啓明醫大論文集 第7卷 第2號
The Keimyung Univ Med J
Vol 7, No.2, December, 1988

Pulmonary Function Parameters and Their Prediction Equations in Atheletes of Different Events*

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運動選手의 競技種目別 肺機能과 그 推定式의 比較*

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本 研究에서는 各種目 運動選手들의 肺機能指數와 그 推定式을 서로 比較함을 目的으로 하였다.

19~22才의 男子 大學生 總 112名中 運動選手는 71名이고 非選手는 41名이며, 選手 71名은 陸上(選手) 18名, 테니스 6名, 럭비 15名, 하키 7名, 排球 6名, 농구 8名, 헨드볼 9名, 射擊 7名 및 體操 5名으로 되어있고 이들은 모두 各 運動分野에서 最小 5年의 選手經歷을 갖고 있는 사람들이다.

各 群에서 身體的 差異에서 오는 誤差를 없애기 위해서 各 運動對象者의 身長을 170cm로 하였을 때를 基準으로 하여 實驗値를 다시 較正하였다.

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* A part of this article was presented at the 86 Asian Sports Seientific Congress.

본 논문은 전영준의 박사학위 논문임.

肺機能 測定은 Spirometric Computer를 使用하여 努力性肺活量(FVC), 努力性呼氣量 0.5秒値(FEV0.5)와 0.5秒率(FEV0.5%) 및 1秒値(FEV1)와 1秒率(FEV1%)이 最大呼氣流速(PEF), 努力性呼氣流速 200~1200ml(FEF200~1200ml), 25~75%値(FEF25~75%)와75~85%値(FEF 75~85%), 그리고 最大吸氣流速(PIF)를 測定하였다. 또한 最大換氣能法에 의해서 最大換氣能(MVV)도 測定하였다.

그 結果를 綜合하면 FEV는 體操種目을 除外하고는 全運動種目에서 選手群이 非選手群보다 높았다. 이중 FVC는 陸上種目에서 가장 높았고, 다음이 排球, 농구, 핸드볼, 하키, 테니스의 順이었다.

FEV0.5는 陸上選手가 非選手群보다 有意하게 높았고, FEV1은 陸上 및 농구選手가 非選手群보다 높았다. 그러나, FEV0.5%와 FEV1%는 非選手群에 비하여 選手群이 오히려 낮았다.

呼吸流速에서는 PEF가 非選手群에 비하여 體操種目을 除外하고는 全選手群에서 높은 값을 나타내었고, 特히 陸上選手의 그것이 有意하게 높았다. FEF25%는 排球 및 體操種目을 除外하고는 全選手群이 높았다. FEF50%는 陸上, 럭비, 농구 및 테니스種目을 除外하고는 모든 運動種目에서 낮았고, FEF75%는 陸上을 除外하고는 모든 種目에서 낮았다. PIF는 全種目에서 모두 非選手群보다 높았고, 特히 陸上, 射擊, 핸드볼, 排球 및 농구種目에서는 有意한 差異를 나타내었다.

FEF200~1200ml는 排球를 除外한 全種目에서 非選手群보다 높았고, 特히 陸上, 럭비, 농구 및 射擊에서는 有意한 差異를 나타내었다. FEF25~75%는 運動種目中 陸上, 럭비, 하키 및 농구種目에서 높았고, 反對로 FEF75~85%는 陸上을 除外하고는 全種目에서 非選手群보다 낮았다.

MVV는 非選手群에 비하여 陸上種目에서만 有意하게 높았고, 排球種目에서는 有意하게 낮았다.

以上의 實驗値에서 身長을 基準으로한 推定式을 誘導하였다.

以上의 結果로서 選手群은 非選手群에 비하여 努力性呼氣量中 FVC 및 FEV1과 PEF, PIF 및 PEF20~1200ml 등 努力依存性 流速은 有意하게 높았고, FEF50%, FEF25~75%, FEF75% 및 FEF75~85% 등 努力非依存性流速은 낮았음을 알 수 있었다.

그 理由로서 運動選手에서는 큰 氣道가 非選手群보다 잘 發達되어있을 것이나, 작은 氣道는 그렇지 못한 것이라고 思料된다. 特히 注目할 것은 陸上選手에서 가장 높은 肺機能指數를 나타낸 것이다.

INTRODUCTION

During exercise, energy metabolism is invariably increased. Therefore exercise requires an adequate supply of oxygen to the active tissues which in turn require fitness of the pulmonary function, namely, pulmonary ventilation, alveolar gas exchange and pulmonary perfusion.[1]

It has been well established that the pulmonary function of athletes is superior to that of non-athletes. But whether all the parameters of pulmonary function are uniformly superior in athletes is a subject to be further pursued. It is also expected that there is a variation in the pulmonary function in athletes of different events.

Therefore, it is important to analyze the pulmonary function in athletes by measuring not only the forced vital capacity[2-3] but also effort-dependent pulmonary air flows which indicate function of large airways, and effort-independent air flows which reveal that of small airways.[4-5]

This study is aimed at comparing the pulmonary function in athletes of different events with that of non-athletes, and establishing the prediction equations for the pulmonary function.

METHODS

The subjects were 19 to 22 year-old healthy college students consisting of 41 non-athletic and 71 athletic subjects. All the athletic subjects had athletic career of more than 5 years. The events of athletes include running(18), tennis(6), rugby(7), volleyball(6), basketball(8), handball (9), shooting(7) and gymnastics(5). Those with history of any specific disease or with current illness were excluded from the experiment. Smokers were also excluded.

