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Pulmonary function is related to basic physical fitness and physical activity in college students

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대학생의 폐활량에 대한 기초체력과 신체활동량의 관계

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Abstract : The purpose of this study was to analyze the correlation between pulmonary function, basic physical fitness (PF), and physical activity (PA), and to compare the differences by gender in Korean college students. Measurements of body composition, basic PF, PA (questionnaire), and pulmonary function tests of forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) using a Quark pulmonary function test were carried out on 312 healthy participants (150 males [mean age: 19.29±1.72 years] and 162 females [mean age: 19.05±1.17 years]). The pulmonary function of male students was related to right-handedness, left-handedness, and back strength, and the pulmonary function of female students was related to all basic PF. The pulmonary function of male students was related to all PA variables, whereas the pulmonary function of female students was related to middle-intensity PA. The findings of this study suggest that male students need to increase

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PA, and female students need to improve basic PF to sustain a healthy pulmonary function. Understand gender differences for pulmonary function-related factors and the gender-specific educational efforts are needed to improve and maintain pulmonary capacity in college students.

Keywords : body composition, forced expiratory volume in one second, forced vital capacity, gender difference, pulmonary function test

요 약 : 본 연구의 목적은 한국 대학생들의 기초체력과 신체활동량이 폐기능과 상관관계가 있는지를 분석하고, 성별에 따른 차이를 검증하는데 있다. 건강한 참여자 312명(남성 150명[평균연령: 19.29±1.72세], 여성 160명[평균연령: 19.05±1.17세])은 신체조성, 기초체력, 신체활동량 설문지, 그리고 노력성폐활량(FVC)과 1초간 강제호기량(FEV1)의 폐기능 검사를 수행하였다. 연구결과, 남학생의 폐기능은 우악력과 좌악력, 그리고 배근력과 관련이 있었고, 여학생의 폐기능은 모든 기초체력 하위 요인과 관련이 있었다. 또한 여성의 폐기능은 중강도 신체활동량과 관련이 있는 반면 남성의 폐기능은 신체활동량의 모든 하위 요인과 관련이 있었다. 본 연구의 주요 발견은 폐기능을 개선하기 위해서 남학생은 신체활동량을 증가시키고, 여학생은 기초체력을 향상시킬 필요가 있음을 제안한다. 대학생들의 폐기능을 유지하고 개선시키기 위해서는 폐기능 관련 인자에 대한 성별의 차이를 이해하고, 성별에 맞는 교육적 노력이 필요할 것이다.

주제어 : 신체조성, 1초간 강제호기량, 노력성폐활량, 성차, 폐기능 검사

1. Introduction

Chronic obstructive pulmonary disease (COPD) is a heterogeneous disease which is a leading cause of mortality [1], and is associated with a high economic burden worldwide [2]. Risk factors, including smoking, advanced age, biomass fuels [3,4], occupational dust, socio-economic status, respiratory infections, pulmonary tuberculosis, and asthma, have been suggested to contribute to the development of COPD [5]. The burden of COPD is expected to increase in the coming decades due to an aging population and longer exposure to COPD risk factors such as smoking and air pollution [6].

Pulmonary function test (PFT) is the most frequently used method to assess pulmonary function in patients with chronic lung disease. As PFT is a noninvasive tool for the evaluation of respiratory status [7]. The measurement of forced vital capacity (FVC) and forced expiratory flow in 1 sec (FEV1) by PFT is standard practice in the fields of occupational health and sports sciences [8]. A progressive decline in lung function is the hallmark of COPD and it is also possible that a normal decline in FEV1 can lead to COPD [9,10].

Physical activity (PA) is well known to have a protective effect against chronic diseases. Lack of PA is a major factor that contributes to the development of COPD and associated mortality [11]; a lower risk of hospital admissions and mortality has been seen in COPD patients with higher PA levels [12]. PA could be used therapeutically for patients with COPD or asthma [13], and it is used already used as part of pulmonary rehabilitation for lung disease [14]. Along with PA, basic physical fitness (PF) is associated with pulmonary function. Previous studies have reported that pulmonary function is also associated with muscle strength such as handgrip strength [15] and Sargent jump [16]. Most studies have analyzed this relationship using handgrip strength measurement which is easily measured and evaluated. Therefore, analysis of various PF factors related to pulmonary function is required for early detection of pulmonary dysfunction at a pre-clinical stage of lung disease to prevent the occurrence of severe forms of COPD.

