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ASTHMA AND EXERCISE

The Effect of Moderate Altitude on Some Respiratory Parameters of Physical Education and Sports' Students

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Objectives. Analysis of the effects of moderate altitude on some respiratory functions of students enrolled in School of Physical Education and Sports. *Methods*. The study group comprised of 9 female and 10 male volunteers who were attending a 5-day skiing training camp. All participants were enrolled in School of Physical Education and Sports at Gazi University. The male students had an age range of 22.2 ± 1.7 years, height of 175.0 ± 4.3 cm, and body weight of 71.0 ± 10.4 kg; the female students had an age range of 21.2 ± 1.7 years, height of 167.1 ± 4.9 cm, and body weight of 53.7 ± 4.8 kg. Respiratory tests were performed on the 1st and 5th days (the first and second measurements) at an altitude of 1880 m (in Ilgaz Mountain); 10 days after being exposed to high altitude, further tests were performed at an altitude of 856 m (in Ankara) (the third measurement). Data were analyzed using SPSS software (version 10.0). Intragroup differences were analyzed using repeated measures analysis of variance (ANOVA). According to the results of normality test results, an independent-sample *t* test was used in comparisons between the groups. A significance level of $p < .05$ was used in analysis. *Results*. Statistical analysis indicated that there was no significant difference between the intragroup comparisons of female and male students. Intergroup comparisons showed significant differences in forced vital capacity (FVC), forced expiratory volume (FEV), peak expiratory flow (PEF), maximal voluntary ventilation (MVV), and VC parameters ($p < .05$). *Conclusion*. The authors conclude that moderate altitude does not have any effect on some respiratory parameters after 5 days of skiing camp.

Keywords moderate altitude, respiratory parameters, student

Introduction

In recent years, millions of people have ascended to high altitude for various reasons, including recreation, high-altitude climbing, skiing, and camping requirements of athletes. As one climbs higher, physiologic belt of atmosphere (low, moderate, extreme) significantly affect vital functions. Although changes occur in some flow rates in respiratory functions up to 1500 m altitude, no significant, measurable changes occur (1).

Although sporting activities are mostly performed at altitudes up to 500 m above sea level (ASL), the number of people participating sport across the world has increased, and therefore, it becomes important to determine the factors effecting performance at altitude. Elevations of 1000 m and higher are considered high altitude (2). Altitudes of 1500 m and higher may adversely affect physical performance, and these effects vary according to the increase in altitude (3).

The time required to adapt to altitude generally depends on individual characteristics. However, for adaptation to altitudes up to 1200 m, a 2-week time is required, and for each 610 m above 2300 m (up to 4572 m), an additional 1 week was required for acclimatization (4). Ventilation at rest and during exercise is higher at high altitude compared to at sea level (5–7). Adaptation ratio and the volume of ventilation to high altitude varies according to gender (8). It was reported that female subjects who were not adapted to high altitude who stayed at 4300 m altitude for 2 weeks achieved faster ventilation adaptation when compared to males (9).

In the literature, limited number of studies found analyzing the changes in lung volume and capacity of individuals living at low altitude when they ascend to higher altitude. Therefore, the aim of this study is to examine the effects of moderate altitude on some respiratory parameters of students who were enrolled in School of Physical Education and Sports.

Materials and Methods

Subjects

The study group comprised of 9 female and 10 male volunteers who were attending a 5-day skiing training camp. All subjects were enrolled in School of Physical Education and Sports at Gazi University. All subjects were nonsmokers and clinically healthy with no recent history of infection or other disease and had no family history of respiratory disease.

Study

Respiratory tests were performed at 1880 m (Ilgaz Mountain) on days 1 and 5 (first and second measurements), and at 856 m (Ankara) 10 days post altitude (third measurement) and all measurements were taken between 8 am and 9 am at rest. A Portable Vitalograph Spirometer (Cosmed PFT Software Suite Pony FX, Italy) was used in order to determine lung volumes and capacities. Physical characteristics of the subjects are given in Table 1. All subjects lived at 1880 m for 5 days and they attended 4 hours of skiing course program each day. Skiing course program was conducted on January 2008. The temperature was −6∞C at 1880 m, 2–3°C at 856 m.

