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Selection of effective maximal expiratory parameters to differentiate asthmatic patients from healthy adults by discriminant analysis using all possible selection procedure.

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Tadamichi Meguro

Abstract

Maximal expiratory volume-time and flow-volume (MEVT and MEFV) curves were drawn for young male nonsmoking healthy adults and for young male nonsmoking asthmatic patients. Eleven parameters, two MEVT (%FVC and FEV1.0%), six MEFV (PFR, V75, V50, V25, V10 and V50/V25), and three MTC parameters (MTC75-50, MTC50-25 and MTC25-RV) were used for the multivariate analysis. The multivariate analysis in this study consisted of correlation coefficient matrix computation, the test for mean values in the multivariates, and the linear discriminant analysis using the all possible selection procedure (APSP). Correlation coefficients among flow rate parameters and flow rate related parameters in high lung volumes were different between the two groups. In the eleven-parameter discriminant analysis by APSP using single parameters, PFR, V75 (flow rate at 75% of forced vital capacity), and FEV1.0% were considered to be the effective parameters. In the seven-parameter discriminant analysis using the parameter groups, the group of all parameters and the %FVC and flow rate-related parameter group were considered to be the effective numerical alternatives to MEFV curves discriminating between healthy adults and asthmatic patients.

KEYWORDS: asthma, discriminant analysis, flow-volume parameters

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Selection of Effective Maximal Expiratory Parameters to Differentiate Asthmatic Patients from Healthy Adults by Discriminant Analysis Using All Possible Selection Procedure

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Maximal expiratory volume-time and flow-volume (MEVT and MEFV) curves were drawn for young male nonsmoking healthy adults and for young male nonsmoking asthmatic patients. Eleven parameters, two MEVT (%FVC and $FEV_{1.0\%}$), six MEFV (PFR, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$ and $\dot{V}_{50}/\dot{V}_{25}$), and three MTC parameters (MTC_{75-50}, MTC_{50-25} and MTC_{25-RV}) were used for the multivariate analysis. The multivariate analysis in this study consisted of correlation coefficient matrix computation, the test for mean values in the multivariates, and the linear discriminant analysis using the all possible selection procedure (APSP). Correlation coefficients among flow rate parameters and flow rate related parameters in high lung volumes were different between the two groups. In the eleven-parameter discriminant analysis by APSP using single parameters, PFR, $\dot{V}_{75}$ (flow rate at 75% of forced vital capacity), and $FEV_{1.0\%}$ were considered to be the effective parameters. In the seven-parameter discriminant analysis using the parameter groups, the group of all parameters and the %FVC and flow rate-related parameter group were considered to be the effective numerical alternatives to MEFV curves discriminating between healthy adults and asthmatic patients.

Key words : asthma, discriminant analysis, flow-volume parameters

The maximal expiratory volume-time (MEVT) curves of asthmatic patients in the asymptomatic state are nearly identical to those of healthy adults (1). When precise pulmonary function analysis is done by MEFV curve, flow rates in high lung volumes fall concavely even in the asymptomatic state of asthmatic patients. These MEFV curves are different from those of healthy adults.

We have reported two discriminant analyses by the forward selection procedure (FSP)(2) between healthy adults and asthmatic patients (3), one with six pulmonary function parameters (%FVC, $FEV_{1.0\%}$, PFR, $\dot{V}_{50}$, $\dot{V}_{25}$ and $\dot{V}_{50}/\dot{V}_{25}$) and another with eight ($\dot{V}_{75}$ and $\dot{V}_{10}$ added to the six above). $\dot{V}_{75}$ was the most effective parameter. At each step of the FSP, a parameter is selected as the best one of the remaining parameters except the effective parameter selected in the former step. We have also reported

Abbreviations : MEVT, Maximal expiratory volume-time ; MEFV, Maximal expiratory flow-volume ; %FVC, Percent of forced vital capacity to predicted vital capacity ; $FEV_{1.0\%}$, Percent of forced expiratory volume in one second to forced vital capacity ; $\dot{V}_X$, Flow rate at x% lung volumes of forced vital capacity ; MTC_{X-Y}, Mean time constant at (X-Y) % lung volume of forced vital capacity ; APSP, All possible selection procedure ; FSP, Forward selection procedure ; PFR, Peak flow rate.

the discriminant analysis by the all possible selection procedure (APSP) using eleven parameters (4), in which $\dot{V}_{75}$ was also the most effective. In APSP, the best of all combination is selected at each step as the set of parameters. Therefore, the results of the FSP are not always in concord with those of the APSP.

