Effect of High Altitude on Endurance Exercise Performance in Normal Healthy Subjects

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Abstract: Objective: This study was conducted to investigate the effect of high altitude on endurance exercise performance in normal healthy subjects. **Subjects and Methods:** One hundred normal healthy female students from Taif University incorporated in this study; their ages ranged from 18 to 25 years old. All subjects had assessed for some parameters of physical fitness and endurance including pulmonary function tests (PFT) using Spirolab III in two steps; the first step measurements tested before starting specific endurance exercise program on a treadmill for continuous 25 minutes. Endurance exercises were provided five times per week for continuous four weeks. The second step measurements were performed at the end of the endurance exercise program (after four weeks). **Results:** There was a statistical significant increase in the measured spirometric parameters at post intervention as compared to pre intervention (p>0.05). The measured parameters were: vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1) and maximum voluntary ventilation (MVV) C**onclusion**: Endurance exercise can improve physical fitness in normally healthy females living at high altitude in terms of improvement in PFT .

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1. Introduction

Regions on the Earth's surface that are high above mean sea level are referred to as high altitude **[1, 2].** In recent years there has been a growing interest in the effects of high altitudes on the human body. High altitudes are being frequented by more and more people for sport and leisure pursuits, and are increasingly being used both as a training environment and for investigating the healthy body in hypoxic conditions **[3]**. During the ascent from sea level, atmospheric pressure and partial oxygen pressure decrease, humidity and temperature decrease, and radiation is elevated. The altitudes at which physiological changes and clinical symptoms occur are not constant, but variations may usually appear above 2300-2800 meters. There is a wide variability of reactions to low oxygen in the air inhaled. The physiological parameters during both rest and physical activity at high altitudes are different from those at sea level, and the differences are reflected in concomitant changes in attitude and behavior **[3]**.

Medicine recognizes that altitudes above 1,500 metres (4,900 ft) start to affect humans **[4],** and extreme altitudes above 5,500–6,000 metres (18,000–20,000 ft) cannot be permanently tolerated by humans [5]. The higher you go in the atmosphere, the thinner the air. Thinner air means less air resistance, so athletes who sprint, jump, or cycle will perform better at high-altitude venues. But thinner air also means less oxygen, so the pace of hard endurance training and competition-which depends on high rates of oxygen consumption--gets slower at altitude **[6]**.

Endurance exercise can be defined as cardiovascular exercise–such as running, cross-country skiing, cycling, aerobic exercise or swimming–that is performed for an extended period of time **[7]**. Endurance exercise involves complex integration of multiple physiological functions, but despite its multifaceted nature, this type of exercise is characterized by one simple requirement–the ability to sustain repeated muscle contraction. Endurance exercise involves complex integration of multiple physiological functions, but despite its multifaceted nature, this type of exercise is characterized by one simple requirement–the ability to sustain repeated muscle contraction **[8].**

Research into altitude as a training environment that could improve exercise endurance and performance has grown in the last decade, with the development of a number of new training methods, such as "Living High--Training Low" and "Training High--Living Low". These have contributed to an improvement of performance in a significant number of athletes **[9]**. Generally, research involving high altitude focuses on heights of 3,000 m or more. There is less research, and less of an adaptation reaction at moderate altitude (1,500 to 3,000 m). It would be incorrect to assume that the magnitude and timing of adaptations to high altitude are the same as those of moderate altitude **[10]**. This paper will demonstrate the impact of high altitude on endurance exercise performance in normal healthy subjects in terms of measuring specific lung functions.

2. Materials and Methods

Subjects:

A sample of one hundred normal healthy female students collected from different faculties in Taif University, Taif city, kingdom of Saudi Arabia. The study was carried out using a cross sectional design. Random sample of female students from different faculties; their age ranged from 18 to 25 years old were included in this study. Exclusion criteria: Participants excluded if 1) they have history of chronic systemic diseases (chronic obstructive respiratory disease such as asthma, cardiovascular disease /or renal disease). 2) Any pathology or injury of any joint of the lower limb.