As the maintenance of pulmonary health is an important issue for modern society due to severe environmental pollution and the presence of fine dust in the environment, major factors related to pulmonary function are constantly being studied. Despite the need to improve or maintain pulmonary function in a healthy state to prevent lung disease, the associations, and differences between gender in healthy young people have not been studied.

Therefore, the purpose of this study was to analyze and determine whether the pulmonary function is related to basic PF and PA according to gender-specific effects in healthy college students. Our hypothesis is that there will be a relationship between pulmonary function and PF and PA according to the gender of healthy college students.

2. Materials and Methods

2.1. Study design and subjects

This study was an observational and cross-sectional study. The required sample size was calculated using the G-power version 3.1 Windows program (Kiel University, Kiel, Germany), based on a 0.25-point effect size (default), an alpha level of 0.05, and 70% power. 330 freshmen at the Dong-A University in Korea were initially enrolled in this study, but 18 of them were excluded (insufficient spirometry results: 4, underweight or obese: 12 subjects, common cold: 2 subjects). A total of 312 healthy young adults (150 males and 162 females) participated in this study. The inclusion criteria for participants were as follows: a) no chronic or acute disease, b) no respiratory disease or asthma, c) a history of respiratory and cardiovascular disease, d) a body mass index (BMI) in the normal range, e) non-smoker. Exclusion criteria for participants were as follows: a) chronic lung diseases such as COPD or asthma, b) underweight or obese (18.5 kg/m^2 >BMI >30 kg/m^2), c) respiratory tract infection symptoms during the experimental period. All participants were fully informed of the purpose and method of the study and gave their informed consent before inclusion in this study. All procedures of this study were conducted in accordance with the Declaration of Helsinki of 1975. Table 1. shows the characteristics of the subjects.

2.2. Pulmonary function examination

Pulmonary function examinations were conducted under standard laboratory conditions (temperature: 22~25° C, relative humidity: 55~60%). All the Spirometry tests were conducted by the same trained expert to exclude inter-observer variability according to the American Thoracic Society/European Respiratory Society guidelines. The participants were seated wearing a nose clip and were given sufficient explanation about instrument use. The pulmonary function parameters such as FVC and the forced expiratory volume in one second (FEV1) were assessed using a Quark PFT (Cosmed, Italy).

2.3. Body composition and basic physical fitness

Height, weight, BMI, and body fat (%) were measured using a body composition analyzer VENUS 5.5 (JAWON MEDICAL, Korea). Basic PF was measured as previously described [16]. Briefly, all participants conducted each equipment twice in the correct posture after a full explanation of how to use of each piece of equipment. Handgrip strength (GRIP-D Grip Strength Dynamometer, Takei, Japan) and lower back strength (Helmas Ⅲ lower back strength instrument, O2run, Korea) were measured to evaluate muscle strength. Sargent jump (Helmas Ⅲ Sargent Jump instrument, O2run, Korea) was used to evaluate muscle power. Sit and reach distance (Helmas III Trunk Forward Flexion instrument, O2run, Korea) was measured to evaluate flexibility, and blind single-leg standing time (Helmas Ⅲ Blind Single-Leg Stand instrument, O2run, Korea) was used to evaluate balance. Reaction time was evaluated by measuring the reaction speed at which a participant responded to a sudden sound and light using a Helmas III Reaction Time instrument (O2run, Korea) with 0.01 sec accuracy.

2.4. Physical activity questionnaire

The short form of the Korean version of the self-filled questionnaire formally recognized by the International Physical Activity Questionnaires (www.ipaq.ki.se) was used to analyze the amount of PA. Briefly, the amount of PA in the past week was calculated by the Metabolic Equivalent of Task score (METs, in minutes), based on PA time categorized as high-intensity, middle-intensity, and low-intensity. METs of the subjects are presented in Table 3.