In this study, the author attempted to: 1) find the difference in correlation coefficients of eleven parameters between healthy adults and asthmatic patients, 2) select effective parameters, 3) select effective parameter groups, and 4) find the significance of parameters in high lung volumes of MEFV curves using the probability of misclassification.

Materials and Methods

Materials. The subjects consisted of 32 nonsmoking healthy young males and 26 nonsmoking asthmatic young males (Table 1).

The patients, who had been under medical control for more than six months when the severity of their bronchial asthma was determined, were chosen while they were under medical control at the Allergy Outpatient Clinic of the Department of Internal Medicine of Okayama University Medical Hospital. The severity of bronchial asthma was classified according to Oshima's criteria (5), which is based on the frequency of monthly attacks, the intensity of asthmatic attacks shown by dyspnea, and the effects of asthma on daily life. Though all the patients had been given bronchodilators, they had had no asthmatic attacks for at least two days including test day.

The healthy males were medical students and young doctors, who had no respiratory symptoms, no past history of respiratory diseases and no physical abnormalities.

Methods. A flow-volume curve recorder (O-ST-70D, Chest Co. Ltd.) was used for the maximal expiratory procedure, which consisted of the MEVT and MEFV maneuvers. MEVT and MEFV measurements were performed at least twice in the sitting position. One of the larger MEFV

Table 1 Anthropometric data[a]

Subject	Healthy adults	Asthmatic patients	t-test
Number	32	26	
Age(yrs)	23.6±1.5 (range: 21-29)	29.2±8.2 (range: 18-44)	(+)
Height (cm)	169.1±5.6	166.5±5.1	(−)

a: Mean ± unbiased standard deviation.

Table 2 Pulmonary function parameters in the discriminant analysis by all possible selection procedure (APSP)

Parameter or parameter group	Parameters used[a]
One parameter	%FVC, $FEV_{1.0}$%, PFR, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{50-25} and MTC_{25-RV}
MEVT parameter group	%FVC and $FEV_{1.0}$%
MEFV parameter group	PFR, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$ and $\dot{V}_{50}/\dot{V}_{25}$
MEVT and MEFV parameter group	%FVC, $FEV_{1.0}$%, PFR, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$
FVC and flow rate-related parameter group	%FVC, PFR, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{50-25} and MTC_{25-RV}
All parameter group	%FVC, $FEV_{1.0}$%, PFR, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$, $\dot{V}_{50}/\dot{V}_{25}$, MTC_{75-50}, MTC_{50-25} and MTC_{25-RV}

a: %FVC: Percent of forced vital capacity to predicted vital capacity obtained from Baldwin's equation, $FEV_{1.0\%}$: percent of first One-second volume in maximal expiratory volume-time curve, PFR: peak flow rate in maximal expiratory flow volume curve (MEFV curve), $\dot{V}_{75}$: flow rate at 75% of FVC in MEFV curve, $\dot{V}_{50}$: flow rate at 50% of FVC in MEFV curve, $\dot{V}_{25}$: flow rate at 25% of FVC in MEFV curve, $\dot{V}_{10}$: flow rate at 10% of FVC in MEFV curve, $\dot{V}_{50}/\dot{V}_{25}$: ratio of $\dot{V}_{50}$ to $\dot{V}_{25}$, MTC_{75-50}: mean time constant (MTC) in the range of lung volume, 75-50% of FVC in MEFV curve, MTC_{50-25}: MTC in the range of lung volume, 50-25% of FVC in MEFV curve, MTC_{25-RV}: MTC in the range of lung volume, 25-RV% of FVC in MEFV curve.

charts with a sharp PFR was selected from those obtained. The chart obtained at the first measurement was never used for calculation. The eleven pulmonary function parameters calculated were two MEVT (%FVC and $FEV_{1.0\%}$), six MEFV (PFR, $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$, $\dot{V}_{10}$ and $\dot{V}_{50}/\dot{V}_{25}$), and three MTC ($MTC_{75-50}$, MTC_{50-25} and MTC_{25-RV}) were divided into seven groups (Table 2).

