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Original Article

Correlation between basic physical fitness and pulmonary function in Korean children and adolescents: a cross-sectional survey

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Abstract. [Purpose] The purpose of the present study was to determine whether there was a correlation between basic physical fitness and pulmonary function in Korean school students, to present an alternative method for improving their pulmonary function. [Subjects and Methods] Two hundred forty healthy students aged 6–17 years performed physical fitness tests of hand-grip strength, sit and reach, Sargent jump, single leg stance, and pulmonary function tests of forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) using a Quark PFT. [Results] Muscle strength and power of boys improved in the late period of elementary school and middle school. Muscle strength of girls improved in the late period of elementary school. Analysis of factors affecting pulmonary function revealed that height, weight, BMI, and body fat significantly correlated with spirometric parameters. Right hand-grip strength, left hand-grip strength, and Sargent jump also significantly correlated with FVC and FEV1. [Conclusion] In order to improve the pulmonary function of children and adolescents, aerobic exercise and an exercise program to increase muscle strength and power is needed, and it should start in the late period of elementary school when muscle strength and power are rapidly increasing.
Key words: Body composition, Basic physical fitness, Pulmonary function

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INTRODUCTION

Many problems occur while we are trying to improve the quality of life and material wealth by the development of modern society. Among them, air pollution is a serious problem in western and developing countries. Long-term exposure to air pollution has a high correlation with the incidence of cardiovascular disease, respiratory diseases, and diabetes[1–3)], threatening health. In particular, air pollution is a major cause of respiratory diseases such as asthma and allergic diseases[4, 5)] and it has a negative effect on the healthy growth and development of growing children and adolescents.

Another problem caused by the development of modern society is the reduction in physical activity across all generations throughout the world. The time spent in physical activity by children has decreased significantly compared to before[6, 7)]. The time spent using visual media and watching TV has increased[8, 9)], and physical inactivity due to excessive academic pressure and the influence of parents[10)], has increased obesity, incorrect posture, and muscle weakness. In addition, energy consumption has increased due to environmental, metabolic, and genetic factors[11)]. Thus, children living in modern society are showing gradually decreasing physical fitness.

The change in the environment due to the development of modern society is a threat to the health of growing children. According to the Korea Education Development Institute, respiratory system abnormalities have been much higher than those other systems over the last three years. Reduced basic physical fitness and reduced pulmonary functions are seriously threating the physical development of Korean elementary, middle, and high school students.

Although the physical fitness and lung health of growing children and adolescents is threatened, some studies have reported a relationship between air pollution and pulmonary function[12, 13)]. However, there has been insufficient research on the relationship between exercise and lung function. Most studies on exercise have only suggested lung function is improved by regular exercise[14, 15)]. The present study is to our knowledge the first to investigate the relationship between basic physical fitness and lung function.

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The purpose of the present study was to determine the relationship between basic physical fitness and pulmonary function in healthy Korean school students to enable us to present an alternative method for improving their pulmonary function.

SUBJECTS AND METHODS

A total 240 healthy children and adolescents aged 6–17 years who lived in Busan in Korea were recruited for the present study. The participants had a body mass index (BMI) < 25 kg/m^2, and no respiratory system abnormalities. The sample comprised 20 healthy students (10 boys and 10 girls) of each age from 6 to 17. The participants who did not meet the BMI criteria or who showed significantly low pulmonary test values were excluded, and replacements were recruited in order to conduct the analysis with the same numbers of subjects. The participants were divided into the early period of elementary school (6–8 y), the late period of elementary school (9–11 y), the period of middle school (12–14 y), and the period of high school (15–17 y) in order to investigate the rapid changes in body composition and basic physical fitness with growth. All participants gave their informed consent and the experimental protocol was approved by the Ethical Committee of Dong-A University.

Body composition including height, weight, BMI, and body fat (%) was measured using a body composition analyzer VENUS 5.5 (JAWON MEDICAL, Korea) while subjects were fully relaxed. Muscle strength, muscle power, flexibility, and balance were measured to evaluate basic physical fitness. All participants were given a full explanation about the correct posture and procedure of each measurement. Two measurements were conducted and the average value was calculated. Hand-grip strength was evaluated using a GRIP-D Grip Strength Dynamometer (Takei, Japan) with 0.1 kg accuracy of both the right and left hands. Flexibility was evaluated by measuring sit and reach using a Helmas III Trunk Forward Flexion instrument (O2run, Korea) with 0.1 cm accuracy. Muscle Power was evaluated by measuring the Sargent jump height using a Helmas III Sargent Jump instrument (O2run, Korea) with 0.1 cm accuracy. Balance was evaluated by measuring the eyes-closed single-leg standing time using a Helmas III Blind Single-Leg Stand instrument (O2run, Korea) with 0.1 sec accuracy, and the participants performed the test using their preferred leg.

