

ปริมาตรและสมรรถภาพปอดของวัยรุ่นชายในภาคตะวันออกเฉียงเหนือของประเทศไทย: เปรียบเทียบระหว่างนักเรียนโรงเรียนกีฬาจังหวัดขอนแก่นและโรงเรียนอื่นในจังหวัดขอนแก่น

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Lung Volume and Function in Male Adolescents in Northeast, Thailand: Students from Khon Kaen Sports School in Comparison with Other Schools in Khon Kaen Province

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หลักการและวัตถุประสงค์: การออกกำลังกายเป็นประจำอาจทำให้สมรรถภาพปอดเพิ่มขึ้นในวัยรุ่นชาย การศึกษานี้จึงมีวัตถุประสงค์เพื่อทดสอบสมมติฐานว่านักกีฬาชายจากโรงเรียนกีฬาจังหวัดขอนแก่นอาจมีสมรรถภาพปอดสูงกว่านักเรียนซึ่งมีนิสัยไม่ออกกำลังกาย (sedentary subject)

วิธีการ: ทำการวัดสมรรถภาพปอดในนักเรียนโรงเรียนกีฬาจังหวัดขอนแก่นซึ่งทำการฝึกซ้อมกีฬาประเภทต่างๆ 8 ชนิด จำนวน 293 ราย และนักเรียนโรงเรียนแก่นนครวิทยาลัยจำนวน 295 ราย ทั้งหมดมีอายุระหว่าง 13 - 19 ปี

ผลการศึกษา: พบว่านักกีฬาวัยรุ่นชายที่ออกกำลังกายเป็นประจำมีค่าสมรรถภาพปอดโดยการวัดอัตราการไหลออกของอากาศสูงสุด (PEF) อัตราการไหลออกของอากาศช่วงกึ่งกลางสูงสุด (FEF25-75%) อัตราการไหลออกของอากาศที่ร้อยละ 75, 50 และ 25 (FEF75%, FEF50%, FEF25%) ปริมาตรอากาศทั้งหมดที่เป่าออกอย่างแรงและเร็วที่สุด (FVC) ปริมาตรอากาศที่เป่าออกอย่างแรงและเร็วที่สุดใน 1 วินาทีแรก (FEV1) และดัชนีของ FVC และ FEV1 (FVCindex, FEV1index) สูงกว่านักเรียนซึ่งมีนิสัยนั่งอย่างมีนัยสำคัญทางสถิติ ($p < 0.001$) ประมาณร้อยละ 20

สรุป: ข้อมูลบ่งชี้ว่าค่าปริมาตรปอดในนักเรียนที่เล่นกีฬาจากโรงเรียนกีฬาขอนแก่นมีปริมาตรปอดสูงกว่าวัยรุ่นทั่วไป

Background and Objectives: Regular athletics or physical exercise may enhance dynamic lung volumes in male adolescents. This study aims to test the hypothesis that male adolescents from Khon Kaen Sports School would have greater dynamic lung volumes than sedentary subjects.

Methods: A pulmonary function test was collected on 293 males training in 8 different types of sports and on 295 sedentary persons, all of whom were between 13 and 19 years of age.

Results: The athletes showed approximately 20% greater peak expiratory flow rates (PEF), maximal mid expiratory flow (FEF25-75), forced expiratory flow at 75, 50 and 25 percent of the FVC (FEF75%, FEF50%, FEF25%), forced vital capacity (FVC), forced expiratory volume in the first second (FEV1) and their indices (FVCindex, FEV1index) compared to those of sedentary peers ($p < 0.001$).

Conclusions: The data indicate that students from Khon Kaen Sports School who engaged to regular exercise had greater lung volumes than their sedentary counterparts. In order to increase dynamic lung volumes, sports should be promoted among children and adolescents.