Statistical analysis. The data were analyzed by multivariate analysis including the correlation coefficient matrix computation, the test for mean values in the multivariates, and the linear discriminant analysis by the APSP (2). The significance test for the difference in two correlation coefficients between the healthy adults and the asthmatic patients was performed. In the APSP, a set of parameters was selected at every step in order to maximize the Mahalanobis distance in all the combinations of assigned parameters, *i.e.*, the number of parameters was four at the fourth step, seven at the seventh step, and so on. The Mahalanobis distance and the probability of misclas-

Table 3 Results of pulmonary function tests in healthy adults and asthmatic patients

	Parameters[a]		Healthy adults		Asthmatic patients		t-test[c]
			Mean value and U. S. D.[b]		Mean value and U. S. D.		
1	%FVC	(%)	110.7	9.5	105.1	15.9	1.58 (−)
2	$FEV_{1.0\%}$	(%)	86.6	6.4	72.9	14.8	4.40 (***)
3	PFR	(L/sec)	10.7	1.4	8.4	2.4	4.33 (***)
4	$\dot{V}_{75}$	(L/sec)	9.3	1.5	5.6	2.6	6.44 (***)
5	$\dot{V}_{50}$	(L/sec)	5.9	1.4	3.2	1.9	6.22 (***)
6	$\dot{V}_{25}$	(L/sec)	2.5	0.8	1.3	0.8	5.68 (***)
7	$\dot{V}_{10}$	(L/sec)	1.0	0.6	0.5	0.4	3.79 (***)
8	$\dot{V}_{50}/\dot{V}_{25}$	(L/sec)	2.5	0.4	2.7	0.6	1.46 (−)
9	MTC_{75-50}	(1/sec)	2.85	0.89	2.19	0.80	2.94 (**)
10	MTC_{50-25}	(1/sec)	2.99	0.90	1.72	0.94	5.23 (***)
11	MTC_{25-RV}	(1/sec)	2.15	0.78	1.20	0.74	4.72 (***)

a: Detail explanation of parameters are described in Table 2.
b: U. S. D.: Unbiased standard deviation.
c: (*** or **): Statistically significant at the critical level of 0.1% or 1%, (−): Not significant at the critical level of 5%.

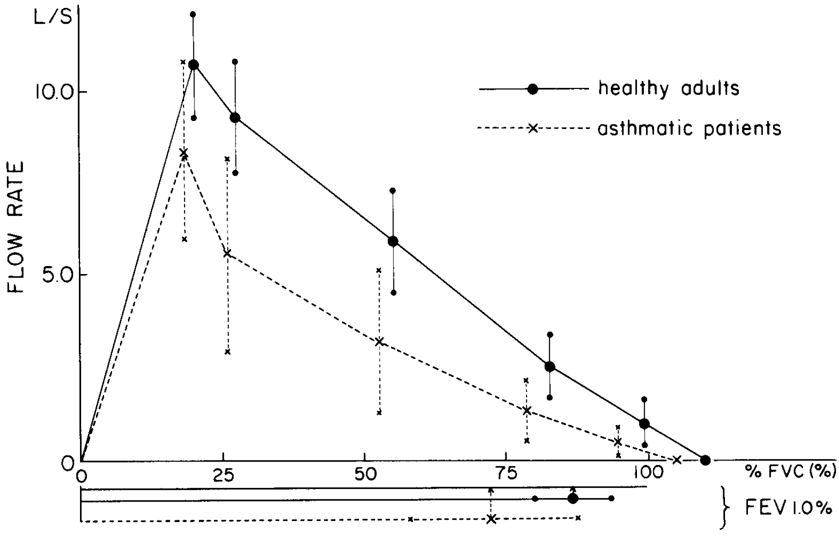

Fig. 1 MEVT and MEFV parameters in healthy adults and asthmatic patients.

sification were computed at every step, although the Mahalanobis distance was not used for this study. All the multivariate analyses were performed by means of electronic computer (NEC ACOS 700-S) at Okayama University Computer Center.

Results

The results of the pulmonary function tests are shown in Table 3 and Fig. 1. The mean values of maximal expiratory flow-volume ($\dot{V}_{75}$, $\dot{V}_{50}$ and $\dot{V}_{25}$) and mean time constant (MTC_{50-25} and MTC_{25-RV}) obtained from asthmatic patients were lower than those from healthy adults. Other parameters, for example, $FEV_{1.0\%}$, PFR, $\dot{V}_{10}$ and MTC_{75-50} were also lower. The difference in mean values of those parameters were statistically significant except for %FVC and $\dot{V}_{50}/\dot{V}_{25}$.