Pulmonary function tests were conducted under standard laboratory conditions (temperature: 22–25 °C, relative humidity: 55–60%). All spirometric tests were conducted by the same technician to reduce inter-observer variability and to prevent the failure of the measurement due to the young age of the subjects. The participants were given sufficient explanation about the method and instrument use, and the tests were performed in a sitting position while wearing a nose clip. The forced vital capacity (FVC) and the forced expiratory volume in one second (FEV1) were measured using a Quark PFT (Cosmed, Italy). All of the pulmonary tests were conducted following the standards presented by the American Thoracic Society/European Respiratory Society[16].

The data were analyzed using the Statistical Package for the Social Sciences (SPSS version 22.00) and the results are presented as the mean ± standard deviation. The significance of differences between boys and girls were examined using the independent t-test. The differences within groups were determined using one-way ANOVA. Pairwise comparisons were performed using Duncan's test. The relationships between body composition and pulmonary function, and basic physical fitness and pulmonary function were analyzed using simple linear regression analysis. Significance was accepted for values of $p < 0.05$ in all tests.

RESULTS

Table 1 shows the differences in body composition between groups (gender and age) and within groups. Height was significantly different in the early period of elementary school (boys: $p<0.01$, girls: $p<0.001$) and the late period of elementary school ($p<0.001$ for both boys and girls). Weight was significantly different in the periods of early and late elementary and middle school for boys ($p<0.05$), and in the periods of early and late elementary school for girls ($p<0.01$).

Table 2 shows the differences in basic physical fitness and pulmonary function between and within groups. For boys, right and left hand-grip strength were significantly different in the late period of elementary school (right: $p<0.001$, left: <0.05) and middle school ($p<0.01$). The Sargent jump height was only significantly different in the late period of elementary school ($p<0.01$) for boys. In the case of girls, right and left hand-grip strength significantly different in the late period of elementary school ($p<0.01$), and the sit and reach distance was significantly different in the early period of elementary school ($p<0.01$). For boys, FVC was significantly different in the late period of elementary school and middle school ($p<0.05$), and FEV1 was significantly different only in the late period of elementary school ($p<0.05$), and for girls, FVC and FEV1 were significantly different in the late period of elementary school ($p<0.05$).

Table 3 shows the results of the simple linear regression analysis that was performed for FVC and FEV1 against height, weight, BMI, and body fat (%). For boys, FVC significantly correlated with height ($r^2=0.827$, $p<0.001$), weight ($r^2=0.677$, $p<0.001$), BMI ($r^2=0.168$, $p<0.001$), and percent body fat ($r^2=0.048$, $p<0.05$) in descending order. FEV1 significantly correlated with height ($r^2=0.758$, $p<0.001$), weight ($r^2=0.658$, $p<0.001$), and BMI ($r^2=0.144$, $p<0.001$); however, there was no significant correlation with percent body fat ($r^2=0.037$, $p=0.077$). In the case of girls, FVC significantly correlated with height ($r^2=0.756$, $p<0.001$), weight ($r^2=0.728$, $p<0.001$), BMI ($r^2=0.455$, $p<0.001$), and percent body fat ($r^2=0.392$, $p<0.001$) in descending order. FEV1 significantly correlated with height ($r^2=0.764$, $p<0.001$), weight ($r^2=0.733$, $p<0.001$), BMI ($r^2=0.462$, $p<0.001$), and percent body fat ($r^2=0.400$, $p<0.001$) in descending order.

The results of the comparison between boys and girls revealed that height and weight were similarly correlated. However, BMI (FVC: 0.455 vs. 0.168, FEV1: 0.462 vs. 0.144) and percent body fat (FVC: 0.392 vs. 0.048, FEV1: 0.400 vs. 0.037) showed higher correlations with pulmonary function in girls than in boys.