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ที่ไม่ออกกำลังกาย ดังนั้นควรส่งเสริมการเล่นกีฬาในเด็ก และวัยรุ่นเพื่อให้มีการเพิ่มสมรรถภาพปอด

คำสำคัญ: ปริมาตรปอด สมรรถภาพปอด วัยรุ่นชาย การออกกำลังกาย

Keywords: lung volume, lung function, male adolescents, exercise

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Introduction

Development of lung begins during prenatal life and childhood, after which it increases in size. Such development and its function are influenced by both purely genetic mechanisms and interactions between genes and environmental factors¹. The genetic influence is not well understood whereas multiple atmospheric pollutants have been related to genetic makeup and decreased lung function¹. Moreover, exposure to environmental insults during early life can lead to an alteration in lung development i.e. reduced lung function². Moreover, foetal nutrition is one of the factors implicated in the programming of the respiratory system that have been demonstrated^{3,4} and nutritional differences influence qualitative aspects of lung development in childhood beyond simple isotropic lung growth⁵. In fact, lung function and socioeconomic status, anthropometric, nutritional and environmental factors have been shown previously^{6,7}.

Apart from those factors mentioned earlier, enhanced and prolonged sports training during childhood and youth might protect against the respiratory problems of old age⁸. Reports indicate that regular physical activity reduces the risk of heart disease, diabetes and obesity in the rapidly growing population of Asian American immigrants⁹ and delays the decline in pulmonary function with age as seen at the 25-year follow-up¹⁰. Men who remain active have higher forced expiratory volume in the first second (FEV1) and forced vital capacity (FVC) than inactive and insufficiently active persons¹¹. Additionally, physical training helps improve lung function in children and adolescents with asthma^{12,13} such that the American College of Athletics

Medicine and the American Thoracic Society endorse a prescription for exercise to all asthmatic subjects¹⁴.

After 6 years of training young male swimmers, between 13 and 16 years of age, had greater total lung capacity (TLC), FVC, FEV1, functional residual capacity (FRC), residual volume (RV) and resting diffusing capacity of the lung for carbon monoxide (DLCO) than their untrained counterparts of a similar age¹⁵. Swimmers between 15 and 20 years of age had significantly higher FVC, FEV1 and peak expiratory flow rate (PEFR) than control subjects¹⁶. The vital capacity (VC), inspiratory reserve volume (IRV), FVC and FEV1 of swimmers who regularly swam a distance of 2 to 5 km per day were higher than those of age-, sex-, height- and weight-matched controls¹⁷ suggesting the number of years of vigorous distance swimming, and/or the earlier the age at which training begins, may have a significant influence on subsequent FEV1¹⁸.

These observations do not obviate genetic endowment as the key determinant of the better lung volume observed in swimmers since a low level of habitual physical activity does not influence FVC¹⁹. Evaluation of lung function in Indian athletes and non-athletes during adolescence suggests that the maturity of the lung during adolescence, provided that they have proper nutritional and health conditions, is influenced by the process of growth with negligible additional effects ascribed to physical activity^{20,21}.

Apparently, physical activity either increases or has no additional effect on lung volumes in children and adolescents. We therefore aimed to assess the influence of the practice of sports training upon spirometric and expiratory flow values among male adolescents.

Materials and Methods

Subjects

The study was approved by the Human Research Ethics Committee, Khon Kaen University, and informed assent was obtained from each subject and signed consent from their parents/guardians. We examined the daily activities of 295 sedentary students randomly chosen from Kaen Nakorn Wittayalai (high school) and 293 athletes from Khon Kaen Province Athletics School, both in Northeast Thailand. The students were attending Mattayom 1 (Grade 7) to Mattayom 6 (Grade 12) and were between 12 and 19 years of age. Sedentary controls had not more than 2 hr per week of playing sports for recreation. None of the subjects had any history of smoking or apparent signs of malnutrition (body mass index is ≥ 18.5 and < 22.9 kg/m²) and were free of cardiopulmonary disease. The socioeconomic status was not assessed in this study.

Procedures

The athletes were training in eight different types of sports: swimming (N=25), running (N=41), football (N=77), traditional Thai foot volleyball (Takraw) (N=48), table tennis (N=19), tennis (N=8), cycling (N=25) and boxing (N=50). They boarded at school from mid-May to mid-March (one full academic year) followed by a two-month vacation. The training program for each sport is presented in Table 1. Each sport underwent training between 2½ and 3½ hr daily for about 4 months (in Grade 7) to 54 months (in Grade 12). In addition, they had to join in sports competitions from time to time throughout the academic year.