Correlation coefficient matrices among pulmonary function parameters for healthy adults and asthmatic patients are shown in Table 4-1 and Table 4-2. Correlation coefficients with high values of coefficients of determination ($r^2 = 0.50$) were found between the following parameters: $FEV_{1.0\%}$ vs. flow rate parameters of $\dot{V}_{75}$, $\dot{V}_{50}$, $\dot{V}_{25}$ and $\dot{V}_{10}$; $FEV_{1.0\%}$ vs. MTC_{25-RV}; $\dot{V}_{50}$ vs. $\dot{V}_{25}$, MTC_{50-25} and MTC_{25-RV}; and $\dot{V}_{25}$ vs. $\dot{V}_{10}$ and MTC_{25-RV}. Correlation coefficients among those parameters for asthmatic patients were higher than those of corresponding pairs of parameters in healthy adults. The number of coefficients with high values of coefficients of determination ($r^2 = 0.50$) was also greater in asthmatic patients than in healthy adults.

Table 4-1 Correlation coefficient matrix in healthy adults

	%FVC	$FEV_{1.0\%}$	PFR	$\dot{V}_{75}$	$\dot{V}_{50}$	$\dot{V}_{25}$	$\dot{V}_{10}$	$\dot{V}_{50}/\dot{V}_{25}$	MTC_{75-50}	MTC_{50-25}	MTC_{25-RV}
%FVC	1.000	−0.419	0.293	−0.061	−0.271	−0.209	−0.010	0.049	−0.065	−0.618	−0.546
$FEV_{1.0\%}$		1.000	0.416	0.721	0.712	0.885	0.768	−0.647	0.196	0.463	0.876
PFR			1.000	0.711	0.436	0.566	0.530	−0.338	0.322	0.364	0.356
$\dot{V}_{75}$				1.000	0.688	0.757	0.599	−0.409	0.494	0.391	0.655
$\dot{V}_{50}$					1.000	0.827	0.505	−0.186	−0.244	0.817	0.797
$\dot{V}_{25}$						1.000	0.777	−0.669	0.415	0.455	0.922
$\dot{V}_{10}$							1.000	−0.626	0.163	0.110	0.657
$\dot{V}_{50}/\dot{V}_{25}$								0.000	−0.323	0.200	−0.578
MTC_{75-50}									1.000	−0.293	0.057
MTC_{50-25}										1.000	0.626
MTC_{25-RV}											1.000

Table 4-2 Correlation coefficient matrix in asthmatic patients

	%FVC	$FEV_{1.0\%}$	PFR	$\dot{V}_{75}$	$\dot{V}_{50}$	$\dot{V}_{25}$	$\dot{V}_{10}$	$\dot{V}_{50}/\dot{V}_{25}$	MTC_{75-50}	MTC_{50-25}	MTC_{25-RV}
%FVC	1.000	0.256	0.703	0.458	0.418	0.317	0.133	−0.062	0.140	0.282	0.135
$FEV_{1.0\%}$		1.000	0.683	0.899	0.892	0.881	0.759	−0.358	0.732	0.861	0.913
PFR			1.030	0.861	0.842	0.714	0.481	−0.081	0.546	0.779	0.598
$\dot{V}_{75}$				1.000	0.968	0.904	0.726	−0.273	0.760	0.896	0.854
$\dot{V}_{50}$					1.000	0.935	0.749	−0.316	0.600	0.928	0.885
$\dot{V}_{25}$						1.000	0.919	−0.555	0.567	0.770	0.967
$\dot{V}_{10}$							1.000	−0.656	0.479	0.536	0.915
$\dot{V}_{50}/\dot{V}_{25}$								1.000	−0.054	−0.077	−0.582
MTC_{75-50}									1.000	0.622	0.609
MTC_{50-25}										1.000	0.771
MTC_{25-RV}											1.000

Table 5 Results of significantce test in correlation coefficients between healthy adults and asthmatic patients[a]