2.5. Statistical analysis

The data were analyzed using the SPSS Statistics Version 24.0 (IBM Corp., NY, USA), and the results are presented as the mean ± standard deviation. Independent t-tests were performed to verify the differences between groups. The Pearson coefficient of correlation was used to analyze the association between parameters of pulmonary function and the other variables. Statistical significance was considered as $p < 0.05$ in all tests.

3. The Results

3.1. Characteristics of the subjects

The age of the participants was 19.17±1.46 (male; 19.29±1.72, female; 19.05±1.17) years of age. The characteristics of the subjects are shown in Table 1. All parameters relating to body composition were significantly different between genders. Male students had a significantly higher height (male; 175.48±5.72 cm, female; 163.26±5.53 cm, $p < 0.001$), weight (male; 68.28±8.36 kg, female; 55.41±6.48 kg, $p < 0.001$), BMI (male; 22.14±2.18 kg/m2, female; 20.78±1.98 kg/m2, $p < 0.001$), muscle mass (male; 52.01±4.72 g, female; 38.15±3.55 g, $p < 0.001$), lean body mass (male; 55.99±5.14 g, female; 41.33±3.88 g, $p < 0.001$), but body fat of the male students was significantly lower than that of the female students (male; 12.30±4.44 g, female; 14.08±3.41 g, $p < 0.001$).

Table 1. Characteristics of the subjects

Variable	Total (n=312)	Male (n=150)	Female (n=162)	t	df	p
Age (years)	19.17±1.46	19.29±1.72	19.05±1.17	1.452	260.27	.167
Height (cm)	169.13±8.30	175.48±5.72	163.26±5.53	19.19	310	.000
Weight (kg)	61.60±9.84	68.28±8.36	55.41±6.48	15.12	280.39	.000
BMI (kg/m^2)	21.44±2.18	22.14±2.18	20.78±1.98	5.791	310	.000
Body fat (g)	13.22±4.03	12.30±4.44	14.08±3.41	-3.96	279.30	.000
Muscle (g)	44.81±8.08	52.01±4.72	38.15±3.55	29.13	275.99	.000
LBM (g)	48.38±8.62	55.99±5.14	41.33±3.88	28.24	276.38	.000
FVC (L)	3.88±0.92	4.62±0.66	3.19±0.48	21.60	271.26	.000
%FVC (predicted)	85.95±11.01	88.58±11.40	83.51±10.08	4.17	310	.000
FEV1 (L)	3.60±0.94	4.28±0.66	2.96±0.69	17.15	310	.000
%FEV1 (predicted)	91.03±12.16	95.36±11.95	87.01±10.94	6.44	310	.000

Data are presented as means ± SD. BMI; body mass index, LBM; lean body mass, FVC; forced vital capacity, FEV1; forced expiratory volume in 1 second

All parameters of pulmonary function were also significantly different between genders. Male students had a significantly higher FVC (male; 4.62±0.66-liter, female; 3.19±0.48 liter, $p < 0.001$), %FVC (male; 88.58±11.40%, female; 83.51±10.08%, $p < 0.001$), FEV1 (male; 4.28±0.66 liter, female; 2.96±0.69 liter, $p < 0.001$), and %FEV1 (male; 95.36±11.95%, female; 87.01±10.94%, $p < 0.001$).

3.2. Gender differences in basic physical fitness and physical activity

Table 2. shows the differences in basic PF between genders. All parameters of basic PF were significantly different between genders. Male students had a significantly higher right handgrip strength (male; 41.22±7.13 kg, female; 24.57±4.65 kg, $p < 0.001$), left handgrip strength (male; 39.69±7.89 kg, female; 23.11±4.63 kg, $p < 0.001$), lower back strength (male; 110.65±26.29 kg, female; 56.53±16.93 kg, $p < 0.001$), Sargent jump height (male; 49.87±10.75 cm, female; 30.18±8.02 cm, $p < 0.001$), but sit and reach distance (male; 10.37±9.82 cm, female; 12.73±9.54 cm, $p < 0.05$), and reaction time (male; 0.25±0.08 s, female; 0.33±0.11 s, $p < 0.001$) of the male students was significantly lower than that of the female students.