Table 1. Physical characteristics of different athletic groups

	Age(yr)	Height(cm)	Body weight(kg)	Body surface area(m^2)	Chest circum-ference(cm)	Exercise career(yr)	No. of subjects
Non-athletes	20.9±0.20	171.2±0.60	61.2±1.03	1.71±0.01	90.3±0.80	—	41
Athletes	20.8±0.24	173.9±0.73*	66.4±0.81***	1.80±0.01***	95.8±0.76***	5.2±0.51	71
Runners	21.6±0.44	173.6±1.09*	66.8±1.69**	1.80±0.03***	96.3±1.65***	6.9±0.68	18
Tennis	21.2±0.70	173.9±1.91	67.2±1.76*	1.81±0.03**	99.0±2.56***	8.9±0.29	6
Rugby	20.5±1.19	169.8±2.39	64.5±2.66	1.76±0.04	98.5±1.26**	6.0±0.32	5
Hockey	20.5±0.56	172.2±2.06	66.9±1.93*	1.80±0.03**	95.5±2.79*	5.3±0.65	7
Volleyball	19.7±0.33*	180.7±2.99***	72.8±3.26***	1.92±0.06***	98.0±1.93**	8.1±1.30	6
Basketball	20.4±0.57	179.1±1.46***	70.8±1.80***	1.89±0.03***	97.1±1.42***	7.8±0.59	8
Handball	19.5±0.38**	176.9±2.36**	68.1±2.45**	1.83±0.04***	93.6±0.95	7.9±0.75	9
Shooting	21.8±0.09	171.0±1.65	63.0±1.46	1.74±0.02	92.7±1.71	8.0±0.97	7
Gymnastics	20.4±2.24	163.9±1.21***	59.6±1.99	1.65±0.03	92.6±1.29	9.5±0.69	5

Values are means and standard errors.
Significantly different from non-athletes: *$p<0.05$, **$p<0.01$, ***$p<0.001$.

Table 2. Forced expiratory volumes in different athletic groups

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	FVC	FEV0.5(FEV0.5%)		FFV1(FEV1%)		No. of subjects
Non-athletes	4.02±0.07	2.97±0.06	(73.9±1.30)	3.79±0.07	(94.3±0.08)	41
Athletes	4.51±0.08***	3.04±0.06	(69.6±1.12)*	4.11±0.07**	(91.1±1.15)*	71
Runners	4.75±0.16***	3.37±0.10***	(71.0±1.95)	4.34±0.12***	(91.4±1.22)	18
Tennis	4.51±0.03*	3.12±0.17	(69.2±2.37)	4.02±0.20	(89.1±1.44)	6
Rugby	4.39±0.27	3.11±0.16	(70.8±1.75)	3.99±0.20	(90.9±2.06)	5
Hockey	4.54±0.20**	3.15±0.18	(69.4±3.27)	4.16±0.22	(91.6±2.27)	7
Volleyball	4.64±0.25**	3.11±0.29	(67.0±3.65)	4.16±0.29	(89.7±3.37)	6
Basketball	4.59±0.12**	3.25±0.08	(70.8±1.95)	4.22±0.08*	(91.9±1.26)	8
Handball	4.59±0.23**	3.07±0.14	(66.9±1.42)*	4.11±0.22	(89.5±1.53)	9
Shooting	4.28±0.18	3.10±0.01	(72.4±1.85)	4.01±0.14	(93.7±1.13)	7
Gymnastics	3.84±0.35	2.59±0.28	(67.5±3.60)	3.50±0.30	(91.1±2.18)	5

Values are means and standard errors.
Values are obtained by the following formula: observed value$\times\frac{170cm}{\text{height of subject(cm)}}$
Significantly different from non-athletes: *$p<0.05$, **$p<0.01$, ***$p<0.001$.
FVC : forced vital capacity.
FEV0.5 : forced expiratory volume for 0.5 second.
$FEV0.5\% = \frac{FEV0.5}{FVC}\times 100$
FEV1 : Forced expiratory volume for 1 second.
$FEV1\% = \frac{FEV}{FVC}\times 100$

The pulmonary function was measured with Cavitron SC-20 spirometric computer by use of forced vital capacity(FVC) maneuver and maximal voluntary ventilation(MVV) maneuver.

Pulmonary function parameters measured by FVC maneuver include FVC, forced expiratory volume for 0.5 sec(FEV0.5) and its percentage (FEV0.5%), for 1 sec(FEV1) and its percentage (FEV1%), effort-dependent air flows including peak inspiratory flow(PIF), forced expiratory flow 25(FEF25%) and FEF200-1200ml, and effort-independent air flows including FEF50, FEF25-75%, FEF75% and FEF75-85%. MVV also was measured by MVV maneuver.

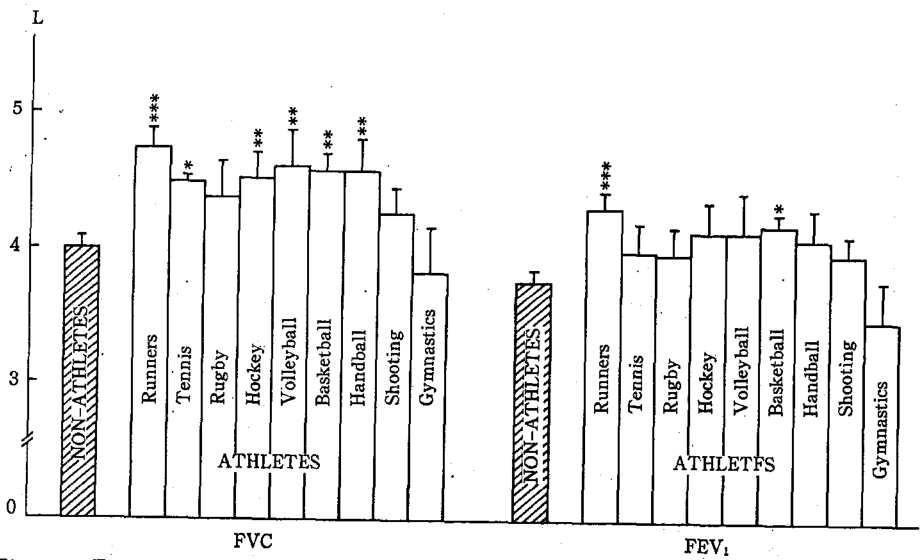

Fig 1-1. Forced expiratory volumes in different athletic groups.
Significantly different from non-athletes: *p<0.05, **p<0.01, ***p<0.001.
FVC : forced vital capacity.
FEV1 : forced expiratory volume for 1 second.

