hypocapnia can cause broncho-constriction in human subjects, and this could have a bearing on performance at high altitude. The object of this study was to examine how pulmonary ventilatory functions during high-altitude trekking.

This study is a cohort study on spirometric parameters at different altitudes. Fifty six healthy male volunteers from a university student population were enrolled in the study (ages  $22.9 \pm 5.3$  years). Pulmonary function was assessed with a Spirolab II in all participants before ascending at baseline (1150 meter), after ascending at different altitudes (2850, 4150 meter), and after descending at sea level during a 3-day trek in Sialan Mount.

This study indicates that in an actual trek, ascending results in significant decrease in forced vital capacity (FVC). FVC significantly decreased with increasing altitude from baseline level and at the sea level it was significantly less than baseline level. Peak flow increased with increasing altitude from baseline (1150 m) to 2850 m and decreased with decreasing altitude ( $p < 0.01$ ). Maximal midexpiratory flow rate (FEF 25-75%) and forced expiratory volume in 1 second to forced expiratory volume ratio (FEV1.0%) significantly increased with increasing and decreasing altitude from baseline level ( $p < 0.001$ ). There was no significant change in FEV1.

It could be concluded that changes in some pulmonary ventilatory parameters were proportional to the magnitude of change in altitude during a high-altitude trek. These changes are significant at the beginning of ascending.

**Key words:** Altitude; Mountain; PFT; Pulmonary function test; Spirometry; Trekking

## INTRODUCTION

Trekking at high altitude is a popular recreation and each year approximately 140 million people worldwide visit high altitudes.<sup>1</sup> Studies of ventilatory changes at

high altitude occupy an important position in high altitude medicine and respiratory physiology. The physiological effects of high altitude exposure are mainly attributable to the reduced inspired PO<sub>2</sub>, ambient pressure and fall in arterial O<sub>2</sub> saturation as well as gas density. Therefore, upon arriving at high altitude, many trekkers experience hypoxic-related sickness such as acute mountain sickness, high altitude cerebral edema, high altitude pulmonary edema, and

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sleep disorders.<sup>2</sup> The changes of pulmonary function parameters at high altitudes have not been well studied. Pulmonary function studies on high altitude residents have shown an adaptation in response to chronic hypoxia and high level of habitual exercise.<sup>3-5</sup>

In addition, ventilatory studies at simulated altitude in hypobaric chambers have shown decrease in forced vital capacity (FVC) and sometimes decrease in forced expiratory volume in 1 second (FEV1) or maximal midexpiratory flow rate (FEF<sub>25-75%</sub>).<sup>6-8</sup> However, actual field and participant conditions during the course of a trek differ from those of chronic state or more controlled experiments. Relatively few studies of ventilatory impairment at high altitude have been done because of logistic and technical difficulties.<sup>9,10</sup> But we did not find any study, comparing the changes of pulmonary function test (PFT) at altitude of residency with higher and lower altitudes after ascending and descending.

Therefore, the aim of this study was to determine the changes in ventilatory functions parameters during an ascent to 4150 m and then descending to sea level in Iranian trekkers.

## MATERIALS AND METHODS

### Participants

A cohort study was performed in the summer of 2004 at Sialan Mountain in Iran.

Fifty six healthy male volunteers from a university student population were enrolled in the study. Inclusion criteria were residency in Tehran, having no history of smoking, and no chronic systemic diseases (chronic obstructive respiratory disease such as asthma, cardiovascular disease /or renal disease). Exclusion criteria were any type of altitude disease (such as acute mountain sickness, gastroenteritis or motion sickness), upper respiratory infection, or any unavoidable condition (such as injury in the mountain) which predisposed the participants not climbing to top of Sialan. None of them had trekked to high altitude during the six months preceding the study and no one had taking drugs except dexamethasone.

All subjects had a pre-trek physical examination and they used 4 mg dexamethasone in 2 divided doses (2 mg every 12 hours) 36 and 24 h before trekking for prevention of acute mountain sickness.