Height and weight were measured for each participant, according to the WHO guidelines²². Participants wore light clothing and no shoes. Weight was determined using a digital scale (TCS-150-B), to the nearest tenth. Height was measured standing with feet together and arms relaxed at the sides. The BMI was calculated as weight (W, kg) divided by height (H, m²)

Dynamic lung volume was performed according to the American Thoracic Society (ATS) criteria using

a Collins Respirometer (*i.e.*, at least three trials in which the two largest forced FVC were within 5% of each other). The largest FVC was chosen as 'the best' according to the ATS criteria (Standardization of Spirometry²³). The peak expiratory flow rates (PEF), maximal mid expiratory flow (FEF₂₅₋₇₅), forced expiratory flow at 75, 50 and 25 percent of the FVC (FEF_{75%}, FEF_{50%}, FEF_{25%}), forced expiratory volume in the first second (FEV₁) were derived from the best FVC. FVC and FEV₁ indices (FVC_{index}, FEV_{1index}) were calculated from dividing the FVC and FEV₁ by height. All measurements were done either before or after the sport competition all year round.

Table 1 Daily training program for athletes.

Time	Duration (min)	Activity
0530-	10-20	Warm-up
	40-50	General/skills training
1630-	10-20	Warm-up
1640-	30-40	General training
	50-60	Skills training
1800-	10-20	Cool down

Statistical Analyses

Descriptive statistics were calculated for subjects on variables. The FVC, FEV₁, PEF, FEF₂₅₋₇₅ and 75, 50 and 25 percent of the FVC (FEF_{75%}, FEF_{50%}, FEF_{25%}) are shown as absolute values and those corrected by subject height. Pearson correlation coefficients were analyzed to determine the relationship between age, height and weight and lung volume and capacity. Values are expressed as mean±SD. Statistics were tested at the p<0.05 level of significance.

Results

The general characteristics of the population studied are summarized in Table 2. The athletes were slightly taller (p<0.05), heavier (p<0.05) and older (p<0.05) than those of sedentary subjects; nonetheless, the average body mass indices (BMI) were comparable.

Table 2 Anthropometric characteristics of the study population.

Characteristics	SS (N=295)	AT (N=293)	p-value
Age (years)	14.9±1.8	15.2±1.8	p < 0.05
Weight (kg)	50.3±11.3	52.4±9.6	p < 0.05
Height (m)	1.62±0.10	1.64±0.09	p<0.05
BMI (kg/m ²)	18.9±3.1	19.3±2.1	NS

BMI, body mass index; SS, sedentary subjects; AT, athletes; NS, not significantly different

Table 3 Comparisons of spirometric parameters in athletes (AT) and sedentary subjects (SS)

Spirometric parameters	SS (N=295)	AT (N=293)	%	p-value
FVC (L)	3.05±0.69	3.68±0.74	20.7	<0.001
FVCindex (L/m)	1.86±0.34	2.23±0.37	19.8	<0.001
FEV1 (L)	2.81±0.62	3.33±0.62	18.5	<0.001
FEV1index (L/m)	1.72±0.32	2.02±0.31	17.4	<0.001
%FEV1	93± 6	91± 5	0.98	<0.001
PEF (L/s)	6.18±1.56	6.88±1.70	11.3	<0.001
FEF25-75% (L/s)	3.77±1.06	4.02±0.99	6.6	<0.01
FEF25% (L/s)	5.68±1.51	6.25±1.58	10.0	<0.001
FEF50% (L/s)	4.26±1.21	4.66±1.21	9.4	<0.001
FEF75% (L/s)	2.39±0.85	2.51±0.80	1.05	NS

Comparisons of spirometric parameters in athletes (AT) and sedentary subjects (SS) are summarized in Table 3. FVC and FEV1 values showing large airway function were significantly greater (20.7% for FVC, 18.5% for FEV1) (p<0.001) and %FEV1s was slightly less (2%, p<0.001) in athletes than the sedentary controls. After normalizing FVC and FEV1 by height, FVCindex and FEV1index were 19.9% and 17.4% greater in AT than in SS. In addition, the peak expiratory flow, forced expiratory flow rates over mid (FEF25-75%) and low volumes (FEF50%, 25%), but not the high range (FEF75%), were 6.6% to 11.3% significantly higher in athletes (p<0.01).