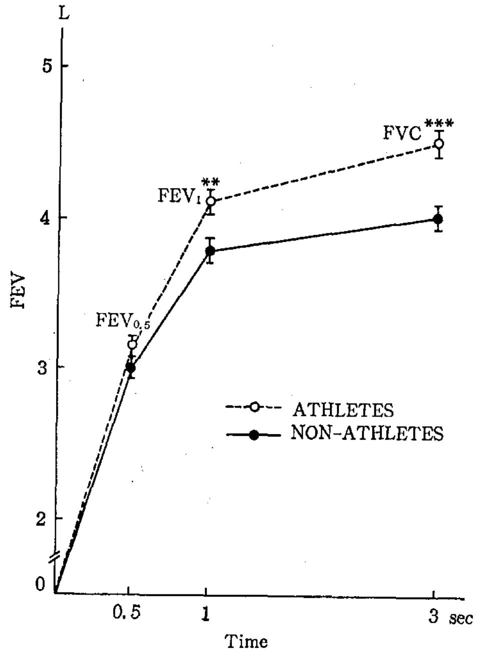

Fig 1-2. Forced expiratory volumes in athletes and non-athletes.
Significantly different from non-athletes: **p<0.01, ***p<0.001.
FVC : forced vital capacity.
FEV0.5 : forced expiratory volume for 0.5 second.
FEV1 : forced expiratory volume for 1 second.

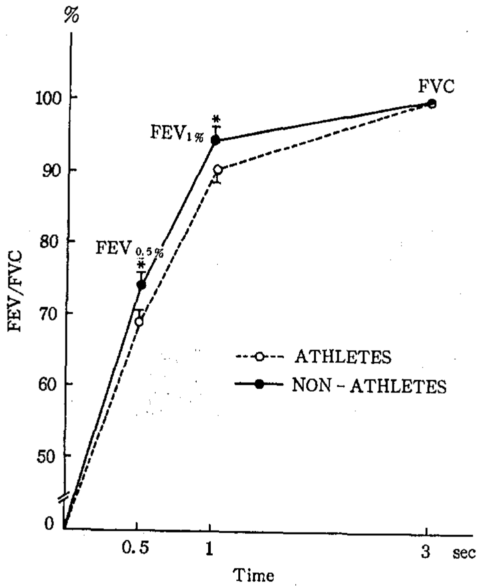

Fig 1-3. Forced expiratory volumes percent in athletes and non-athletes.
Significantly different from non-athletes: *p<0.05.
FVC : forced vital capacity.

$$FEV0.5\% = \frac{FEV0.5}{FVC} \times 100,$$

$$FEV1\% = \frac{FEV1}{FVC} \times 100.$$

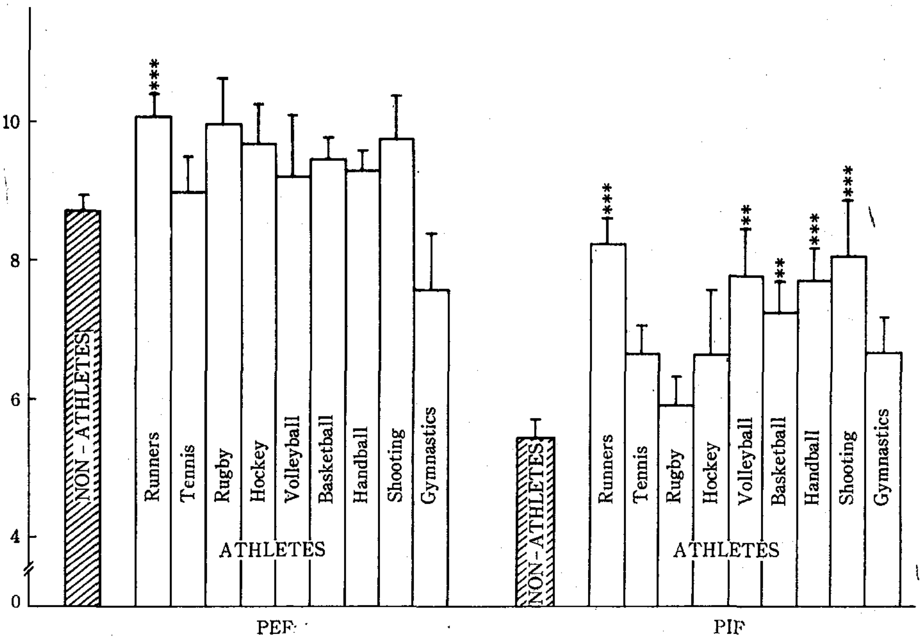

Fig 2-1. PEF(peak expiratory flow) and PIF(peak inspiratory flow) in different athletic groups. Significantly different form non-athletes: **p<0.01, ***p<0.001.