This study was approved by research committee of Sports Medicine Research Center and ethics committee of Tehran University, faculty of Medicine.

### Trek

Baseline studies were performed in Tehran (1150 m above sea level). All participants lived at baseline altitude. After a six- hours bus trip (about 330 km) they arrived at an altitude of 2850 meters (m) above sea level (Alamout area) at 7PM. They stayed ten hours at that altitude before beginning the trek. After 10 hours of trekking (about 30 km), they reached at altitude of 4150 m (Sialan Mount) at 5 PM. Participants descended to the camp at 3200 m and after 7 hours of resting they descended to the sea level (Tonekabon city). This city rests 30 m below sea level (Figure 1).

### Spirometry

Pulmonary function test (PFT) was performed for each participant in 4 steps. The first step pulmonary function was tested at living altitude (1150m), before dexamethasone consumption. The second and third steps of PFT were performed for every participant after 30-60 minutes of arriving at 2850 m, 4150 m at Sialan peak. The final step of PFT was performed after 1 hour of arriving at 30m below sea level in Tonekabon city. Figure 1 shows ascent program and location of stations for performing PFT in this study.

PFT was assessed in each subject using a calibrated spirometer (Spirolab II, Medical International Research, Rome, Italy). Spirometer is daily calibrated automatically by itself with a 3 liters calibration syringe as well as at each altitude change. Temperature of the air in the calibrating 3-L syringe was the same as that of the sensor in the spirometer. All participants were trained for performing spirometry and everyone performed a maximal inspiration, followed immediately by a forced maximal expiration in upright position. By this procedure, FVC, FEV1, FEF<sub>25-75%</sub>, and peak expiratory flow rate (PEFR) were determined based on the best of the three efforts.

### Statistics

Assuming a change of 170ml in FVC in Hashimoto study (3.8%/1000m determined in a study at altitudes 1624 to 5265m in Himalaya) and considering  $d=0.15$ , sample size was calculated to be 57.

## PFT Changes at Different Altitudes

**Table 1. The changes in mean values for FVC, FEV1, FEF<sub>25-75%</sub> and PEFR at different altitudes**

Parameters	Altitude 30 <sup>m</sup> below sea level	1150 <sup>m</sup>	2850	4150 <sup>m</sup>	P*
FVC	4.4±0.5	4.5±0.6	4.3±0.5	4.2±0.5	0.01
FEV1	4.1±0.5	4.2±0.6	4.2±0.5	4.1±0.5	>0.05
FEV1/FVC(%)	93.7±6.2	91.7±5.4	96.7±4.5	96.7±4.8	0.001
Peak Flow (lit/s)	9.2±1.7	9.2±1.9	10.1±1.7	9.9±1.9	0.01
FEF <sub>25-75%</sub> (lit/s)	5.2±1.1	5.1±1.2	5.8±1.2	5.7±1.3	0.001

\* ANOVA, df=3

All variables were evaluated for normality using the Kolmogorov-Smirnov test against a standard normal distribution, using the Lilliefors two-tailed probability. FVC, FEV1, FEF<sub>25-75%</sub> and PEFR changes in each level were compared using paired t-test and analysis of variance (ANOVA). Statistical analysis computations were performed by SPSS11.5 (SPSS Inc., Chicago O/IL). P<0.05 was considered significant.

### RESULTS

Fifty six subjects included in our study. The mean (±SD) age of participants was 22.9(±5.3) year and the mean (±SD) weight, height and body mass index (BMI) were 67.1(±9.2) kg, 1.76(±0.2) m and 21.5(±2.5), respectively.

FVC, FEV1.0%, FEF<sub>25-75%</sub> and PEFR changes were significant in different altitudes, but the change in FEV1 was not. Table 1 shows these changes.

#### Altitude Effect on FVC

FVC was significantly decreased with increasing altitude from baseline level (Tehran, 1150 m). After descending and at the sea level, FVC was significantly less than baseline level. FVC fell by a mean 4.8% at 2850m (3.2% per 1000m increment) and 7.1% at 4150m (2.4% per 1000m increment) compared to 1150m.