	%FVC	$FEV_{1.0\%}$	PFR	$\dot{V}_{75}$	$\dot{V}_{50}$	$\dot{V}_{25}$	$\dot{V}_{10}$	$\dot{V}_{50}/\dot{V}_{25}$	MTC_{75-50}	MTC_{50-25}	MTC_{25-RV}
%FVC		**	**	**	***	*	—	—	—	—	—
$FEV_{1.0\%}$			—	**	*	—	—	—	***	***	—
PFR				—	***	—	—	—	—	**	—
$\dot{V}_{75}$					***	*	—	—	—	***	*
$\dot{V}_{50}$						*	—	—	***	*	—
$\dot{V}_{25}$							*	—	—	***	—
$\dot{V}_{10}$								—	—	*	***
$\dot{V}_{50}/\dot{V}_{25}$									—	—	*
MTC_{75-50}										***	***
MTC_{50-25}											—
MTC_{25-RV}											

a: *** $P < 0.01$, ** $0.01 \leqq P < 0.05$, * $0.05 \leqq P < 0.10$, — $P \geqq 0.10$.

Table 6 Probabilities of misclassification obtained with one parameter.

Rank	Parameter	Probability of misclassification (%)
1	$\dot{V}_{75}$	18.78
2	$\dot{V}_{50}$	20.01
3	$\dot{V}_{25}$	23.35
4	MTC_{50-25}	24.59
5	MTC_{25-RV}	26.45
6	$FEV_{1.0\%}$	26.58
7	PFR	27.66
8	$\dot{V}_{10}$	31.81
9	MTC_{75-50}	35.04
10	%FVC	41.37
11	$\dot{V}_{50}/\dot{V}_{25}$	43.03

Correlation coefficient matrices of healthy adults and asthmatic patients were markedly different. Results of the significance test for the difference in correlation coefficients between healthy adults and asthmatic patients are shown in Table 5. The coefficients between MEVT and flow rate parameters in high lung volumes were significantly different between the two groups, and the coefficients between MTC_{50-25} and the other parameters were also significantly different between the two groups.

The effectiveness of the linear discriminant analysis by APSP was evaluated by the probability of calculated misclassification. The parameter groups, of which the Mahalanobis distances were maximized, were selected at every step. The results of the eleven-parameter discriminant analyses using single parameters are shown in Table 6. Flow rate parameters ranked higher, *i.e.*, $\dot{V}_{75}$ was the first, $\dot{V}_{50}$ the second, and $\dot{V}_{25}$ the third with probabilities of 18.78 %, 20.01% and 23.35%, respectively. MTC parameters (MTC_{50-25} and MTC_{25-RV}) also ranked higher.

The result of the discriminant analyses in the APSP using eleven parameters is shown in Table 7-1. At every step, the probability of misclassification was calculated, and the most effective set of parameters was selected. The probability of misclassification was lower from the first to the fourth step, but decreased little from the fifth step to the final step. New parameters were added from the first to the fourth step ($\dot{V}_{75}$, $FEV_{1.0\%}$, PFR and MTC_{75-50}) respectively. The remaining sets of parameters from the fifth to the final step are also shown in Table 7-1. In the remaining sets, the number of added parameters was always one, and parameters except for the newly added one coincided with those at the former step. Therefore, the set of newly added parameters was arranged in the descending order of effectiveness. The result of the analysis with the set of new added parameters and the probability of misclassification at every step are shown in Table 7-2. Newly added parameters ranged in the following order:

Table 7-1 Selection of the set of parameters and the probability of misclassification at each step in discriminant analysis by APSP.

Step	Parameter[a] 1	2	3	4	5	6	7	8	9	10	11	Probability of misclassification (%)
1	–	–	–	(*)	–	–	–	–	–	–	–	18.78
2	–	(*)	–	*	–	–	–	–	–	–	–	17.91
3	–	*	(*)	*	–	–	–	–	–	–	–	16.70
4	–	*	*	*	–	–	–	–	(*)	–	–	15.65
5	–	*	*	*	–	–	–	(*)	*	–	–	15.60
6	–	*	*	*	(*)	–	–	*	*	–	–	15.56
7	(*)	*	*	*	*	–	–	*	*	–	–	15.49
8	*	*	*	*	*	–	–	*	*	–	(*)	15.47
9	*	*	*	*	*	–	(*)	*	*	–	*	15.46
10	*	*	*	*	*	(*)	*	*	*	–	*	15.46
11	*	*	*	*	*	*	*	*	*	(*)	*	15.46

a: Parameter: 1; %FVC, 2; $FEV_{1.0\%}$, 3; PFR, 4; $\dot{V}_{75}$, 5; $\dot{V}_{50}$, 6; $\dot{V}_{25}$, 7; $\dot{V}_{10}$, 8; $\dot{V}_{50}/\dot{V}_{25}$, 9; MTC_{75-50}, 10; MTC_{50-25}, 11; MTC_{25-RV}. (*): A newly added parameter which was one of the parameters selected at each step.