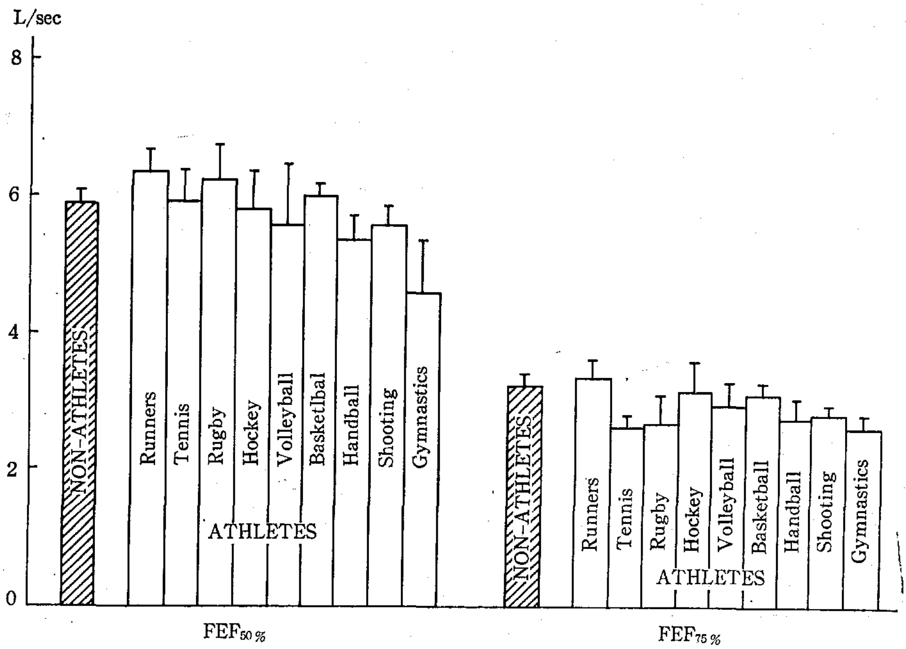

Fig 2-2. FEF50%(forced expiratory flow 50%) and FEF75% in different athletic groups.

Table 3. Expiratory and inspiratory flow rates in different athletic groups

L/sec

	PEF	FEF25%	FEF50%	FEF75%	PIF	No. of subjects
Non-athletes	8.69±0.21	8.21±0.23	5.86±0.22	3.21±0.17	5.43±0.27	41
Athletes	9.39±0.19*	8.36±0.22	5.77±0.17	2.72±0.11	7.46±0.20***	71
Runners	10.07±0.31***	8.90±0.34	6.32±0.32	3.30±0.26	8.22±0.36***	18
Tennis	8.96±0.52	8.24±0.58	5.90±0.45	2.58±0.19	6.68±0.36	6
Rugby	9.96±0.67	8.64±0.43	6.19±0.52	2.63±0.44	5.89±0.43	5
Hockey	9.66±0.61	8.72±0.75	5.78±0.56	3.11±0.45	6.67±0.87	7
Volleyball	9.19±0.86	7.62±0.91	5.56±0.88	2.89±0.43	7.76±0.67**	6
Basketball	9.45±0.31	8.65±0.29	5.97±0.23	3.06±0.17	7.22±0.44**	8
Handball	9.26±0.29	8.34±0.42	5.31±0.37	2.69±0.29	7.68±0.48***	9
Shooting	9.74±0.60	8.78±0.50	5.53±0.28	2.78±0.12	8.03±0.80***	7
Gymnastics	7.56±0.83	6.3. ±1.01*	4.55±0.75	2.56±0.19	6.65±0.52	5

Values are means and standard errors.

Values are obtained by the following formula: observed value$\times\frac{170\text{cm}}{\text{height of subject(cm)}}$.

Significantly different from non-athletes: *p<0.05, **p<0.01, ***p<0.001.
PEF : peak expiratory flow.
FEF25% : forced expiratory flow 25%.
FEF50% : forced expiratory flow 50%.
FEF75% : forced expiratory flow 75%.
PIF : peak inspiratory flow.

Since the pulmonary function parameters have significant correlation with physical characteristics especially with height, the measured parameters were corrected for height of 170 cm as follows: Corrected Value=Measured Value×170 cm/Height(cm).

The results were presented as means and standard errors of corrected values, and Student's t-test was used in comparing data. The prediction equations were derived from the regression equations for different events for those parameters that could be predicted from the height.

RESULTS

Forced expiratory volumes in different athletic groups are shown in Table 2 and Figure 1-1. Forced vital capacity(FVC) in non-athletes was 4.02±0.07L and athletes showed significantly higher values, the highest being 4.75±0.16L in runners, followed by volleyball, basketball, handball, hockey and tennis in the order named. Rugby and shooting groups showed higher FVC values than in non-athletes but the difference FEF75% in runners, 3.30±0.26 L/sec, was

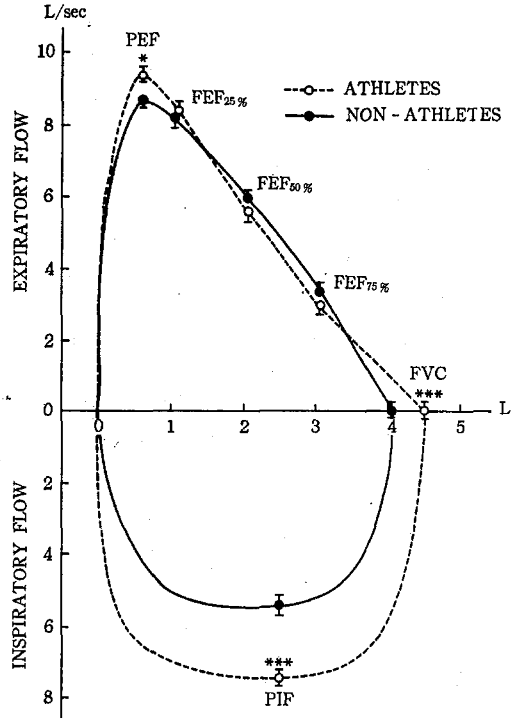

Fig 2-3. Expiratory and inspiratory flow rates in athletes. Significantly different from non-athletes: *p<0.05, ***p<0.001.