FVC, forced vital capacity; FEV1, forced expiratory volume in the first second; FVCindex, forced vital

capacity index; %FEV1, percentage of FEV1/FVC; PEF, peak expiratory flow rates; FEF25-75%, maximal mid expiratory flow; FEF75%, FEF50%, FEF25%, forced expiratory flow at 75, 50 and 25 percent of the FVC; %, (AT/SS)x100

For the completion of comparisons of the two groups, multiple regression equations were calculated for age, height and weight so that reference values could be estimated for the athletes and sedentary controls. Judging from the correlation coefficients (r) and the coefficients of determination (R²), prediction of lung volumes in athletes is less accurate than in normal subjects (0.334-0.755 vs. 0.531-0.867 for r, 0.112 vs. 0.570 vs. 0.282-0.752 for R²) (Table 4).

Table 4 Multiple regression equations for the athletes and sedentary subjects.

Spirometric parameters	Equations	r	R ²
Sedentary subjects			
FVC	- 5.448 + 4.257H + 0.061A + 0.013W	0.867	0.751
FEV1	- 4.869 + 3.777H + 0.068A + 0.011W	0.865	0.749
PEF	- 5.191 + 4.527H + 0.159A + 0.033W	0.601	0.362
FEF25-75%	- 4.181 + 3.065H + 0.153A + 0.014W	0.579	0.335
FEF25%	- 4.546 + 3.711H + 0.196A + 0.027W	0.561	0.314
FEF50%	- 3.677 + 2.574H + 0.178A + 0.012W	0.562	0.316
FEF75%	- 4.245 + 2.849H + 0.126A + 0.002W	0.531	0.282
Athletes			
FVC	- 3.483 + 3.471H + 0.013A + 0.025W	0.755	0.570
FEV1	- 2.915 + 3.016H + 0.026A + 0.017W	0.753	0.566
PEF	- 1.325 + 2.261H + 0.127A + 0.049W	0.487	0.237
FEF25-75%	- 2.479 + 2.827H + 0.080A + 0.012W	0.484	0.234
FEF25%	- 0.394 + 1.400H + 0.149A + 0.040W	0.446	0.199
FEF50%	- 0.775 + 1.629H + 0.108A + 0.022W	0.411	0.169
FEF75%	- 2.521 + 3.030H + 0.025A + 0.006W	0.334	0.112

H, height, m; A, age, yr; W, weight, kg; r, correlation coefficient; R², coefficient of determination; Other abbreviations are as in Table 3.

Normal spirometric values were readily predicted for both groups by using regression equations shown in Table 4. Values from our study and other Thai studies were adjusted for age at 14.4 years, height at 1.62 m and weight of 52.9 kg in order that they could be compared to those reported previously. The values for the mean age, height and weight of the athletes and sedentary controls as well as the values for Thais, Europeans, Polynesians and Chinese (from other references) are presented in Table 5. As can be seen, the FVCs in our sedentary (normal) subjects are approximately 80, 87, 85 and 76% of Europeans, Polynesians, Chinese and Swiss, respectively. Furthermore, when comparing the Thai population

with other studies, the values are either similar or only 77 to 83%. Likewise, the FEV1s in Thais were 82 to 89 % compared to Europeans, Polynesians, Chinese and Swiss and 78 to 87 percent compared to other Thai lung function studies (Table 5). Additionally, similar conclusions could be drawn for the other spirometric values.

It was also demonstrated that the respective FVC and FEV1 values of athletes (AT) in our study, after adjustment for height, age and weight, were 21 and 15 % higher than those of their sedentary counterparts (SS) and comparable with Europeans, Polynesians, Swiss and Chinese and other Thais (Table 5).

Table 5 Comparison with predicted spirometric values adjusted for age (14.4 years), height (1.62 m), and weight (52.9 kg) from different studies. [A previous study done in boys aged between 10-19 years has presented spirometric values for age at 14.4 years, height at 1.62 m and weight of 52.9 kg²⁴.]

