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Research Article

EFFECT OF HIGH ALTITUDE ON PULMONARY FUNCTION IN HEALTHY SCHOOL CHILDREN

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A B S T R A C T

Background: Conflicting results of various studies about the effect of altitude on pulmonary function and it has not been established decisively. So this study was conducted to compare the effect of high altitude versus normal altitude on pulmonary function in healthy school children. **Materials and Methods:** A cross sectional study was conducted in which the pulmonary function of a group of 150 children (80 boys and 70 girls) are living in high altitude and 150 children (90 boys and 60 girls) normal altitude living in Abha and Jeddah, KSA respectively; their ages ranged from 8-11 years old. SpirolabIII was used for assessment of spirometric values (forced expiratory volume in one second, forced vital capacity, peak expiratory flow rate, and maximal voluntary ventilation. **Results:** Significant difference between boys and girls in all measured pulmonary values at high attitude, while non significant difference between them at normal altitude. The mean pulmonary value of boys and girls at high altitude was significantly higher than those in normal altitude. **Conclusion:** The study suggested that, high altitude has an effect on pulmonary function in both sexes.

INTRODUCTION

Children exposed to reductions in inspired oxygen levels as a result of altitude may be vulnerable to the pathological consequences of hypoxaemia[1]. Altitude gain causes a drop in the partial pressure of inspired oxygen and thus a lower hemoglobin oxygen saturation (%SpO2) resulting in a state of hypoxia [2]. At high altitudes (HA), a number of acute and chronic airway mechanisms are activated, which are aimed at optimizing oxygen availability[3].

People who live permanently at HA are exposed to environmental conditions such as hypoxia[4]. This leads to striking differences between HA and LA human populations with respect to various biological traits, including anthropometric and respiratory differences[5]. There is little number of studies which have attempted to investigate the effect of altitude on lung function. Although a few studies have attempted to compare these values of high and normal altitude populations, the effect of altitude on lung function has still not been decisively established, due to the conflicting results reported by this studies[6-8].

A number of studies have compared the lung volumes of indigenous high and normal altitude population who were born and raised at HA[9, 10]. Comparable studies do not exist for children who had born in high and normal altitude. In healthy children of HA who died by accident, anatomic studies recently performed have shown right ventricular hypertrophy and pulmonary arterioles with a muscular wall and a narrow lumen, resembling the fetal pattern of the pulmonary vasculature.2~3[11-14].

Children, adolescents, and adults residing at HA since birth exhibit increased lung growth in response to chronic hypoxia; subjects at HA have larger lung volumes and greater pulmonary diffusing capacities compared to subjects residing at sea-level[15-19]. Although infants and toddlers residing at HA are also exposed to chronic hypoxia, there have been no measurements of lung volumes in these very young subjects to determine whether increased lung growth begins early in life versus occurring at an older age when there are significant increases in physical activity and metabolic requirements[20]. The aim of the present study was to compare the pulmonary function of healthy school children, from these two contrasting geographical locations.

METHODOLOGY

The study was conducted during March to August 2015. 150 normal children (80 boys and 70 girls) are living in normal altitude and 150 high altitude living children (90 boys and 60 girls); their ages ranged from 8-11 years old living in Jeddah, KSA (altitude at sea level) and Abha, KSA (altitude 2200 meters). The study was approved by the ethical committee of the institute. Prior permission of the school authorities was taken and written consent from the parents/guardians of all children was also obtained after clearly explaining them the purpose of the study. The children included in the current study had no previous history of pulmonary disease, no operations in the chest area, no a previous history of bronchial asthma and no cardiopulmonary problems.

Using Spirolab III (SDI Diagnostics Inc, USA) for measuring pulmonary function, the tests were carried out at a fixed time of the day (09:00–13:00 h) to limit diurnal variaty. This spirometer was associated with a lab PC and the parameters were visually displayed and processed in the monitor of the computer by using the appropriate software. The children were asked for 2–3 tidal breaths in and out (optional) and to inhale deeply (inhale fast and deep) with the lips sealed tightly around the mouthpiece. Then they were asked to blow air through the mouthpiece as fast as possible (to blast air from the lungs) and to continue to blow until no air is left to exhale. Amid directions to kids, a few expressions might be utilized, for example, "sucking on a straw" for a profound motivation, "smothering birthday candles" for a powerful lapse, and "continue blowing and continue blowing" for finish exhalation until no air is cleared out. The optional part of the FVC manoeuvre is inhalation as fast and completely as possible at the end of forced expiration. The test should be repeated at least three times. The pediatric simulation screen was displayed during the test automatically for encouragement of the child to continue to perform the test[21-25].