Table 4. Expiratory flow rates and maximal voluntary ventilation in different athletic groups

	FEF200-1200ml (L/sec)	FEF25-75% (L/sec)	FEF75-85% (L/sec)	MVV(L/min)	No. of subjects
Non-athletes	7.55±0.20	5.17±0.19	2.56±0.14	145.2±2.55	41
Athletes	8.33±0.19**	5.04±0.14	2.30±0.09	152.0±2.90	71
Runners	8.91±0.30***	5.53±0.27	2.60±0.23	158.9±5.38*	18
Tennis	8.20±0.48	4.90±0.31	1.95±0.16	152.0±9.39	6
Rugby	8.75±0.40*	5.16±0.39	2.47±0.30	151.0±8.84	5
Hockey	8.31±0.58	5.14±0.51	2.27±0.43	158.3±7.38	7
Volleyball	8.23±0.82	4.86±0.70	2.29±036	153.3±11.72	6
Basketball	8.63±0.25*	5.25±0.25	2.38±0.11	151.8±7.91	8
Handball	8.05±0.22	4.71±0.30	2.14±0.24	145.0±6.05	9
Shooting	8.65±0.53*	4.87±0.19	1.98±0.14	159.6±9.73	7
Gymnastics	6.52±0.97	4.21±0.53	1.95±0.15	123.8±9.90*	5

Values are means and standard errors.

Values are obtained by the following formula: observed value $\times \frac{170cm}{\text{height of subject(cm)}}$

Significantly different from non-athletes: *$p<0.05$, **$p<0.01$.
FEF200-1200ml : forced expiratory flow 200-1200ml.
FEF25-75% : forced expiratory flow 25-75%.
FEF75-85% : forced expiratory flow 75-85%.
MVV : maximal voluntary ventilation.

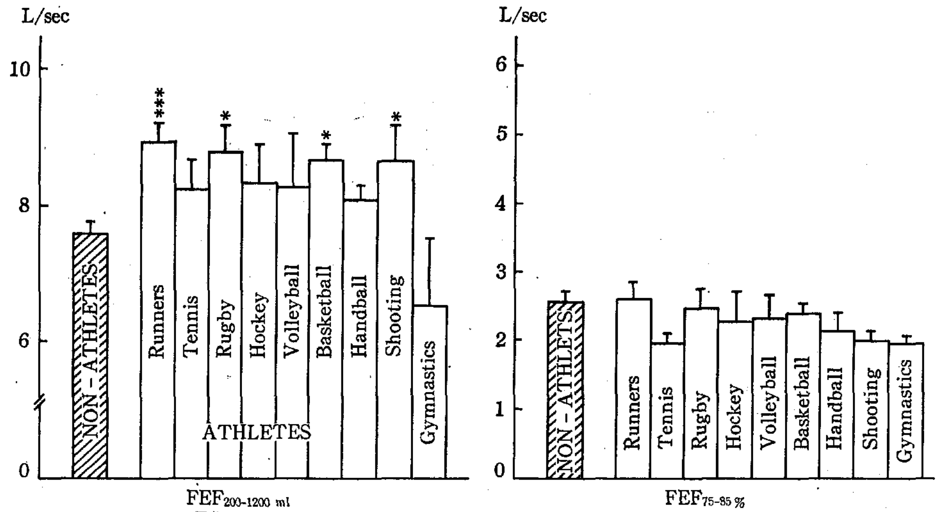

Fig 2-4. FEF200-1200ml and FEF75-85% in different athletic groups.
Significantly different from non-athletes: *$p<0.05$, ***$p<0.001$.

was not significant. FVC in gymnastics group was 3.84±0.35L which was lower than in non-athletes. FEV 0.5 in non-athletes being 2.97±0.06L. Runners showed significantly higher FEV 0.5 value of 3.37±0.10L and other athletic groups showed higher values than non-athletes but the difference was not significant. Gymnastics group showed lower value of 2.59 which is 0.38L lower than non-athletes. FEV1 in non athletes was 3.79±0.07L and FEV1 in runners and basketball group was 4.34±0.12L and 4.22±0.08 L, respectively, and were significantly higher

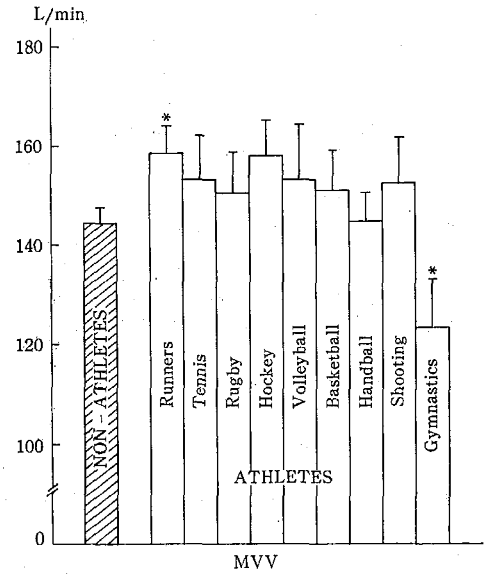

Fig 3. Maximal voluntary ventilation(MVV) in different athletic groups.
Significantly different from non-athletes: $^{*}p<0.05$.

than in non-athletes. FEV1 in other athletic groups were also higher than in non-athletes. On the other hand, FEV0.5% in all the athletes were lower than that of 73.9% in non-athletes, and FEV1% in athletes were also lower than 94.3% in non-athletes. As shown in Figure 1-2, FEVs in athletes were higher than in non-athletes with FEV1 and FVC being significantly higher. As shown in Figure 1-3, FEV0.5% and FEV1% in athletes were lower than in non-athletes.