Table 4 shows the results of the simple linear regression

Table 1. The differences in body composition between groups (gender and age) and within group (n=240)

Groups	Age (yrs)	Height (cm)		Weight (kg)		BMI (kg/m^2)		Body fat (%)	
		Male	Female	Male	Female	Male	Female	Male	Female
Period of early elementary school	6	123.7± 4.43	121.6± 4.96	24.8± 4.56	22.9± 3.48	16.1± 2.04	15.4± 1.74	8.9± 3.01	13.0± 5.06
	7	127.7± 4.66	126.2± 3.97	28.8± 4.37	26.2± 5.07	17.6± 2.20	16.4± 2.61	9.6± 4.42	16.5± 3.61
	8	133.0± 4.57	133.9± 5.46	31.7± 6.67	30.8± 5.41	17.8± 2.91	17.2± 2.43	10.5± 6.17	17.9± 3.46
		1,2<3**	1<2<3***	1<3*	1,2<3**				
Period of late elementary school	9	137.3± 4.62	139.6± 5.71	35.9± 7.76	34.8± 6.77	18.9± 3.18	17.6± 2.23	13.1± 5.96	17.8± 4.51
	10	143.9± 5.80	147.1± 9.42	45.2± 11.92	36.8± 10.11	21.6± 4.12	16.7± 2.88	18.2± 7.80	17.0± 4.76
	11	155.5± 6.65	154.5± 2.86	48.2± 11.59	46.8± 6.14	19.9± 3.99	19.6± 2.20	14.7± 3.82	21.4± 5.17
		1<2<3***	1<2<3***	1<3*	1,2<3**				
Period of middle school	12	164.9± 6.43	158.3± 4.91	49.3± 10.83	47.4± 6.95	19.5± 2.97	18.9± 2.59	13.1± 8.47	20.4± 4.08
	13	165.9± 3.41	159.1± 3.30	55.1± 11.12	50.8± 6.45	20.0± 3.93	20.3± 2.16	12.8± 7.60	21.0± 5.81
	14	169.6± 5.17	158.0± 3.08	64.9± 10.91	53.2± 5.44	21.7± 1.79	21.3± 2.07	16.8± 3.97	21.1± 6.40
				1,2<3*					
Period of high school	15	176.5± 7.30	164.1± 3.81	60.3± 7.92	58.6± 2.24	19.3± 1.49	21.8± 1.53	11.5± 4.81	26.1± 2.94
	16	174.3± 5.63	162.5± 5.80	57.6± 3.54	53.1± 5.87	20.6± 0.57	20.0± 1.45	14.7± 3.00	24.2± 2.36
	17	172.8± 4.01	163.1± 5.01	62.4± 8.18	57.0± 5.32	20.9± 2.38	21.4± 1.57	15.5± 5.83	26.1± 2.06

Values represent means ± SD. BMI: Body Mass Index. *: significant difference within group (* p<0.05, ** p<0.01, *** p<0.001)

analysis that was performed for FVC and FEV1 against right hand-grip strength, left hand-grip strength, sit and reach distance, Sargent jump height, and single-leg standing time. For boys, both FVC and FEV1 showed high correlations with right hand-grip strength (r^2=0.774, r^2=0.794, p<0.001), left hand-grip strength (r^2=0.747, r^2=0.762, p<0.001), Sargent jump height (r^2=0.573, r^2=0.584, p<0.001), and single-leg standing time (r^2=0.058, r^2=0.048, p<0.05) in descending order. In the case of girls, both FVC and FEV1 showed high correlations with right hand-grip strength (r^2=0.619, r^2=0.652, p<0.001), left hand-grip strength (r^2=0.607, r^2=0.641, p<0.001), and Sargent jump height (r^2=0.129, r^2=0.121, p<0.01) in descending order, whereas the sit and reach distance and single-leg standing time showed no significant correlations.

The results of boys and girls were similarly in descending order. However, basic physical fitness parameters were more highly correlated with pulmonary function for boys than for girls, especially the Sargent jump height (FVC: 0.573 vs. 0.129, FEV1: 0.584 vs. 0.121).

DISCUSSION

The purpose of this study was to determine the relationship between basic physical fitness and pulmonary function in healthy Korean school students, in order to present an alternative method for improving their pulmonary function.

An investigation of the development of Korean students was conducted by the Ministry of Education in 2014. The Ministry surveyed 82,581 elementary, middle, and high school students. The results show that boys grow 5–6 cm per year from an average height of 121.5 cm in the first grade of elementary school. The biggest growth was found among 6th grade elementary school students and 1st grade middle school students. After that, the amount of growth gradually reduced. Girls grow around 6 cm per year from an average height of 120.3 cm in the first grade of elementary school. Their degree of growth decreases rapidly after 6th grade elementary school compared to boys. Body weight of boys showed the biggest differences between the first and second grades of middle school (5.9 kg), and between the 5th and 6th grades of elementary school among girls (5.5 kg). The results of the present study show that the height of both boys and girls rapidly increased in the elementary school period. However, weight dramatically increased in the period of elementary school and middle school among boys, and in the period of elementary school among girls. The growth of children and adolescents who participated in this study seems to be representative of Korean children and adolescents since the results appear to be similar to the findings of the Ministry of Education. However, BMI was somewhat different since we selected healthy students, excluding obese children as subjects.