Procedure:

- Full medical history taking was conducted after taking their consent to participate in the study.

- All subjects were assessed for some parameters of physical fitness and endurance including PFT (using Spirolab III) in two steps.

The first step measurement was tested before starting specific endurance exercises on a treadmill for continuous 25 minutes, 5 times/week, for continuous four weeks.

The second step measurement was performed for every participant at the end of the endurance exercise program (after 4 weeks).

For pulmonary function's parameters measurement at first, Spirolab III (made in Italy) and equipped with colour LCD (model Tuk-MIR 009, serial No. A23-053) was adjusted by an expert, and then the required instructions were provided to the participants. During test performance, the operator entered the required information of each participant (height, age, gender, weight and race) in apparatus. The examiner blocked the participants' noses with clips to stop air ways. Then, the participant stood or sit in an arm chair in a way that their ribcage was flat. Then each participant put a disposable cartoon mouth piece on her mouth and blew in it. All participants repeated the test phases 3 times and the best results were recorded by apparatus expert and then were analyzed.

The measured variables were: vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1) and maximum voluntary ventilation (MVV) pre and post exercise.

The spirometry test performed in 3 stages: 1) FVC test: in this stage, participants made a strong breath and filled their lungs totally then immediately made a deep, strong and fast expiration. Via this test, we can measure FVC (L) and FEV1 (L). 2) VC test: the participants made a complete, deep inspiration to the total capacity of lungs and then a deep, gradual expiration and aspirate the lungs completely. Through this test VC (L) of samples can be calculated. 3) MVV test: the participants made fast inspiration and expiration for 10-15 seconds constantly. By this method the amount of MVV (L/m) can be obtained **[6].**

For endurance training:

Tunturi T40 electronic treadmill was used (serial No., 10C6C-00279H). It is composed of a feedback monitor, pulse handgrip, thick full length hand rails, orthopaedic tread belt with a high torque motor.

Each participant was instructed to walk for continuous 25 minutes; Warm up for the first five minutes of the total workout (in a pace of 1Km/h), followed by walking in a pace of 2 Km/h) for 15 minutes, then cooling down for another 5 minutes (in a pace of 1 Km/h)

Statistical Analysis

A) Data collection:

Data have been collected from one hundred female students. The data which had been collected were: 1) Vital Capacity (VC), 2) Forced Vital Capacity (FVC), 3) Forced Expiratory Volume in 1 second (FEV1), and 4) Maximum Voluntary Ventilation (MVV). All these variables were measured before and after the endurance exercise program.

B) Data analysis:

All data were analyzed by the SPSS software; version 16.0.The mean and standard deviation were calculated for the demographic characteristics and all variables before and after the endurance exercise program. The paired t-test was used to compare the pre- and post-intervention values of VC, FVC, FEV1 and MVV. The results were considered significant if the p values were less than 0.05.

3. Results

For this study, 150 female university students were identified as potential participants (Figure 1). Of these, 29 were excluded because they failed to fulfill the inclusion criteria and 21 students refused to participate in the study. Thus, of the original pool, 100 female university students participated in this study with a mean ± SD of age, weight and height were 23.45 ± 4.6 years, 50.43 ± 10.39 Kg and 156.45 ± 7.1 cm respectively.

The results of the present study revealed a statistically significant difference between the mean values of baseline and post intervention of all variables being tested; vital capacity (L), forced vital capacity (L), forced expiratory volume in 1 second (L) and maximum voluntary ventilation (L/min). The mean values of all variables tested are shown in Table 1 and represented in Figure 2.

Table 1: Comparison between pre and post intervention for the tested lung volumes in the students participating in the study.