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TABLE 1.—Physical characteristics of the subjects.

	Age (year)	Body height (cm)	Body weight (kg)
Male ($n = 10$)	22.20 ± 1.75	175.00 ± 4.38	71.00 ± 10.48
Female ($n = 9$)	21.22 ± 1.71	167.11 ± 4.96	53.77 ± 4.89

Statistical Analysis

Data was analyzed using SPSS software (version 10.0). Repeated measures analysis of variance (ANOVA) was used to determine intragroup differences. An independent-sample t test was used for comparisons between the groups, according to the results of normality ranking. Significance was analyzed at the level of $p < .05$.

RESULTS

All subjects' physical characteristics were given in the Table 1.

In the spirometric tests there was no statistically difference between the first and second measurement taken at an altitude of 1880 m and third measurement taken at 856 m of female subjects (Table 2) and male subjects (Table 3).

Forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) values decreased whereas VC, FEV_1, FVC, and peak expiratory flow (PEF) increased at the moderate altitude compared to low altitude both in male and female subjects, but all the changes were not statistically significant.

Our findings are similar to what has been observed by other investigators, demonstrating that male subjects have higher FVC, FEV, VC, maximal voluntary ventilation (MVV), and PEF values than female subjects (Table 4, Figure 1; $p < .01$ and $p < .05$).

DISCUSSION

At high altitude, hypoxia stresses the organism and the oxygen-carrying capacity system even at rest, and causes some short-term and long-term adaptations in the organism. The duration required for adaptation to high altitude generally depends on personal characteristics. However, it was reported that adaptation to altitude up to 2700 m required 7–10 days, whereas adaptation to each 600 m above 2300 m altitude (up to 4572 m) required an extra week (10, 11).

Changes in oxygen concentration have no direct effect on respiratory centers in changing respiratory motives. It was reported that the most important factor that controls respiration is carbon dioxide (CO_2), rather than oxygen (O_2). Changes in CO_2 concentration have a significant acute effect on respiratory control. However, it has a weak chronic effect after several days of adaptation (12). A previous study analyzed alveolar carbon dioxide pressure (PCO_2) differences between females and males who adapted to high altitudes. It was reported that alveolar PCO_2 of females was 2 mm Hg lower than that of males and oxygen pressure (PO_2) of female subjects was slightly higher than that of males. It was reported that lower PCO_2 values in females resulted from bicarbonate levels. In addition, high ventilation values of females at all altitudes are associated with the stimulating effect of sex hormones (13).

A study that analyzed individuals who were exposed to high altitude (4560 m) for a short-term reported that VC decreased by 10%. The researchers found that acute exposure to high altitude decreased VC by 7–15% and, in the following days, VC tended to return to values recorded at sea level (14).

Basu et al. reported that at day 1 of high altitude, no difference was observed in FVC and FEV_1 values; however at day 2, these values decreased significantly. The researchers further indicated that, on day 3 at 3110 m, FVC and FEV_1 returned to values observed at sea level; as altitude increased (from 3445 m to 4177 m), the decrease in FVC and FEV_1 continued (15).

Forte et al. found a moderate increase in FEV_1 at high altitude and a slight decrease in FVC (16). They reported that the decrease in FVC at high altitude might have resulted from the decrease in respiration muscle force (17). It was found that on day 1 at high altitude, FVC of males decreased 2.56%, whereas FVC of females decreased by 3.19%; on day 5 at high altitude, these values increased by 1.72% in males and 0.89% in females. The results of the present study are consistent with those reported in the literature (16, 17). However, the decrease in FVC values during adaptation to high altitude was not statistically significant. The male and female groups showed a significant difference in terms of FVC at the level of $p < .05$. It is estimated that this difference in FVC values was gender-based.