Basic physical fitness is closely related to health. Especially, it has a negative correlation with the prevalence of obesity[17], hypertension[18], and cardiovascular disease[19]. In this respect, the Korean government has implemented the Physical Activity Promotion System (PAPS) in order to systematically measure the physique and fitness, as well as to prescribe physical activity for individuals, highlighting the need of regular exercise. However, accurate measurement, evaluation, and prescription of exercise seem insufficient. In the present study, basic physical fitness was measured using the correct postures and methods by a fully trained technician. Muscle strength increased sharply in the late period of elementary and middle school in boys, and in the late period of elementary school in girls. In addition, muscle power of boys increased sharply only in the late period of elementary school.

Pulmonary function was reported as being correlated with age[20, 21], in addition, height, weight, area of body surface, percent body fat, smoking status, and residential

Table 2. The differences in basic physical fitness between groups (gender and age) and within group (n=240)

Groups		Age (yrs)	Basic physical fitness					Pulmonary function	
			Right hand grip (kg)	Left hand grip (kg)	Sit and reach (cm)	Sargent jump (cm)	Single-leg stance (sec)	FVC (L)	FEV1 (L)
Boys	Period of early elementary school	6	8.4±2.50	8.8±1.95	4.7±5.28	23.2±3.80	8.4±6.07	1.36±0.32	1.30±0.20
		7	10.6±2.36	10.5±2.67	8.0±5.83	26.6±4.56	15.9±11.37	1.73±0.45	1.54±0.40
		8	9.3±2.60	10.9±2.59	4.4±4.82	26.0±2.59	10.9±7.18	1.84±0.35	1.72±0.44
	Period of late elementary school	9	12.5±1.47	14.1±3.32	5.6±6.35	28.1±3.69	25.8±19.00	2.00±0.38	1.85±0.41
		10	17.8±2.75	17.0±2.76	5.6±6.72	30.1±5.65	44.2±24.67	2.55±0.44	2.22±0.32
		11	19.1±4.10	18.7±3.89	7.9±9.17	38.5±6.59	33.1±18.67	2.59±0.53	2.39±0.53
			1<3***	1<2,3*		1,2<3**		1<2,3*	1<3*
	Period of middle school	12	20.9±7.52	21.8±9.11	2.2±9.62	38.5±5.52	26.3±17.33	3.43±0.70	3.19±0.62
		13	26.6±4.30	29.9±4.38	5.2±7.61	41.2±6.56	26.2±22.53	3.54±0.56	3.53±0.29
		14	36.6±9.39	37.9±7.13	7.8±9.11	45.3±5.75	30.8±13.51	4.27±0.49	3.84±0.51
			1<2,3**	1,2<3**				1,2<3*	
	Period of high school	15	31.9±6.12	32.6±7.11	7.0±5.63	43.6±4.41	31.4±25.80	4.18±0.65	4.01±0.57
		16	36.3±0.35	38.5±0.85	12.1±2.25	43.5±0.50	52.5±6.50	4.60±0.72	4.39±0.66
		17	36.8±3.04	38.3±2.86	11.5±9.51	47.6±9.82	36.4±22.78	4.12±0.70	3.85±0.65
Girls	Period of early elementary school	6	7.7±1.87	8.5±2.05	9.4±3.31	22.1±4.14	11.1±7.90	1.46±0.26	1.23±0.21
		7	8.8±1.58	9.2±1.95	10.8±3.78	25.9±6.09	16.3±15.78	1.43±0.27	1.31±0.27
		8	9.3±1.82	9.3±3.45	6.1±3.75	25.0±3.13	4.3±2.09	1.66±0.28	1.57±0.28
					3<1*				
	Period of late elementary school	9	10.2±3.03	10.9±3.22	6.4±6.23	27.9±4.42	23.9±17.79	1.83±0.41	1.58±0.31
		10	12.7±2.68	13.8±4.00	9.8±8.54	30.0±4.83	29.6±21.72	2.04±0.59	1.93±0.53
		11	16.8±3.53	17.4±3.99	10.8±7.40	30.4±8.67	35.4±22.81	2.54±0.39	2.33±0.34
			1<3***	1,2<3**				1<3*	1<3*
	Period of middle school	12	18.9±2.55	20.0±1.93	13.4±8.53	33.6±5.85	12.6±5.73	2.63±0.44	2.49±0.37
		13	21.7±4.83	22.6±4.83	10.3±8.73	29.8±2.57	27.8±20.37	2.61±0.32	2.58±0.24
		14	20.1±2.70	21.7±3.63	11.7±8.34	28.4±4.03	37.4±22.33	2.51±0.57	2.30±0.50
	Period of high school	15	23.6±2.42	25.5±3.99	10.9±11.31	29.8±7.80	23.3±19.16	2.78±0.37	2.68±0.37
		16	22.2±3.93	24.1±4.04	15.3±10.66	29.6±4.13	30.2±15.85	3.01±0.47	2.85±0.37
		17	20.2±3.23	23.0±3.41	10.3±11.70	28.9±5.05	24.7±6.58	2.92±0.21	2.81±0.16