Variable	Pre	Post	t-value	p-value
VC (L)	2.93±0.58	6.48±16.07	-2.22	0.029*
FVC (L)	4.09±0.33	4.75±0.32	-26.80	0.0001*
FEV1 (L)	3.66±0.16	4.55±0.18	-45.36	0.0001*
MVV (L/min)	149.72±5.8	169.86±17.73	-11.45	0.0001*

Values are mean ± SD. VC: Vital Capacity. ERV: Expiratory Reserve Volume.
FVC: Forced Vital Capacity. FEV1: Forced Expiratory Volume in 1 second.
MVV: Maximum Voluntary Ventilation. Pre: pre-intervention assessment
Post: post-intervention assessment * Significant at P <0.05

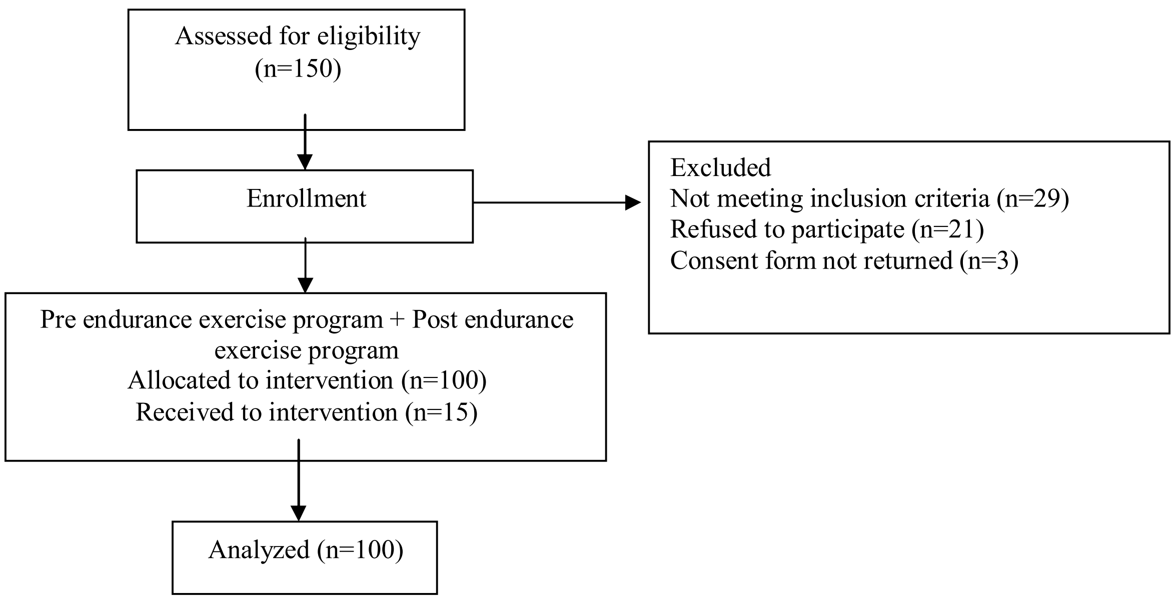

Fig 1. Participants flow through the study.

