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Original Article

Analysis of changes in pulmonary functions at rest following humidity changes

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Abstract. [Purpose] The purpose of this study was to compare the effect of humidity changes on the values of pulmonary function at rest. [Subjects and Methods] This study was conducted with 30 young adults (9 males, 21 females; mean age 19.4 years). Participants' mean height was 165.1 cm, and their mean weight was 60.2 kg. The experimental setting was a laboratory in which temperature was fixed at 25 °C. Using a humidifier, relative humidity was successively to adjusted 25%, 50%, and 90%, and pulmonary were measured functions at each level. Using a spirometer, forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), expiratory reserve volume (ERV), and tidal volume (TV) were measured, and the results were compared and analyzed. [Results] Controlling for temperature, FVC and FEV_1 showed statistically significant differences among different levels of relative humidity, but FEV_1/FVC, TV, and ERV showed no significant difference. [Conclusion] In the case of exercises that require large respiration volumes, such as aerobic exercises or exercise load tests, it is recommended that higher than normal humidity levels should be maintained.
Key words: Pulmonary function, Humidity, Temperature

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INTRODUCTION

Vital capacity tests measure air flow rate and volume to assess the ventilator function, in which air enters the alveoli from the atmosphere and then returns from the alveoli to the atmosphere during inspiration and expiration, respectively[1)]. Pulmonary function tests, using spirometers, are useful for evaluating and helping patients with respiratory problems, and there are standards and guidelines for accurate and appropriate testing[2)].

Pulmonary function tests may be conducted by doctors, nurses, and physical therapists, providing clinical measurements that are essential for early diagnosis of respiratory diseases[3)]. Education of testers, testing postures, and the selection of appropriate reference values all affect the measurement of vital capacity. Recently, proper measurement and analysis of pulmonary functions across occupations and occupational environments has become a legal requirement in Korea[4)].

With regard to the environment, humidity is one of the factors that must be considered for accurate measurement of pulmonary function. Moyen et al.[5)] reported that when exercising at low intensity, the maximal evaporative capacity and the degree of heat loss gradually decreases with increasing relative humidity. Havenith et al.[6)] measured stress reactions to heat after one hour of exercising at a fixed temperature of 35 °C and a high relative humidity level of 80%. According to their results, sweat losses throughout the body were most affected by body size. While there are numerous studies of the relationship between exercise and humidity, the effects of changes in humidity on pulmonary functions at rest have rarely been studied. The purpose of the present study was to examine whether pulmonary functions differ in temperature-controlled environments with different levels of humidity.

SUBJECTS AND METHODS

The experiment was conducted with 30 healthy young adults (9 males, 21 females) selected for the study. The participants had not performed any strenuous exercise for 24 hours, were non-smokers, and were free of respiratory disease. Their mean age, height, and weight were 19.4 ± 1.4 years, 165.1 ± 8.6 cm, and 60.2 ± 8.6 kg, respectively.

A portable device for measuring pulmonary function (Pony Fx; COSMED, Italy) was used to measure participants' pulmonary functions. The researcher had sufficient knowledge of the theory and practice of pulmonary function measurement. For pulmonary functions, forced vital capacity (FVC), forced expiratory volume of one second (FEV_1), expiratory reserve volume (ERV), and tidal volume (TV) were measured. During measurement participants sat on chair and asked to try to avoid bending their trunk forward. Other instructions were that a full inspiration should be completed before immediately commencing a forced expira-

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tion, without hesitation. Maximum effort was to be applied to each expiration, and each expiration was required to be at least six seconds in duration. When breathing stopped during the test, for coughing or other reasons, the measurement was repeated after a rest period of five minutes. The temperature in the laboratory was controlled at 25 °C, and the levels of relative humidity were successively adjusted to dry (relative humidity = 25%), ambient (relative humidity = 50%), and high (relative humidity = 90%) using a humidifier. Participants acclimatized to the laboratory conditions for 10 minutes before measurements were taken, and there was a washout period of 24 hours between each humidity condition to eliminate any carry-over effects. All participants signed an informed consent form, and the study was approved by the institutional review board of the Catholic University of Busan.