Table 7-2 Newly added parameters and the probabilities of misclassification

Step	Newly added parameter	Probability of misclassification (%)
1	$\dot{V}_{75}$	18.78
2	$FEV_{1.0}$	17.91
3	PFR	16.70
4	MTC_{75-50}	15.65
5	$\dot{V}_{50}/\dot{V}_{25}$	15.60
6	$\dot{V}_{50}$	15.56
7	%FVC	15.49
8	MTC_{25-RV}	15.47
9	$\dot{V}_{10}$	15.46
10	$\dot{V}_{25}$	15.46
11	MTC_{50-25}	15.46

Table 8 Comparison of the final probabilities of misclassification among parameter groups

Rank	Parameter group	Probability of misclassification (%)
1	All parameter group	15.46
2	MEVT and MEFV parameter group	15.77
3	%FVC and flow rate related parameter group	15.99
4	Flow rate related parameter group	16.26
5	MEFV parameter group	17.45
6	MTC parameter group	22.14
7	MEVT parameter group	25.91

$\dot{V}_{75}$ was the first, $FEV_{1.0\%}$ the second, PFR the third, and MTC_{75-50} the fourth. These parameters were all in high lung volumes. The ranking of the remaining parameters is shown in Table 7-2.

The discriminant analysis in the APSP was also performed in seven-parameter groups as a numerical analysis of the MEFV curve. The results of the final probabilities of misclassification in the seven discriminant analyses are shown in Table 8. The probability of misclassification in the MEVT parameter group was 25.91%, the highest percentage of all the groups. The probability of misclassification in the five groups was close, except in the MEVT and MTC parameter groups. The probability in the all-parameter group was 15.46%, the lowest. The probability in the %FVC and flow rate-related parameter group, which was considered to be the numerical alternative closest to the MEFV curve, was 15.99%. This probability was similar to that in the all-parameter group.

Discussion

MEVT, MEFV and other pulmonary function tests enable us to estimate the extent of ventilatory abnormality in bronchial asthma. In the field of public health, MEVT and MEFV measurements are useful, because they are easy to perform and also because we can indicate the extent of bronchoconstriction.

Though spirometric data of asthmatic patients in the asymptomatic state are considered close to those in healthy subjects, MEFV curves in patients are different from those in healthy subjects. The profile analysis of the MEFV curve is useful, because the sudden drop in flow rate near $\dot{V}_{75}$ and the change in flow rate PFR to V_{50} are marked (6, 7). Therefore, FVC, flow rates and flow rate changes in high lung volumes are regarded as important parameters in the profile analysis of the MEFV curve.

We have performed linear discriminant analysis as a numerical analysis of MEFV curves in discriminating asthmatic patients from healthy adults. The probabilities of misclassification have been discussed (3, 4). In the FSP, $\dot{V}_{50}$ gave the lowest probability of misclassification with six parameters (two MEVT and four MEFV parameters) (3). We have also used linear discriminant analysis employing the APSP with eleven parameters (by adding three MTC parameters), because we expected that MTC parameters would act effectively to lower the probabilities of misclassification (4). MTC parameters were effective.

In this study, the results of the discriminant analysis was evaluated to compare differences in correlation coefficients between healthy adults and asthmatic patients, to select effective parameters, to select effective parameter groups, and to find the significance of MEFV curves according to probabilities of misclassification.

In the correlation coefficient matrix, correlation coefficients in asthmatic patients were significantly higher than those in healthy adults. The healthy subjects studied in this work were those without subjective respiratory symptoms, past history of respiratory diseases, or physical abnormalities. Some undetermined factors which influenced the flow rates in healthy subjects explained the lower values of correlation coefficients found in healthy subjects. The high correlation coefficients found in asthmatic patients could be due to the presence of a common factor of airway obstruction in those patients.