#### Altitude Effect on FEV1

There was no significant change in FEV1 at any of measured levels in comparison with the baseline altitude.

**Table 2. The mean of PFT parameters changes in each altitude in comparison to another altitude**

Parameters	Altitude	2850 <sup>m</sup> related to 1150 <sup>m</sup>	4150 <sup>m</sup> related to 1150 <sup>m</sup>	4150 <sup>m</sup> related to 2850 <sup>m</sup>	30 m below sea level related to 4150 <sup>m</sup>
FVC	Mean	-0.22	-0.32	-0.11	0.17
	CI*	-0.32_-0.11	-0.47_-0.17	-0.20_0.02	0.05-0.29
	t	-4.2	-4.4	-2.5	2.8
	P value†	0.000	0.000	0.017	0.008
FEV1/FVC	Mean	5.45	6.24	0.34	-3.47
	CI*	4.08_6.82	4.06_8.42	-0.91_1.59	-5.14_-1.81
	t	8.0	8.0	-0.5	-4.2
	P value†	0.000	0.000	0.5	0.000
peak flow	Mean	0.91	0.67	-0.39	-0.76
	CI*	0.43_1.38	-0.07_1.42	-0.97_0.19	-1.19_-0.33
	t	3.8	1.9	-1.3	-3.6
	P value†	0.000	0.07	0.17	0.001
FEF <sub>25-75%</sub>	Mean	0.72	0.81	-0.01	-0.72
	CI*	0.46_0.97	0.53_1.09	-0.23_0.21	-0.91_-0.53
	t	5.7	6.0	-0.08	-7.5
	P value†	0.000	0.000	0.9	0.000

\* Confidence Interval

† Paired t-test

Table 3. comparison between our study and other studies in actual field.

Studies Parameters	Our study	Pollrd <i>et al.</i> <sup>12</sup>	Hashimoto <i>et al.</i> <sup>9</sup>	Saldias <i>et al.</i> <sup>13</sup>	Mason <i>et al.</i> <sup>10</sup>
No of trekkers	56	51	19	48	46
The changes of altitude	1150m to 4150m	Sea level to 5300m	1624m 5265m	4600m	2800m to 5300m
FVC	↓	↓	↓	↓	↓
FEV1	→	↓	↓	→	→
FEF <sub>25-75%</sub>	↑	-	↓	↑	-
peak flow	↑	→	-	↑	↑

### Altitude Effect on FEV1/FVC Ratio

FEV1/FVC ratio was significantly increased with increasing and decreasing altitude from base line level, except from 2850 m to 4150 m. In addition, it decreased significantly after descending from high altitude to below sea level.

### Altitude Effect on Peak flow

With increasing altitude, there was an increase in peak flow, and with decreasing altitude there was a decrease in this parameter; however these changes were not significant at 4150 m in comparison to 2850 m and baseline.

### Altitude Effect on FEF<sub>25-75%</sub>

Similar to FEV1/FVC ratio, with increasing altitude compared to baseline, there was an increase in FEF<sub>25-75%</sub>; however, there was not any significant change in this parameter from 2850m to 4150 m. In addition, FEF<sub>25-75%</sub> decreased significantly with decreasing altitude from high altitude to below sea level.

Table 2 shows the changes in all parameters in different altitudes. All PFT parameters had significant changes at different altitudes but there were not any significant changes in PFT parameters from 2850m to 4150 m except FVC.

## DISCUSSION

This study describes a comparison between pulmonary function tests in altitude residency and higher altitude at 4150m and lower altitude at sea level. Relatively few studies of ventilatory impairment at altitudes have been done because of logistic and technical difficulties. Most have utilized high altitude laboratories or hypobaric chambers<sup>6,7</sup> or their sample sizes were low.<sup>9</sup> Our study is unique because it was

performed during the course of high-altitude trek with relatively large sample size.