Zverev found that FEV_1 and FVC values of males were 9.8% and 10.8% higher than those of females (17). It was found that there was a slight decrease in FEV_1 in both genders at the first exposure to high altitude. However, on day 5 at altitude, this decrease slightly increased but did not return to the values measured previously at 840 m. Although no significant difference was observed between the intragroup measurements of males and females, there was a significant ($p < .05$) difference between gender groups. As for the $FEV_{1/}$FVC ratios, there was 0.1% and 0.5% difference in

TABLE 2.—Pulmonary ventilation function of female subject.

Measurements	FVC (L)	FEV_1 (L)	FEV_1/FVC (%)	VC (L)	MVV (L)	PEF
1st (1880 m)	3.44 ± 0.41	3.29 ± 0.31	95.44 ± 4.55	3.17 ± 0.38	125.60 ± 16.65	6.84 ± 1.35
2nd (1880 m)	3.41 ± 0.33	3.28 ± 0.30	95.55 ± 3.46	3.08 ± 0.59	126.92 ± 20.76	6.96 ± 1.31
3rd (856 m)	3.55 ± 0.31	3.40 ± 0.35	95.00 ± 4.76	2.87 ± 0.63	133.28 ± 15.62	6.17 ± 2.09
% Difference (1–2)	0.89	0.30	0.11	2.83	1.05	1.75
% Difference (1–3)	3.19	3.34	0.46	9.46	6.11	9.79
% Difference (2–3)	4.10	3.65	0.57	6.81	5.01	11.35

Note. No significant differences between measurements. FVC = force vital capacity; FEV = force expiratory volume; VC = vital capacity; MVV = maximal voluntary ventilation; PEF = peak expiratory flow.

TABLE 3.—Pulmonary ventilation function of male subjects.

Measurements	FVC (L)	FEV_1 (L)	FEV_1/FVC (%)	VC (L)	MVV (L)	PEF
1st (1880 m)	4.64 ± 0.68	4.32 ± 0.55	93.00 ± 4.52	4.27 ± 0.58	188.34 ± 32.45	9.95 ± 1.31
2nd (1880 m)	4.56 ± 0.71	4.32 ± 0.55	94.70 ± 4.47	4.03 ± 0.57	185.22 ± 40.74	10.20 ± 1.68
3rd (856 m)	4.76 ± 0.80	4.34 ± 0.61	91.20 ± 5.99	3.58 ± 0.49	182.70 ± 36.70	9.27 ± 1.83
% Difference (1–2)	1.72	0	1.82	5.62	1.65	2.51
% Difference (1–3)	2.58	0.46	1.93	16.15	2.99	6.83
% Difference (2–3)	4.38	0.46	3.69	11.16	1.36	9.11

Note. No significant differences between measurements. FVC = force vital capacity; FEV = force expiratory volume; VC = vital capacity; MVV = maximal voluntary ventilation; PEF = peak expiratory flow.

females between the 1st, 2nd, and 3rd measurements. This difference was 1.93% and 3.69% in males. These findings are in accordance with those in the literature (17, 18). As indicated by this difference between females and males, we can conclude that the differences are gender-based.

FEV_1 and MVV continued to decrease slowly, whereas FEV_1/FVC ratio stabilized during the rest of the expedition. FEV_1/FVC ratio showed an initial decrease that occurred at the lower altitude, whereas a slight but significant increase in the FEV_1/FVC ratio was observed with chronic exposure to the higher altitude (19).

Forte et al. found that MVV increased by 20% at high altitude (16). It was reported that, in acute and short-term exposure to high altitude, the principle factor affecting MVV was the decrease in air density (14). Apart from gas density, the changes in MVV at high altitude depend on various factors, such as difficult and fast activation of inspiration and expiration muscles, compressibility of thorax gases, mechanical properties of the respiratory system, and respiratory frequency (20, 21). Some studies report that MVV increases with altitude. When subjects were acutely exposed to high altitude (3050 m, 5200 m, and 8200 m), it was found that MVV increased by 13%, 24%, and 31%, respectively. It was reported that the decrease in respiratory tract resistance at high altitude is possibly a result of low air density and bronchodilatation, which increase MVV at high altitude (14).