Values represent means ± SD. FVC: Forced Vital Capacity, FEV1: Forced expiratory volume in 1 second.
: significant difference within group (p<0.05, ** p<0.01, *** p<0.001)

Table 3. The results of simple linear regression analysis between pulmonary function and body composition

		FVC	FEV1
		R^2	R^2
Boys	Height	0.827***	0.758***
	Weight	0.677***	0.658***
	BMI	0.168***	0.144***
	Body fat (%)	0.048*	0.037
Girls	Height	0.756***	0.764***
	Weight	0.728***	0.733***
	BMI	0.455***	0.462***
	Body fat (%)	0.392***	0.400***

* p<0.05, ** p<0.01, *** p<0.001

Table 4. The results of simple linear regression analysis between pulmonary function and basic physical fitness

	Variable	FVC	FEV1
		R^2	R^2
Boys	Right hand grip strength	0.774***	0.794***
	Left hand grip strength	0.747***	0.762***
	Sit and reach distance	0.042	0.039
	Sargent jump height	0.573***	0.584***
	Single-leg standing time	0.058*	0.048*
Girls	Right hand grip strength	0.619***	0.652***
	Left hand grip strength	0.607***	0.641***
	Sit and reach distance	0.020	0.015
	Sargent jump height	0.129**	0.121**
	Single-leg standing time	0.018	0.020

* p<0.05, ** p<0.01, *** p<0.001

environment also have effects on spirometry[22–25]. Height is a factor positively influencing lung function at all ages[26], whereas age and body fat mass sometimes have an inverse correlation in accordance with the age of subjects. The present study revealed that pulmonary function increased with age for subjects during the growth period. In addition, pulmonary function was influenced by height, weight, BMI, and percent body fat, in descending order. A recent study of Korean children showed that FVC increased with age. No difference was found between boys and girls. Height, area of body surface, and weight correlate with pulmonary function in descending order[27], a result which is consistent with the results of our present study. Girls showed higher correlation than boys between percent body fat and pulmonary function in the present study. However, the percent body fat showed slight or no correlation with pulmonary function for boys, a result which differs from those of previous studies. Rossi et al.[28] found that body fat and lung function showed an inverse correlation in obese female adults. Gonzalez-Barcala et al.[29] conducted a study of children aged 6 to 18 years whose BMI was under 30 kg/m^2. They suggested that lung function can be difference depending on individual differences. In the present study, subjects had normal weight and BMI < 25 kg/m^2. Park et al.[30] reported that it was difficult to explain the effects of BMI, percent body fat, and muscle mass on pulmonary function. Therefore, different results of pulmonary function could be occurred depending on the body composition of the individual subjects.

It is well known that regular aerobic exercise can positively change lung health[31–33]. Moreover, resistance exercise also has positive effects on lung health[34, 35]. Thus, aerobic exercise and resistance exercise are effective ways of improving lung function. Besides, recent studies have shown that muscle strength and respiratory function are correlated[36]. Hand-grip strength also affects the pulmonary function of healthy older adults[37]. Therefore, resistance exercise is also an effective method of improving pulmonary function. The present study revealed that pulmonary function is highly correlated with right hand-grip strength, left hand-grip strength, and Sargent jump height in descending order. Therefore, exercises for muscle strength and power could be effective at improving school students' pulmonary function.

In summary, in order to improve the pulmonary function of growing children and adolescents, aerobic exercise and exercise programs to increase muscle strength and power are needed, and they would be especially effective if they were to begin in the late period of elementary school when the muscle strength and power of students are rapidly increasing.

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