Table 3. shows the differences in physical activity between gender. Male students had a significantly higher in total physical activity (male; 3353.37±2946.26 METs, female; 2127.62±2215.92 METs, $p < 0.001$) and high-intensity physical activity (male; 1488.53±1913.12 METs, female; 512.10±1138.92 METs, $p < 0.001$). Middle-intensity physical activity (male; 663.20±1095.99 METs, female; 495.56±847.46 METs, $p = 0.130$) and low-intensity physical activity (male; 1201.64±1204.58 METs, female; 1119.96±1217.78 METs, $p = 0.595$) does not differentiate between gender.

3.3. Correlation between pulmonary function and basic physical fitness

Table 4. shows the results of the correlation analysis between pulmonary function and basic PF. While the pulmonary function of male students was related to right handgrip strength, left handgrip strength, and lower back strength, the pulmonary function of female

Table 2. Gender differences in basic physical fitness

Variable	Total (n=312)	Male (n=150)	Female (n=162)	t	df	p
Right handgrip strength (kg)	32.57±10.25	41.22±7.13	24.57±4.65	24.23	253.18	.000
Left handgrip strength (kg)	31.08±10.48	39.69±7.89	23.11±4.63	22.40	236.86	.000
Lower back strength (kg)	82.55±34.83	110.65±26.29	56.53±16.93	21.43	251.18	.000
Sit and reach distance (cm)	11.60±9.73	10.37±9.82	12.73±9.54	-2.15	310	.032
Sargent jump height (cm)	39.64±13.63	49.87±10.75	30.18±8.02	18.22	274.66	.000
Reaction time (sec)	0.29±0.11	0.25±0.08	0.33±0.11	-6.96	286.85	.000

Data are presented as means ± SD.

Table 3. Gender differences in physical activity

Variable	Total (=312)	Male (n=150)	Female (n=162)	t	df	p
Total (METs)	2741.26±2655.54	3353.37±2946.26	2127.62±2215.92	4.128	275.909	.000
High-intensity (METs)	996.14±1631.55	1488.53±1913.12	512.10±1138.92	5.424	239.02	.000
Middle-intensity (METs)	585.30±970.95	663.20±1095.99	495.56±847.46	1.518	310	.130
Low-intensity (METs)	1159.83±1202.27	1201.64±1204.58	1119.96±1217.78	0.595	310	.552

Data are presented as means ± SD. METs; Metabolic Equivalent of Task score.

Table 4. Correlation between pulmonary function and basic physical fitness

	Variable	FVC	FEV1	%FVC	%FEV1
Male	Right handgrip strength	.304***	.367***	.241**	.294***
	Left handgrip strength	.294***	.354***	.229**	.300***
	Lower back strength	.280**	.251**	.211**	.212**
	Sit and reach distance	.149	.156	.152	.170*
	Sargent jump height	.024	.064	.002	.029
	Reaction time	-.093	-.052	-.064	-.083
Female	Right handgrip strength	.319***	.225**	.194*	.257**
	Left handgrip strength	.300***	.246**	.171*	.218**
	Lower back strength	.383***	.312***	.260**	.307***
	Sit and reach distance	.262**	.085	.300***	.257**
	Sargent jump height	.276***	.151	.211**	.270**
	Reaction time	-.147	-.082	-.174*	-.158*

FVC; forced vital capacity, FEV1; forced expiratory volume in 1 second. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

students was related to all basic PF.