Forced expiratory and inspiratory flows in different athletic groups are shown in Table 3 and Figures 2-1, 2. Peak expiratory flow(PEF) in non-athletes was 8.69±0.21 L/sec. Runners showed significantly higher value of 10.07±0.31 L/sec and other athletes showed higher values, but gymnastics group showed lower value than non-athletes, runners showing the highest value of 8.90±0.34 L/sec, but volleyball and gymnastics groups showed lower values. FEF50% in runners, rugby, basketball and tennis groups were higher than 5.86±0.22 L/sec in non-athletes, but other athletes showed lower values. slightly higher than 3.21±0.17 L/sec of non-athletes, but other athletes showed lower FEF75% values than non-athletes. PIF in athletes was significantly higher than 5.43±0.27 L/sec of non-athletes, runners showing the highest value of 8.22±0.36 L/sec followed by shooting, 8.03±0.80 L/sec, handball, 7.68±0.48 L/sec, volleyball, 7.76±0.67 L/sec, and basketbll, 7.22±

Table 5-1. Prediction equations for forced expiratory volumes using body height in different athletic groups

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	FVC	FEV0.5	FEV1
Non-athletes	−5.028+0.0530 HT	−5.504+0.0496 HT	−6.409+0.0597 HT
Athletes	−8.015+0.0726 HT	−3.520+0.0387 HT	−5.590+0.0563 HT
Runners	−8.526+0.0770 HT	−1.815+0.0303 HT	−2.598+0.0405 HT
Tennis	−8.561+0.0757 HT	−8.874+0.0693 HT	−8.590+0.0730 HT
Rugby	−13.169+0.1027 HT	−7.135+0.0607 HT	−10.846+0.0878 HT
Hockey	−7.843+0.0710 HT	−6.939+0.0576 HT	−9.284+0.0768 HT
Volleyball	−5.530+0.0579 HT	−10.075+0.0740 HT	−8.757+0.0729 HT
Basketball	−1.596+0.0364 HT	−0.179+0.0181 HT	−0.683+0.0287 HT
Handball	−11.010+0.0890 HT	−4.198+0.0417 HT	−10.067+0.0811 HT
Shooting	−7.509+0.0696 HT	−0.417+0.0207 HT	−5.559+0.0561 HT
Gymnastics	−1.794+0.0335 HT	−12.343+0.0905 HT	−9.200+0.0767 HT

HT : height(cm)
FVC : forced vital capacity.
FEV0.5 : forced expiratory volume for 0.5 second.
FEV1 : forced expiratory volume for 1 second.

Table 5-2. Prediction equations for PEF, PIF and MVV using body height in different athletic groups

	PEF(L/sec)	PIF(L/sec)	MVV(L/min)
Non-athletes	−2.733+0.0671 HT	−9.638+0.0882 HT	−74.715+1.2902 HT
Athletes	−2.458+0.0694 HT	−6.595+0.0818 HT	117.068+0.2210 HT
Runners	−13.211+0.1353 HT	−5.797+0.0817 HT	272.976−0.6373 HT
Tennis	−27.835+0.2127 HT	−1.872+0.0501 HT	260.208−0.6021 HT
Rugby	−11.964+0.1283 HT	−20.919+0.1602 HT	−96.648+1.4956 HT
Hockey	7.060+0.0127 HT	−13.098+0.1152 HT	−37.824+1.0942 HT
Volleyball	−28.777+0.2133 HT	−28.109+0.2012 HT	−366.953+2.9352 HT
Basketball	10.245−1.5751 HT	−2.117+0.0543 HT	−102.994+1.4678 HT
Handball	6.333+0.0167 HT	−21.638+0.1677 HT	27.050+0.7048 HT
Shooting	24.043−0.0825 HT	−6.111+0.0829 HT	85.929+0.4298 HT
Gymnastics	−39.270+0.2841 HT	−42.451+0.2981 HT	−533.429+3.9832 HT

HT : height(cm)
PEF : peak expiratory flow.
PIF : peak inspiratory flow.
MVV : maximal voluntary ventilation.

Table 5-3. Prediction equations for FEF25%, FEF50% and FEF75% using body height in different athletic groups

L/sec

	FEF25%	FEF50%	FEF75%
Non-athletes	−0.368+0.0505 HT	−11.018+0.0988 HT	−16.062+0.1127 HT
Athletes	−3.658+0.0702 HT	−4.221+0.0582 HT	0.538+0.0141 HT
Runners	−7.412+0.0951 HT	9.083+0.0152 HT	13.234−0.0568 HT
Tennis	−29.670+0.2191 HT	−21.832+0.1602 HT	−1.660+0.0247 HT
Rugby	−3.296+0.0732 HT	−14.833+0.1230 HT	2.596+9.2512 HT
Hockey	5.506+0.0149 HT	−24.177+0.1713 HT	−28.989+0.1872 HT
Volleyball	−35.807+0.2430 HT	−29.496+0.1960 HT	−12.413+0.0857 HT
Basketball	9.440−1.8350 HT	1.607+0.0262 HT	5.984−0.0154 HT
Handball	10.946−0.0145 HT	−2.585+0.0462 HT	−10.027+0.0730 HT
Shooting	34.384−1.1488 HT	25.209−0.1137 HT	−0.662+0.0204 HT
Gymnastics	−57.725+0.3896 HT	−43.513+0.2923 HT	−10.380+0.0784 HT

HT : height(cm)
FEF25% : forced expiratory flow 25%.
FEF50% : forced expiratory flow 50%.
FEF75% : forced expiratory flow 75%.

Table 5-4. Prediction equation of FEF200-1200ml, FEF25-75% and FEF75-85% using body height in different athletic groups

L/sec

	FEF200-1200ml	FEF25-75%	FEF75-85%
Non-athletes	−0.891+0.0496 HT	−12.979+0.1062 HT	−12.626+0.0890 HT
Athletes	−4.053+0.0723 HT	−2.067+0.0415 HT	−0.172+0.0145 HT
Runners	−16.752+0.1489 HT	12.515−0.0396 HT	8.779−0.0353 HT
Tennis	−27.084+0.2039 HT	−13.719+0.1077 HT	−1.227+0.0185 HT
Rugby	−13.058+0.1289 HT	−6.325+0.0677 HT	−4.220+0.0391 HT
Hockey	17.098−0.0539 HT	−23.726+0.1653 HT	−20.481+0.1322 HT
Volleyball	−33.401+0.2333 HT	−23.931+0.1611 HT	−10.172+0.0697 HT
Basketball	15.400−0.0352 HT	4.575+5.3232 HT	−0.413+0.0163 HT
Handball	11.774−0.0209 HT	−7.224+0.0688 HT	−9.756+0.0682 HT
Shooting	18.164−0.0546 HT	9.588−0.0268 HT	−1.747+0.0219 HT
Gymnastics	−46.718+0.3234 HT	−29.330+0.2037 HT	−12.489+0.0877 HT

HT : height(cm)
FEF200-1200ml : forced expiratory flow 200-1200ml.
FEF25-75% : forced expiratory flow 25-75%.
FEF75-85% : forced expiratory flow 75-85%.