In a previous study MVV values were measured (856 m altitude on day 1, 1880 m on day 5, and at 856 m after 10 days). MVV values of female subjects were found to decrease by 1.05%, 6.11%, and 5.01%, respectively; MVV values of male subjects were found to decrease by 1.65%, 2.99%, and 1.36% at day 1 at 856 m. These values were found to increase on day 5 at altitude. Female subjects were found to be affected more by exposure to altitude than males. This may be because females have weaker respiratory muscles than males, which is a gender-based difference.

In a study that analyzed pulmonary ventilation functions at high altitude, when the initial values measured at 1624 m were compared with values measured after 2 weeks of exposure to altitudes from 3404 to 4896 m, it was found that at each 1000 m altitude, $PEF_{25-75\%}$ values decreased by 3.6% (22).

Seedhouse et al. studied elite and nonelite sportsmen, and found that different altitudes (2200 m, 2400 m, 3000 m, 3400 m, 4100 m, 4300 m) had significant effects on PEF values between the groups. They attributed this difference to the difference between the groups (23). In another study, Padilla et al. found that PEFR values of males were higher than those of females (24).

In the present study it was found that moderate altitude did not have a significant effect on some respiratory parameters of the subjects; however, a statistically significant gender difference was found between groups. Therefore it is suggested that future studies should analyze acute and chronic effects of different altitudes on respiratory parameters and these effects should be evaluated according to age, gender, and exercise

TABLE 4.—Spirometric measurements of female and male subjects.

	Measurements	Female ($n = 9$) Mean + SD	Male ($n = 10$) Mean + SD	t value
FVC (L)	1st (1880 m)	3.44 ± 0.41	4.64 ± 0.68	4.57**
	2nd (1880 m)	3.41 ± 0.33	4.56 ± 0.71	4.38**
	3rd (856 m)	3.55 ± 0.31	4.76 ± 0.80	4.21**
FEV (L)	1st (1880 m)	3.29 ± 0.31	4.32 ± 0.55	4.87**
	2nd (1880 m)	3.28 ± 0.30	4.32 ± 0.55	4.99**
	3rd (856 m)	3.40 ± 0.35	4.34 ± 0.61	4.00**
FEV_1/FVC (%)	1st (1880 m)	95.44 ± 4.55	93.00 ± 4.52	1.17
	2nd (1880 m)	95.55 ± 3.46	94.70 ± 4.47	0.46
	3rd (856 m)	95.00 ± 4.76	91.20 ± 5.99	1.51
VC (L)	1st (1880 m)	3.17 ± 0.38	4.27 ± 0.58	4.81**
	2nd (1880 m)	3.08 ± 0.59	4.03 ± 0.57	3.53**
	3rd (856 m)	2.87 ± 0.63	3.58 ± 0.49	2.29*
MVV (L)	1st (1880 m)	125.60 ± 16.65	188.34 ± 32.45	5.20**
	2nd (1880 m)	126.92 ± 20.76	185.22 ± 40.74	3.85**
	3rd (856 m)	133.28 ± 15.62	182.70 ± 36.70	3.54**
PEF	1st (1880 m)	6.84 ± 1.35	9.95 ± 1.31	5.07**
	2nd (1880 m)	6.96 ± 1.31	10.20 ± 1.68	5.20**
	3rd (856 m)	6.17 ± 2.09	9.27 ± 1.83	3.44**

Note. $^*p < 0.05$; $^{**}p < 0.01$; FVC = force vital capacity; FEV = force expiratory volume; VC = vital capacity; MVV = maximal voluntary ventilation; PEF = peak expiratory flow.