The collected data were analyzed using SPSS (v. 18.0). One-way repeated measures ANOVA was used to examine differences in pulmonary functions among the different levels of humidity. For all analyses, the significance level was chosen as α = 0.05.

RESULTS

Pulmonary function showing significant differences among the humidity levels were FVC and FEV_1 ($p < 0.05$). Comparisons revealed significant differences between the 25% and 50% levels, and between the 25% and 90% levels ($p <0.05$) (Table 1).

Table 1. Comparisons of measured values of pulmonary functions among humidity levels (N=30)

	Dry (25%)	Ambient (50%)	High (90%)
FVC (l)	3.62±0.67	3.74±0.69*	3.73±0.69†
FEV_1(l)	2.91±0.60	3.09±0.65*	3.09±0.60†
FEV_1/FVC (%)	81.07±7.43	82.00±9.47	82.53±9.06
ERV (l)	1.08±0.46	1.09±0.49	1.04±0.54
TV (l)	0.60±0.39	0.65±0.24	0.63±0.27

FVC: forced vital capacity; FEV_1: forced expiratory volume at one second; ERV: expiratory vital capacity; TV: tidal volume
*p<0.05 compared with dry (25%); †p<0.05 compared with dry (25%)

DISCUSSION

In primary care of adults and children, spirometer-based pulmonary function tests can usefully be employed in clinical decision making, provided that testers are sufficiently trained and guidelines are accurately observed[7, 8]. Pulmonary functions are generally measured in indoor environments, and depend on physical factors such as gender, body mass index, smoking history, and posture[9, 10]. This study began from the hypothesis that changes in humidity alone might change pulmonary functions at rest (i.e., without performing any exercise).

Many studies have detailed the relationship between humidity/temperature and exercise/energy consumption. For instance, Maughan et al.[11] reported that when exercise was performed at an intensity of approximately 70% of maximal oxygen uptake (VO2 max) in a warm environment (30 °C) at relative humidity levels of 24%, 40%, 60%, and 80%, exercise capacity decreased as humidity increased, while skin temperatures and sweat ratios both increased. Moyen et al.[5] reported that when 13 healthy adults performed a walking exercise at low intensity (35% of VO2 max) for 90 minutes at a high temperature (35 °C) at successive relative humidity levels of 40%, 55%, 70%, and 85%, maximal evaporative capacity and degree of heat loss gradually decreased as the level of relative humidity increased. Valencia et al.[12] measured energy expenditure over 24 hours at ambient (50–65%) and high (80–93%) levels of humidity and observed higher energy expenditures at the higher levels of humidity. Garby et al.[13] reported that when 56 healthy persons performed two exercise programs at a fixed temperature of 24 °C at different humidity levels, sensible heat loss was not significantly related to humidity changes, but evaporative heat loss decreased as humidity levels increased. All of the above studies measured changes in the body while exercises were performed at various humidity levels, and the results indicate that at high temperatures, heat loss, sweating, and energy consumption increase as humidity levels increase. In the present study, no significant difference was found in pulmonary functions between ambient and high humidity levels, probably because sweating did not occur as pulmonary functions were measured at rest rather than after exercise, and at dry, ambient, and high humidity levels with the temperature fixed at 25 °C.

In another study of the relation between changes in humidity and pulmonary functions, Turner et al.[14] reported that when exercises were performed at high temperatures and high levels of humidity, frequency of breathing decreased by 9.3% and tidal volume increased by 9.4% compared to exercises performed at low temperatures and low levels of humidity. In the present study, although tidal volume did not differ at rest (without performing any exercise) between dry and ambient or high humidity levels, forced vital capacities such as FVC and FEV_1 showed significant differences between the dry condition and ambient and high humidity levels. Although these increases were small and within the measurement the errors were measured at rest and they would have shown greater difference if they had been measured over a long period of time during working or exercises. There have been few studies about the pulmonary functions at rest following humidity changes, While this study does not present the optimal conditions for enhancing the efficiency of exercises, these results at least indicate that in the case of exercises requiring large respiration volumes, such as aerobic exercises or exercise load tests, pulmonary functions should properly be measured at humidity levels higher than the norm rather than in dry environments.

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