Right handgrip strength was significantly correlated with FVC (male; r=.304, p<.001, female; r=.319, p < 0.001), FEV1 (male; r=.367, p < 0.001, female; r=.225, p < 0.01), %FVC (male; r=.241, p < 0.01, female; r=.194, p < 0.05), and %FEV1 (male; r=.294, p < 0.001, female; r=.257, p < 0.01). Left handgrip strength significantly correlated with FVC (male; r=.294, p < 0.001, female; r=.300, p < 0.001), FEV1 (male; r=.354, p < 0.001, female; r=.246, p < 0.01), %FVC (male; r=.229, p < 0.01, female; r=.171, p < 0.05), and %FEV1 (male; r=.300, p < 0.001, female; r=.218, p < 0.01). Lower back strength significantly correlated with FVC (male; r=.290, p < 0.01, female; r=.383, p < 0.001), FEV1 (male; r=.251, p < 0.01, female; r=.312, p < 0.001), %FVC (male; r=.211, p < 0.01, female; r=.260, p < 0.01), and %FEV1 (male; r=.212, p < 0.01, female; r=.307, p < 0.001). Sit and reach distance significantly correlated with FVC (female; r=.262, p < 0.01), %FVC (female; r=.300, p < 0.001), and %FEV1 (male; r=.170, p < 0.05, female; r=.257, p < 0.01). Sargent jump height significantly correlated with FVC (female; r=.276, p < 0.001), %FVC (female; r=.211, p < 0.01), and %FEV1 (female; r=.270, p < 0.01). Reaction time significantly correlated with %FVC (female; r=-.174, p < 0.05), and %FEV1 (female; r=-.158, p < 0.05).

3.4. Correlation between pulmonary function and physical activity

Table 5. shows the results of the correlation analysis between pulmonary function and PA. While the pulmonary function of male students was related to all PA variables, the pulmonary function of female students was hardly relevant to variables of PA. FVC significantly correlated with total PA (male; r=.319, p < 0.001), high-intensity PA (male; r=.235, p < 0.01), middle-intensity PA (male; r=.236, p < 0.01, female; r=.160, p < 0.05), and low-intensity PA (male; r=.193, p < 0.05). FEV1 significantly correlated with total PA (male; r=.243, p < 0.01) and middle-intensity PA (male; r=.228, p < 0.01). %FVC significantly correlated with total PA (male; r=.296, p < 0.001), high-intensity PA (male; r=.212, p < 0.001), middle-intensity PA (male; r=.229, p < 0.01), and low-intensity PA (male; r=.180, p < 0.05). %FEV1 significantly correlated with total PA (male; r=.293, p < 0.001), high-intensity PA (male; r=.198, p < 0.05), middle-intensity PA (male; r=.251, p < 0.01), and low-intensity PA (male; r=.174, p < 0.05).

Table 5. Correlation between pulmonary function and physical activity

	Variable	FVC	FEV1	%FVC	%FEV1
Male	Total (METs)	.319***	.243**	.296***	.293***
	High-intensity (METs)	.235**	.158	.212**	.198*
	Middle-intensity (METs)	.236**	.228**	.229**	.251**
	Low-intensity (METs)	.193*	.135	.180*	.174*
Female	Total (METs)	.116	.120	.038	.049
	High-intensity (METs)	.110	.034	.045	.017
	Middle-intensity (METs)	.160**	.148	.114	.099
	Low-intensity (METs)	-.002	.084	-.053	.004

METs; Metabolic Equivalent of Task score. *p < 0.05, **p < 0.01, ***p < 0.001

4. Discussion

Absolute pulmonary function parameters decrease with age in asymptomatic adults, and the deteriorating environment in modern society increases the importance of protecting pulmonary function. Since the decline in absolute and relative pulmonary function can be accelerated with age [17], methods to maintain and improve pulmonary function in young adults are required. Therefore, this study analyzed whether the pulmonary function was related to basic PF and PA in healthy college students and identified gender-specific differences. The main findings of this study were that the subcomponents of basic PF were highly related to the pulmonary function of female students, and the PA levels were highly related to the pulmonary function of male students.