In contrast to experimental laboratory studies that can be relatively well controlled, our study was a much less controlled experimental study. The factors such as stress level, temperature, wind, humidification and hydration status all affected the physiologic changes associated with trek. In spite of these difficulties, the studies performed during actual field experiences are valuable because they portray what really occurs.

It is well established that FVC and FEV1 measures are larger in populations living at high altitude comparing with population residing at low altitude<sup>3-6,11</sup> but the changes in pulmonary function parameters have not been well recognized at high altitude during the course of a trek. This study was designed in two steps; the first step was to detect changes in pulmonary function parameters at higher altitude compared with altitudes of their residence and in the second step we compared PFT in altitudes of the residence and lower altitude.

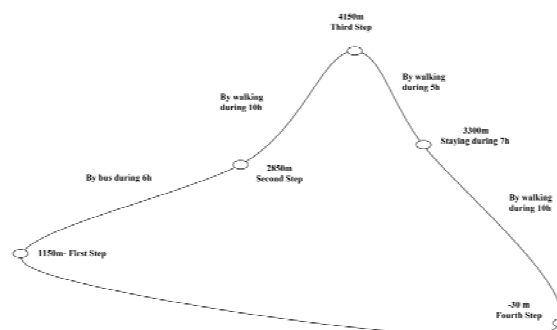


Figure 1. Ascent program and location of performing PFT

Our study indicates that in an actual trek, ascending results in significant decrease in FVC, increase in FEV1/FVC ratio and no significant change in FEV1. Decrease in FVC was shown in previous studies. Table 3 compares our findings with other studies in actual field. Although, the changes were in normal range, this study was performed in healthy people, these changes may be symptomatic in people with underlying diseases.

In all studies, similar to present study, FVC decreases with increasing altitude. Hashimoto showed a 3.8 percent reduction in FVC per 1000m increment<sup>9</sup> and Mason et al showed 1.4-1.6 percent reduction in FVC per 1000m increment.<sup>10</sup> In our study the reduction was higher in the beginning of ascending (3.2% per 1000m increment) and its trend reduced at higher altitude (2.4% per 1000m increment). We suspect, similar to Hashimoto, that this effect is related to pulmonary interstitial changes associated with trek that mimics the restrictive pattern of lung impairment.<sup>9</sup> This had been shown in another study with chest radiographic study.<sup>7</sup> Pulmonary artery enlargement and interstitial edema were radiographic findings that may be causes of the restricted pulmonary function pattern by increasing pulmonary blood volume.<sup>7</sup>

Surprisingly, in our study the mean value for FVC at the sea level was less than Tehran (1150 m). We could not find similar study, and further studies in virtual or experimental situations are needed to document it again. Hashimoto observed that acquired ventilatory changes returned quickly to baseline levels upon descent.<sup>1</sup> We also found this experience but FVC did not return to baseline even after trekkers descended to sea level. Furthermore, FVC was lower at the sea level in comparison to baseline.

In some other similar studies, FEV1 did not change with increasing altitude,<sup>7</sup> but it decreased in Hashimoto and Pollard investigations.<sup>8,9,12</sup> Both the peak flow and FEF25%-75% increased in our study. Previous studies demonstrated both increase<sup>7</sup> and decrease<sup>8,9,12</sup> in FEF25%-75%. This increase may be explained by decreased air density or may be secondary to decreased FVC.<sup>11</sup> FEV1/FVC, FEF25%-75%, and peak flow did not show significant changes at 4150m in comparison to 2850m. Our subjects stayed ten hours at 2850 m before beginning the trek to 4150m. Adaptation of respiratory system may be explained this effect.

In comparison to baseline level, FVC decreased with both ascending higher and descending to lower

altitudes. FEF25%-75%, peak flow and FEV1/FVC all increased with ascending. We concluded that changes in some pulmonary ventilatory parameters were proportional to the magnitude of change in altitude during a high-altitude trek especially at the beginning of ascending.

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