In the linear discriminant analysis based on single parameters, $\dot{V}_{75}$ gave the lowest probability of misclassification, $\dot{V}_{50}$ the second, and $\dot{V}_{25}$ the third. These three flow rate parameters are the most important, although any one of the parameters can be used to differentiate asthmatic patients from healthy adults in discriminant analysis. Since many parameters are involved in the profile of the MEFV curve, as many parameters as possible should be used in discriminant analysis using the MEFV curve.

In the discriminant analysis by the APSP using eleven parameters, $\dot{V}_{75}$, $FEV_{1.0\%}$, PFR and MTC_{75-50} were added one by one from the first to the fourth step. These four parameters were considered effective in the discriminant analysis between healthy adults and asthmatic patients, because the lowering of the probability of misclassification is minimized. The four parameters selected at the fourth step in the APSP using the eleven parameters were different from the four parameters determined on the basis of the rank orders of the probability using one parameter. The discrepancy is mainly due to the difference in the procedure of the discriminant analysis. In the APSP mentioned above, the set of parameters is selected to maximize Mahalanobis distance of all eleven parameters at each step. When a set of parameters is selected at a step and the remaining parameters in the set except the newly added one are the same as the set of parameters selected at the previous step, the set of newly added parameters may be considered to be arranged in the order of effectiveness. Therefore, effective parameters in the eleven-parameter analyses using single parameters are not always the same as the best set of parameters in the APSP. In the discriminant analysis using all eleven parameters, parameters selected in higher ranks of the order of newly added ones were mainly flow rates or flow rate-related ones in high lung volumes. In conclusion, these flow rate parameters in high lung volumes were considered to be the most effective in the discriminant analysis of healthy adults and asthmatic patients.

Though Hyatt (8) stated that the flow rates near the total lung capacity (TLC) were effort dependent and that the maxima of flow rates ($\dot{V}_{max}$) were recorded over approximately the lower two-thirds of the vital capacity, he did not mention whether PFR was $\dot{V}_{max}$ or not, nor mention whether $\dot{V}_{75}$ was $\dot{V}_{max}$ or not. The difference in pressure between $\dot{V}_{75}$ and $\dot{V}_{67}$ (flow rate at 67% of FVC, two-thirds of the vital capacity mentioned above) may be negligible. McFadden *et al.* (9) reported that before they treated their patients, they observed plateaus in the pressure-flow curves up to volumes 0.3 liter below TLC. The applied force generated by respiratory muscles in each subject had a limitation and was considered to be maximal. Therefore, flow rates from PFR to $\dot{V}_{75}$ were considered to be $\dot{V}_{max}$ as well as those in low lung volumes. The present author has experienced that MEFV charts fit each other well in many trials.

In the numerical analyses of the MEFV profile, the following points were discussed: the effectiveness of MEFV parameters, the importance of $FEV_{1.0\%}$ and the significance of the %FVC and flow rate-related parameter group. The probabilities of misclassification were compared among the seven groups. In the five groups containing MEFV parameters, the probabilities ranged from 15.46% to 17.45%. Therefore, MEFV parameters were considered effective in the discrimination. The probability of misclassification was compared between the MEVT and MEFV parameter group and the %FVC and flow rate-related parameter group. The probability in the former (15.77%) was lower than in the latter (15.99%). In the former, $FEV_{1.0\%}$ was one of the components, but it was not a component in the latter. On the other hand, the number of parameters used in the discriminant analysis was smaller in the former (eight) than that in the latter (ten). This fact indicates the importance of $FEV_{1.0\%}$ in the discrimination. Eighteen discriminant analyses of healthy adults and asthmatic patients were all the numerical analyses of the MEFV analysis. The probability of misclassification represented the effectiveness of the profile analysis of the MEFV curve. In the seven-parameter discriminant analyses using pulmonary function parameter groups, the probabilities of the upper three parameter groups were closest. Of the three groups, the %FVC and flow rate-related parameter group was the most approximate numerical alternative of the MEFV curve. Therefore, the %FVC and flow rate-related parameter group was considered to be one of the closest alternatives.

On the basis of these data, we may emphasize the importance of the flow rates in high lung volumes, especially $\dot{V}_{75}$ as the most important parameter.

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