Statistical analysis

All statistical measures were performed using the Statistical Package for Social science (SPSS) program version 20 for windows. Prior to final analysis, data were screened for normality assumption, and presence of extreme scores. To determine similarity between the groups at base line, subject age, height, and body mass were compared using independent t tests. Unpaired *T* test was used to compare the pulmonary values between various groups. $P < 0.05$ was considered statistically significant.

RESULTS

As indicated by the independent t test, there were no significant differences (p>0.05) in the mean values of age, body mass, and height between both tested groups of both sexes (Table 1) indicating that both groups were homogenous. Statistical analysis revealed that there was significant difference between boys and girls in FEV1, FVC, PEFR and MVV at high altitude, while there was non-significant difference at NA Table (3). Children of both sexes had a significantly greater FEV1, FVC, PEFR and MVV at HA compared with children at NA Table (2).

Table 1 Comparison of mean±SD of age and anthropometric parameters of boys and girls

Parameter	Boys mean ±SD			Girls mean ±SD		
	High altitude	Normal altitude	P-value	High altitude	Normal altitude	P-value
Age(yr)	8.6±1.24	8.93±1.03	0.518	8.72±1.09	8.58±1.31	0.439
Wt(kg)	20.73±5.06	20.33±5.2	0.128	21.91±4.07	21.09±2.19	0.793
Ht(cm)	121.33±1.35	124.26±1.73	0.873	122.42±2.08	123.47±2.19	0.793

Wt: weight, kg: kilogram, ht: height, cm: centimeter, P › 0.05 were considered statistically non significant.

Table 2 Comparison of mean±SD values of pulmonary function between boys and girls of HA and NA children

Parameter	High altitude			Normal altitude		
	Boys	Girls	P-value	boys	girls	P-value
FEV1(L)	2.54±0.19	2.07±0.21	0.03	0.76±0.12	0.74±0.09	0.21
FVC(L)	2.55±0.17	2.06±0.33	0.02	0.77±0.12	0.72±0.06	0. 34
PEFR(L/s)	4.9±0.89	4.11±0.96	0.04	1.58±0.32	1.49±0.78	0. 12
MVV(L/m)	68.4±4.03	64.8±4.38	0.03	38.5±2.98	33.95±3.06	0. 29

FEV1: Forced expiratory volume, FVC: Forced vital capacity, PEFR: Peak expiratory flow rate, MVV: Maximal voluntary ventilation, P < 0.05 was considered statistically significant.

Table 3 Comparison of FEV1, FVC, PEFR AND MVV between high altitude and normal altitude children for both genders

Parameter	Boys			Girls		
	High altitude	Normal altitude	P-value	High altitude	Normal altitude	P-value
FEV1(L)	2.54±0.19	0.76±0.12	0.05	2.07±0.21	0.74±0.09	0. 05
FVC(L)	2.55±0.17	0.77±0.12	0.05	2.06±0.33	0.72±0.06	0.05
PEFR(L/s)	4.9±0.89	1.58±0.32	0.05	4.11±0.96	1.49±0.78	0.05
MVV(L/m)	68.4±4.03	38.5±2.98	0.05	64.8±4.38	33.95±3.06	0.05

FEV1: Forced expiratory volume, FVC: Forced vital capacity, PEFR: Peak expiratory flow rate, MVV: Maximal voluntary ventilation, P < 0.05 was considered statistically significant.