Spirometric parameters	Age (years)	FVC (L)	FEV1 (L)	FEF25-75% (L/s)	FEF25% (L/s)	FEF50% (L/s)	FEF75% (L/s)
Our study (AT)	12-19	3.65	3.24	3.89	6.14	4.58	3.06
Our study (SS)	12-19	3.01	2.81	3.73	5.72	3.69	2.29
Thai ²⁷	15	3.09	2.90	NR	NR	NR	NR
Thai ²⁸	18-22	3.62	3.22	4.09	NR	NR	NR
Thai ²⁹	10-92	3.67	3.22	4.26	NR	NR	NR
Thai ³⁰	20-59	3.89	3.60	5.44	NR	NR	NR
EU ²⁴	10-19	3.75	3.40	4.12	6.34	4.53	2.31
PS ²⁴	10-19	3.45	3.16	3.96	6.28	4.39	2.17
CN ²⁴	10-19	3.55	3.30	4.26	6.67	4.69	2.40
SW ³¹	18-25	3.97	3.41	NR	NR	NR	NR

EU, European; PS, Polynesian; CN, Chinese; SW, Swiss; AT, athlete; SS, sedentary subjects; NR, not recorded

Discussion

Male adolescents from the Khon Kaen Sports School (athletes), between 12 and 19 years of age, had been assigned long-term training. They were engaged in regular physical exercise for between 2½ and 3½ hr per day for between 4 and 54 months, whereas the counterpart sedentary controls had not more than 2 hr per week of playing sports for recreation.

In this study, the FVC and FEV1 in sedentary adolescents are close to those of normal subjects 15 years of age from Bangkok²⁷, the capital city of Thailand, where the socioeconomic status is better. Students were recruited from Khon Kaen Witthayalai School which supposedly had majority of students from municipality of Khon Kaen Province which is located in the Northeast of Thailand. Our results may not; therefore, rule out the assumption that people from a low income population are more likely to have low lung volumes^{6,7} since socioeconomic status of the subjects was not assessed by this study. However, FVC, FEV1, FEF25-75%, FEF25%, FEF50% and FEF75% are apparently less than the predicted values from other studies done in Thais

between 10 and 92²⁸, 18 and 22²⁹, and 20 and 59 years of age³⁰. The difference in lung volumes between those studies and this study is probably due to different age groups of participants.

Presumably reference lung volumes for normal healthy adolescents should be performed in the appropriate age group (e.g., 12 to 19 yr) before being used as reference values. We generated reference lung volumes by using multiple regression equations calculated for age, height and weight so that they could be estimated for the athletes and sedentary controls. Moreover, our FVC and FEV1 values and expiratory flow rates were less than those previously reported for European, Polynesian Chinese and Swiss subjects^{24,31}. Differences in pulmonary function among races have been recognized, although it is difficult to differentiate genetic from environmental factors (e.g., childhood health, environmental smoke and pollution, nutritional status and exercise)³¹ which subsequently determine the size and shape of the rib cage, respiratory muscle strength, and possibly parenchymal lung development³².

As lung volume is predominantly determined by height, we normalized FVC and FEV1 by height and, thus, FVCindex and FEV1index were derived. We found that the FVC, FEV1 and their indices, peak expiratory flow and those forced expiratory flows over mid and low, but not the high volume, in athletes were greater than their sedentary counterparts. This is in agreement with previous reports in swimmers^{15, 6, 17, 18}. Total lung capacity, FVC, FEV1, functional residual capacity, residual volume and resting diffusing capacity of the lung for carbon monoxide has been found to be greater in young male swimmers aged 13 to 16 years after 6 years of training than their untrained counterparts of a similar age¹⁵. Similarly, it has been demonstrated that swimmers between 15 and 20 years had significantly higher FVC, FEV1 and peak expiratory flow rate than control subjects¹⁶. In addition, regular swimming of 2 to 5 km per day resulted in higher vital capacity, inspiratory reserve volume, FVC and FEV1 in swimmers compared to those of age-, sex-, height- and weight-matched controls¹⁷ suggesting the number of years of vigorous distance swimming, and/or the earlier the age at which training begins, may have a significant influence on subsequent FEV1¹⁸. Moreover, our results are close to values for European, Polynesian, Chinese and Swiss subjects^{24, 31}. Accordingly, regular and prolonged exercise help develop lung function in adolescents. Likewise, the study in Thai security personnel, at Khon Kaen University, who underwent regular physical training, demonstrated similar lung function to Europeans. By contrast, other authors found that physical activity had negligible additional effects to the maturation of the lung during adolescence as long as the subjects had proper nutritional and health conditions^{20, 21}. The discrepancy between their studies and our study could be due to in these later studies, only 14 boys and 11 girls were evaluated after one year of training for middle distance running events.

Conclusion

In summary, we suggest that physical activity is a crucial determinant of lung development during adolescence.

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