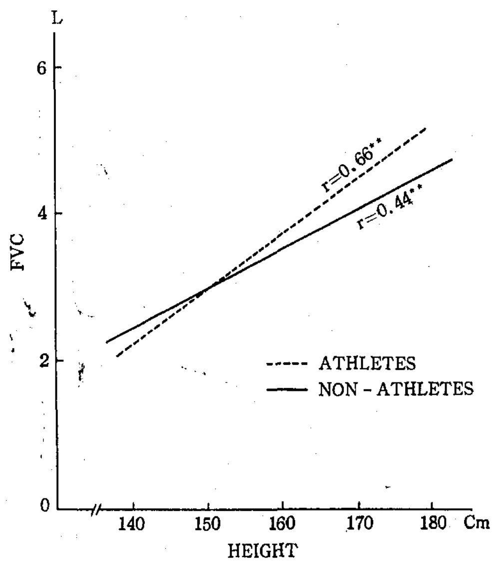

Fig 4. Correlation of forced vital capacity(FVC) with height in athletes and non-athletes. Significant correlation: $^{**}p<0.01$.

0.44 L/sec, group in the order named. As shown in Figure 2-3, PEF, PIF and FEF25% in athletes were higher, but FEF50% and FEF75% in athletes were lower than in non-athletes.

Table 4 shows forced expiratory flows(Figure 2-4) and MVV(Figure 3). FEF200-1200ml in athletes was significantly higher than 7.55±0.20 L/sec of non athletes, runners showing the highest value of 8.91±0.30 L/sec, followed by rugby, shooting and basketball group in the order named. FEF25-75% in runners and basketball groups were higher than 5.17±0.19 L/sec of non-athletes, but other athletes showed lower values. FEF75-85% in runners, 2.60±0.23 L/sec, was higher than 2.56±0.14 L/sec of non-athletes, but other athletes showed lower values. MVV in runners, 158.9±5.31 L/min, was significantly higher than 145.2±2.55 L/min of non-athletes. Other athletes showed higher MVV values, but gymnastics group showed significantly lower value of 123.8±9.90 L/min than in non-athletes.

Prediction equations for the pulmonary function parameters based on height in non-athletes and athletes of different events are shown in Tables 5-1~4. Table 5-1 shows equations for FEV, Table 5-2 for PIF and MVV, Table 5-3 for FEF25%, FEF50% and FEF75% and Table 5-4 for FEF200-1200ml, FEF25-75% and FEF75-85% Figure 4 shows the correlation between FVC and height. The correlation coefficients in athletes and non-athletes was 0.66 and 0.44, respectively, which indicate a high correlation.

DISCUSSION

The pulmonary function is dependent on the physical characteristics of age and sex.[6] Hutchinson[7] reported that the vital capacity is proportional to the height and inversely proportional to age but has little relation with the body weight. Other investigators[8-11] also reported that pulmonary function is dependent on the height. In this study, the physical characteristics have considerable variation not only between athletes and non-athletes but also within the athletes. In order to eliminate the influence of this difference, all the pulmonary function parameters were corrected for average height of 170cm as previously mentioned in methods.

The prediction equations using height derived for each pulmonary function parameter in this study will be helpful in predicting the pulmonary function. Kory et al[12] and Morris et al[13] found that the forced expiratory volumes and flows, and MVV had high correlation with height and age, and derived prediction equations. Cho and Park[14] and other investigators[15-18] have made prediction equations for the pulmonary function in adolescent non-smokers. Chung et al[19] substituted the height, weight and age of their subjects into the prediction equations designed by Kory et al[12] and, by comparing the predicted values with measured ones, found considerable differences between the two. And they attributed this difference to racial variation and emphasized the necessity of designing equations for Koreans. Suck et al[20] have made prediction equation using height for the pulmonary function in Korean smokers.

While it is reported that FVC is not significantly increased by exercise and shows no difference between athletes and non-athletes[21-24], Ishiko[25] says FVC has high correlation with the ability of exercise, and Gaensler[26] and other investigators[27-29] reported that FVC in athletes is higher than in non-athletes. In this study, FVC in athletes was higher than in non-athletes and especially was highest in runners. This might be due to the hypertrophy of the chest wall, diaphragm, ribs and respiratory muscles caused by prolonged exercise.[27]

Forced expiratory volumes for 0.5 sec(FEV0.5) and 1 sec(FEV1) in athletes were higher than in nonathletes, but their percentages to FVC (FEV0.5% and FEV1%) were lower in athletes. This implies that FEVs are not increased to the same proportion as the increase of FVC. It is notable therefore that athletes show lower FEV values than non-athletes while they are expected to show higher ones. These facts provide useful data in differentiating obstructive from restrictive lung disorders. FEV0.5% and FEV1% are decreased in obstructive lung disorders but not in restrictive. Mahler et al[30] studied 127 marathon runners and found low FEV1% values of 66.3% in 9 of them which they attributed to airway obstruction. In this study, however, FEV0.5% and FEV1% in all groups exceeded its normal range of 58—66%[31,32] and 80—85%[33] respectively.