DISCUSSION

The present study aimed at establishing the effect of altitude on pulmonary function by comparing pulmonary values represented by FEV1, FVC, PEFR and MVV of healthy HA and NA school children. In the current study, significantly higher pulmonary values were observed in HA children as compared to their normal altitude counterparts. This are may be related to the more development of the accessory muscles of respiration in higher altitude residents due to hypoxia[26,27]. The consequences of the present review come in consistency with Qazi *et al*. [28] who detailed that elevation more noteworthy than 1500 meters seems to bring about quantifiable changes in lung volumes and flow rates; Also, the higher anthropometric proportions, e.g. trunk to leg proportion (which signifies a high vertical trunk size), and low levels of environmental pollution in HA areas may explain increased values of lung volumes and flow rates in residents of these areas. However, Weitz *et al.*[29] suggested that greater lung function at higher altitude primarily results from development of a hypoxic environment and is less likely to be caused by increased activity or lower pollution. Dr. West [30] suggested that since the air at higher altitude is less dense, airway resistance is reduced, and maximum inspiratory and expiratory flows are greater than that at sea level.

A study by Malamitsi-Puchner *et al*. [31] demonstrated that children residing at HA have increased lung volumes compared to children residing at normal altitude and suggested a gender difference in the response to chronic hypoxia early in life. They also found that serum levels of vascular endothelial growth factor (VEGF) and erythropoietin (EPO) were significantly higher in infants and toddlers at high altitude compared to subjects at normal altitude. These outcomes demonstrate that incessant hypoxia from living at HA expands hypoxia inducible development variables and lung development right on time in life. The findings in infants and toddlers are consistent with the increased lung volumes found in older children and adults at HA compared to those NA, thus indicating that the effects of chronic hypoxia upon lung growth begin very early in life.

HA infants may have a normal specific compliance (CRS/FRC), which would be consistent with the findings in adults that the pulmonary pressure volume curves obtained from adults at HA and LA do not differ when normalized for lung volume. Cumulatively, these studies indicate that subjects at HA have increased lung volumes very early in life and this effect may be initiated in utero[32, 33].

To our knowledge, the effect of altitude on pulmonary function has not been reported previously in children, but similar results have been found in adults. Senn *et al*[34] reported an average fall in FVC and FEV1 of 6% and 5%, respectively, with marked individual variation and concluded that changes in pulmonary function after rapid ascent to HA were consistent with subclinical interstitial fluid accumulation, although respiratory muscle weakness and fatigue could not be excluded. Scrase *et al*[35] suggested that, with sufficient preparation and vigilance, healthy children as young as 6 years of age can be taken to altitudes of 3500 m without major adverse effects, and that such children are willing and able to undertake a wide range of physiological assessments.

In contrast, Debray *et al.* [36] measured the PEFR values of Nepalese young adults and compared them with their Indian counterparts. No significant difference was found either between the mean ± SD PEFR of Nepalese males and Indian males or between the mean ± SD PEFR of Nepalese females and Indian females; this concluded that prediction equations made for Indian adults could also be used to predict PEFR of Nepalese adults. Kashyap *et al.* [37]compared the PEFR values of healthy highlander tribal children with lowlander North Indian urban children, and found that mean PEFR in highlander boys (245.5 ± 74 L/min) was comparable with that in lowlander boys (248 ± 64 L/min).

Increased lung growth early in life is more likely to be secondary to an increase in alveolar number, rather than an increase in alveolar size; however, we are not aware of any human histologic data either in children or adults comparing lung parenchymal structure in subjects at HA versus LA. There are animal studies that demonstrate increased lung volume, pulmonary diffusing capacity, and surface area for gas exchange for animals raised at HA compared to animals raised at LA, and acinar structural changes that developed at HA persisted for years after animals were returned to LA[38-40].

There were an interaction between Altitude and gender. When analyzed by gender, boys and girls at HA had greater lung volumes than boys and girls at NA. Also boys had larger lung volumes than girls at HA; however, there was no gender difference in lung volumes at LA. This comes in consistent with the results of many of previous studies **[41-43].**

In summary, we found that children at high altitude have significantly higher pulmonary function compared to those at normal altitude .Understanding the mechanisms that contribute to the increased lung volumes with high altitude may provide strategies to target compensatory lung growth in infants with lung disease, as well as account for gender related differences in lung diseases from infancy to adulthood.

Future Directions

Clinical research should continue to assess the changes in lung function parameters in children in other age group. Comparing between children and adults may be of interesting studying.

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