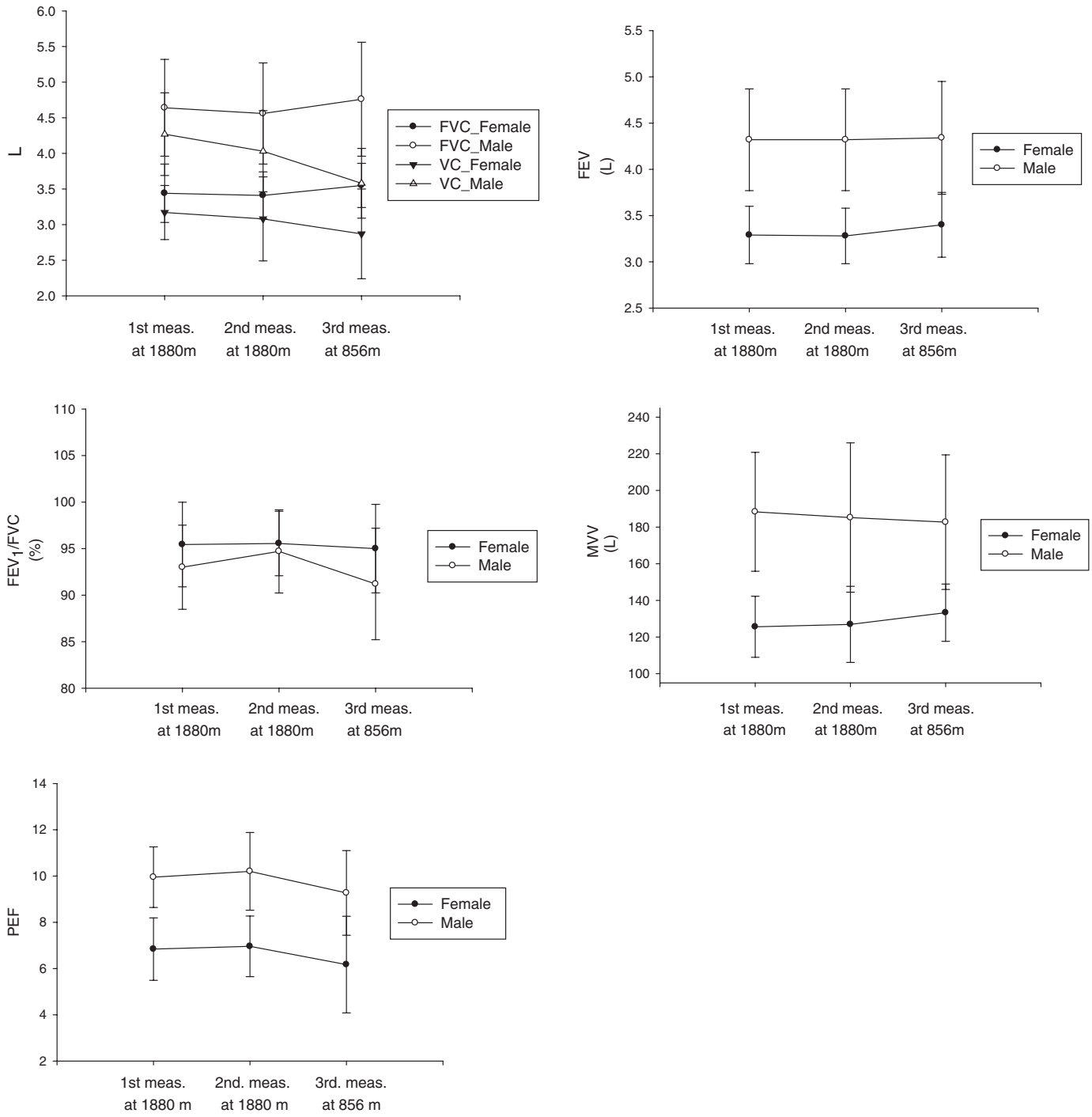


FIGURE 1.Pulmonary ventilation function of female and male subjects (FVC, FEV, FEV_1/FVC, VC, MVV, PEF values).

level. On the other hand, in order to determine the effects of moderate altitude, further research should be carried out on the subjects who have asthma or an upper respiratory disease.

DECLARATION OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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