Basic PF is a representative index of the overall health state of an individual and is widely used regardless of age. A previous study reported that boys showed higher aerobic fitness, strength, and speed, but girls had better flexibility [18]. Another study also reported that excluding the Sit and Reach test, men scored higher in the Course-Navette test, the Horizontal Jump test, and the 20-meter run test than women [19]. In this study, as a result of analyzing basic fitness with respect to gender, men had a higher handgrip strength, lower back strength, Sargent jump height, and reaction time than women, but women were more flexible than male students. The reason for the difference in PF between men and women may suggest physiological differences between men and women, which may provide a disadvantage to physical performance in women [20]. Since the underlying basic PF subcomponents in this study were muscular strength, muscle power, agility and flexibility, the gender differences in skeletal muscle and body fat, may be underly these results. Previous studies reported that lower levels of basic PF were partially explained by lower skeletal muscle mass [21], and the influence factors of fitness differences between men and women were high levels of body fat [22] and a more sedentary lifestyle [23]. This is explained by the differences in the high-intensity PA levels in this study.

In this study pulmonary function was correlated with muscle strength regardless of gender, but additionally correlated to flexibility, balance, and accuracy only in female students. We and other researchers have previously demonstrated that pulmonary function is associated with muscle strength [15,16,24] and power [25]. As subjects with reduced skeletal muscle mass may have a weakened ability to inflate and contract the lungs, reduced skeletal muscle mass was independently associated with low levels of FEV1 and FVC [26]. Therefore, this finding suggests that muscle strength and muscle mass are associated with pulmonary function. In addition, pulmonary function in female students in this study was further associated with flexibility and agility. These results suggest that further studies are needed on the relationship between female pulmonary function and these variables.

There are normal gender differences in PA levels, and in almost all studies of various ages, men have a higher PA than women [27,28]. Barnekow-Bergkvist et al. analyzed changes in PA participation patterns from children to adults and found more boys than girls at the age of 16, participated in leisure sports activities. However, when the same participants were reviewed in adulthood, there was no gender difference in overall PA, but men tended to participate in more intense PA [31]. Another study reported no gender differences in low-intensity PA, because women also participate in walking exercise and housework at an equivalent level to men [32]. Similar to previous studies, we have shown men have a significantly higher total PA and high-intensity PA than females, but there was no difference in middle- and low-intensity PA levels. In our study, we did not analyze the causes of differences in PA levels by gender, but additional studies analyzing these would be interesting.

We found pulmonary function in male students was related to all subcomponents of PA. High levels of PA were associated with improved pulmonary function [33], and slower age-related decline of pulmonary function in healthy adults [34,35]. Lack of regular physical exercise is an important factor contributing to COPD development and mortality [11,36], and the pulmonary capacity index improves after an exercise intervention in young adults [37]. However, there was little correlation between PA levels and pulmonary function of female students in this study. These different results may be due to the nature of the female participants tested here, which is a limitation of the study in which we did not confirm this. College students are easily exposed to unhealthy behaviors and habits [38,39], and compared to male students, female students' lifestyle characteristics may have reduced PA levels, so additional research is needed to analyze this.

Our study has several strengths and potential limitations. The strength of this study is that it evaluated the pulmonary function of healthy young adults and identified the difference in the pulmonary function of gender-specific according to PA and PF ability. We believe that our finding that PA level and basic PF ability are related to COPD development is robust. This study has some limitations. Data concerning PA were purely based on a self-reporting questionnaire, with no objective confirmation using a direct measurement of PA. Therefore, PA may have been exaggerated or reduced depending on the disposition of the subjects. Another limitation is that other factors that could affect basic PF, PA, and pulmonary function were not investigated. Additional studies on the psychological state, nutritional status, and lifestyle of the characteristics may be required to evaluate these related factors.

5. Conclusion

In summary, the results of this study showed that pulmonary function was highly related to basic PF in female students and PA in male students. Therefore, the findings of this study suggest that male students need to increase PA, and female students need to improve basic PF to improve and maintain healthy pulmonary function. Understand gender differences for pulmonary function-related factors and the gender-specific educational efforts is needed to improve pulmonary capacity in college students.

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