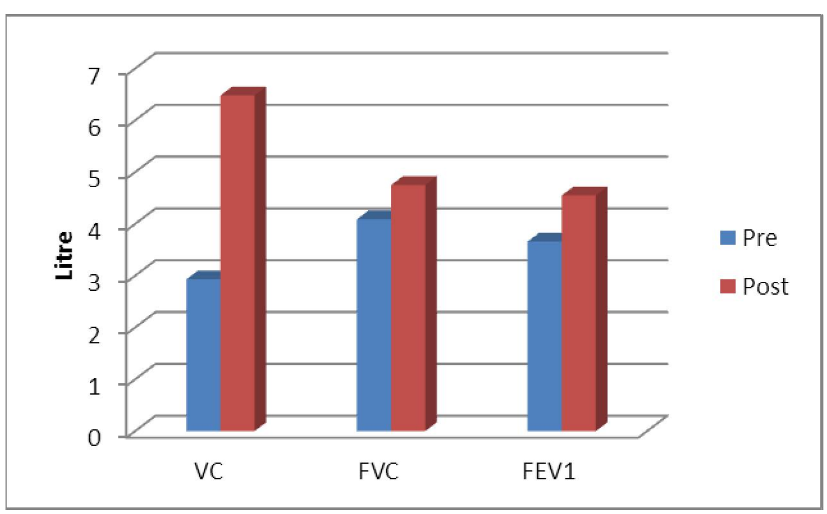

Fig. 2: The mean values of vital capacity (VC), forced vital capacity (FVC), and forced expiratory volume in 1 second (FEV1) at pre and post endurance training program.

4. Discussion:

In recent years there has been a growing interest in the effects of high altitudes on the human body. High altitudes are being frequented by more and more people for sport and leisure pursuits, and are increasingly being used both as a training environment and for investigating the healthy body in hypoxic conditions **[3]**.

This study was conducted to investigate the effect of high altitude on endurance exercise performance in normal healthy subjects in terms of measuring specific lung functions. The results revealed a statistically significant difference between the mean values of baseline and post endurance training program (after four weeks) of all variables being tested; FVC (L) FEV1 (L), VC (L), and MVV (L/min).

Since this study has been done in a real environment, local parameters were out of control and same factors like humidity, wind, temperature and hydration level of individuals may affect the obtained results of spirometry tests. Because of the above mentioned reasons, this study was performed in summer and in dry weather in order to reduce humidity and temperature and wind effects as far as possible. Furthermore, the used spirometer adjusted to the environmental situations like temperature and humidity somehow.

On the other hand, the samples of this study were female faculty students and therefore their menstrual cycle might affect the results obtained. Change of estrogen and progesterone level in menstrual cycle due to the changes of the ventilation responses. Hence, the entire tests were done 3-8 days after the menstrual days of the samples **[11,12].**

Exercise when performed regularly has benefits on the various systems of the body. Regular exercise has a favorable influence on cardiovascular functions and also lung functions. There is an increasing evidence to show that regular physical activity causes many desirable physical, physiological and psychological changes in an individual consequently raising his level of fitness **[13]**.

The significant improvement of spirometry measures at the end of the endurance training program might be attributed to the effect of exercises on improving the strength of pulmonary muscles due to the regular forceful inspiration and expiration for prolonged period during training session. This helps the lungs to inflate and deflate maximally. This maximum inflation and deflation is an important physiological stimulus for the release of surfactant **[14].** This comes in agreement with **Shashikala and Sarath [13] & Uppal and Rajendra [15].**

The increasing of adrenalin hormone at high altitude may have an important role at the decrease of airways resistance. The increasing of this hormone activity causes a decrease at reversibility of lungs and dilatation of the vessels, and consequently airways resistance decreases **[16,17].** This mechanism could provide an additional justification of the significant increase of the spirometry parameters in the female students who participated in this study at end of the endurance training program.

It has been proved that Application of a treadmill walking exercise three times weekly for 8 weeks resulted in increased exercise endurance, improved VC and MVV. These improvements might be due to one or more of the following factors: improved aerobic capacity, or muscle strength or both, increased motivation and improved ventilatory muscle function **[18].**

This study has several limitations. The small number of participants might limit the generalization of the study results. The patients who participated in this study were all aged between 18 and 25 years old. Further studies are recommended to target older ages to enable comparisons of the results across different age groups. The lack of a control group trained at sea level is might limit the generalization of our results. Therefore, a future study is recommended to compare the results between experimental (living at high altitude) and control group (living at sea level). Additionally, the absence of follow-up for the participants might be considered another limitation of this study. We suggest future studies to overcome these limitations.

Conclusion:

Endurance exercises can improve physical fitness in normally healthy females living at high altitude in terms of improvement in selected pulmonary function parameters.

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