Forced respiratory flows are proportional to the pressure difference across the airway, that is, the intrapulmonary pressure, and inversely proportional to the airway resistance.[34] Firstly, PEF and PIF are highly dependent on the expiratory and inspiratory efforts and are useful in diagnosing obstruction of large airways.[4] In this study, PEF and PIF in athletes were higher than in non-athletes which clearly indicate that athletes produced higher intrapulmonary pressure by utilizing well-developed respiratory muscles and had lower resistance of large airways. Secondly, FEF200-1200ml and FEF25% represent the earlier phase of the forced expiration while FEF25-75% and FEF50% show the middle phase. And FEF75% and FEF75-85% show the later phase and are used as indices for the degree of small airway obstruction.[13,35] In particular, FEF25-75%, FEF50%, FEF75-85% and FEF75% are relatively less dependent on the expiratory effort[4] and serve as the most reasonable indices to evaluate the organic nature of the lung and the degree of small airway obstruction.[36,37]

In this study, it should be noted that early-phase flows such as FEF200-1200ml and FEF25% were higher in athletes than in non-athletes but the mid and end-expiratory flows were lower in all the athletic groups except runners. This shows that athletes have higher resistance of small airways than non-athletes. Many factors[16,35,38-40] can impair the pulmonary function. Shephard[41,42] reported that abrupt exercise in cold air caused decrease of the pulmonary function. So the high resistance of small airways shown in athletes in this study might be due to heavy exercise performed by athlete during their trainings and games.

MVV is the maximum air volume that can be inhaled and exhaled during unit time. It is the best index in evaluating the ventilatory function of the lungs dynamically.[43] Factors influencing MVV include strength of the respiratory muscles, compliance of the lungs and thorax and the resistance of the airway and thoracopulmonary tissue[44]. MVV is increased by the increased cathecholamine release during exercise which reduces the airway resistance, stimulation of the respiratory center, and increased strengh of respiratory muscles caused by high body temperature[45], and is decreased in obstructive lung disease in which the airway resistance is increased.[46] Shephard[47] and other investigators[6,15,48,49] reported that MVV in athletes is higher than in non-athletes. In this study, MVV was highest in runners(158.9L/min) and was higher in athletes than in non-athletes. This indicates that runners and other athletes have stronger respiratory muscles, higher compliance of the lungs and thorax, and lower airway resistance than nonathletes.

It should be noted that the pulmonary function in gymnastics group was lower than in other athletes and even lower than in non-athletes. The physical characteristics of gymnastics group such as height and body weight were lower than in other athletes. But the possible influence of the inferior physical constitution on the pulmonary function was eliminated by correcting all the pulmonary function parameters for the standard height of 170cm. In gymnastics, the flexibility of the body is chiefly required and the pulmonary function may not be so important. But the exact cause of this low pulmonary function in gymnastisc is a subject for a further study.

SUMMARY

This experiment was aimed to elucidate the pulmonary function parameters and their prediction equation in different athletic groups.

A total of 112 male college students aged between 19-22 years were divided into 71 athletes and 41 non-athletes. The 71 athletes were subdivided as follows: 18 runners, 6 tennis players, 15 rugby players, 7 hockey players, 6 volleyball players, 8 basketball players, 9 handball players, 7 shooters and 5 gymnastic players who have undergone regular physical training for the respective exercise for at least five years.

In order to eliminate the physical difference in each group, the data obtained were reevaluated to the corrected values by taking the height of each participant to be 170cm.

The pulmonary parameters studied were FVC (forced vital capacity), FEV0.5(forced expiratory volume for 0.5 second), FEV0.5% FEV1, FEV1% PEF(peak expiratory flow), FEF25% (forced expiratory flow 25%), FEF50%, FEF 75%, PIF(peak inspiratory flow), FEF200-1200 ml, FEF25-75%, FEF75-85% and MVV(maximal voluntary ventilation), using a spirometric computer.

The results obtained are summarized as follows:

FEV showed higher values in all the athletic groups except gymnastics comparing with the non-athletes. In the FEV experiment, FVC showed the highest value in runners, followed by the volleyball, basketball, handball, hockey and tennis in the order named. FEV0.5 was significantly higher in runners than in non-athletes, and FEV1 in the runners and basketball were significantly higher than in non-athletes. But FEV0.5% and FEV1% were significantly lower in athletes than in non-athletes.

In the respiratory flow experiment, PEF was higher in all the athletic groups except gymnastics comparing with the non-athletes and particularly the value of runners was significantly higher than the non-athletes. FEF25% was higher in all the athletic groups except volleyball and gymnastics. FEF50% was lower in all the athletic groups except runners, rugby, basketball and tennis. FEF75% was lower in all the athletic groups except runners. PIF(peak inspiratory flow) was higher in all the athletic groups than in non-athletes. In particular the values in runners, shooters, handball, volleyball and basketball were significantly higher than in non-athletes. FEF200-1200ml was higher in all the athletic groups except gymnasts comparing with the non-athletes, with significant increase of FEF200-1200ml in runners, rugby, basketball and shooters. FEF200-1200ml in runners, rugby, basketball and shooters. FEF25-75% was lower in athletes except runners, and basketball groups than in non-athletes. FEF75-85% was lower in all the athletic groups except runners comparing with the non-athletes.

MVV was significantly higher only in the runners than in non-athletes, but significantly lower in gymnastics than in non-athletes.

Prediction equations for all of the pulmonary function parameters in different athletic groups were derived from the observed data and the body height.

From the above, we should note that FVC, FEV1 and effort-dependent air flows such as PEF, PIF and FEF200-1200ml were significantly higher

but effort-independent air flows such as FEF50%, FEF25-75%, FEF75% and FEF75-85% were lower in athletes than in non-athletes. It is likely that large airways of athletes are superior to those of non-athletes, but small airways of athletes are inferior to those of non-athletes. We should also note that pulmonary function parameter showed the highest values in runners.

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