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## Applicability of American and European Spirometry Repeatability Criteria to Korean Adults

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**Background:** The objective of this study was to evaluate the clinical applicability of the repeatability criteria recommended by the American Thoracic Society/European Respiratory Society (ATS/ERS) spirometry guidelines and to determine which factors affect the repeatability of spirometry in Korean adults.

**Methods:** We reviewed the spirometry data of 4,663 Korean adults from the Korean National Health and Nutritional Examination Survey (KNHANES) Chronic Obstructive Pulmonary Disease Cohort (COPD cohort) and the Community-based Cohort Study VI-Fishing village/Islands (community cohort). We measured the anthropometric factors and differences between the highest and second-highest FVC (dFVC) and FEV<sub>1</sub> (dFEV<sub>1</sub>) from prebronchodilator spirometry. Analyses included the distribution of dFVC and dFEV<sub>1</sub>, comparison of the values meeting the 1994 ATS repeatability criteria with the values meeting the 2005 ATS/ERS repeatability criteria, and the performance of linear regression for evaluating the influence of subject characteristics and the change of criteria on the spirometric variability.

**Results:** About 95% of subjects were able to reproduce FVC and FEV<sub>1</sub> within 150 ml. The KNHANES based on the 1994 ATS guidelines showed poorer repeatability than the COPD cohort and community cohort based on the 2005 ATS/ERS guidelines. Demographic and anthropometric factors had little effect on repeatability, explaining only 0.5 to 3%.

**Conclusion:** We conclude that the new spirometry repeatability criteria recommended by the 2005 ATS/ERS guidelines is also applicable to Korean adults. The repeatability of spirometry depends little on individual characteristics when an experienced technician performs testing. Therefore, we suggest that sustained efforts for public awareness of new repeatability criteria, quality control of spirograms, and education of personnel are needed for reliable spirometric results. (*Tuberc Respir Dis* 2007;63:405-411)

**Key Words:** Spirometry, Repeatability, Quality control

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, FEV<sub>1</sub> FVC (repeatability)

2005 / (American Thoracic Society/European Respiratory Society, ATS/ERS) 1, 1994 ATS 2, ATS/ERS

, 2001 1994 ATS dFVC dFEV<sub>1</sub> 200 ml, COPD 2005 ATS/ERS dFVC dFEV<sub>1</sub> 150 ml, 3. 통계 2001, COPD

대상 및 방법

1. 연구대상

가 2001 (Korean National Health and Nutritional Survey, KNHANES) (COPD) VI- / (

1994 ATS 2001 dFVC, dFVC%, dFEV<sub>1</sub>, dFEV<sub>1</sub>,% 90 95, 2005 ATS/ERS COPD dFVC, dFVC%, dFEV<sub>1</sub>, dFEV<sub>1</sub>,% 90 95 1994 ATS 2005 ATS/ERS

2. 연구방법

, 2001 1994 ATS, COPD 2005 ATS/ERS 2001

(multiple regression analysis)

Dry rolling seal spirometer (Model 2130, Sensor-Medics, Yorba Linda, CA, USA) COPD

결 과

가 가 3 가 가 FVC (dFVC) 가 FEV<sub>1</sub> (dFEV<sub>1</sub>) dFVC (dFVC/가 FVC×100, dFVC,%) dFEV<sub>1</sub> (dFEV<sub>1</sub>/가 FEV<sub>1</sub>×100, dFEV<sub>1</sub>,%) dFVC dFEV<sub>1</sub>

4,663 46.8 2,195 (47.1%), 2,468 (52.9%) 63.9% 2,980 COPD 11.1% 517 63 가 (Table 1, 2). dFVC dFEV<sub>1</sub> 95 COPD (dFVC) dFVC dFEV<sub>1</sub> 95 167 ml 152 ml (COPD) dFVC dFEV<sub>1</sub> 95 4.4% 4.9% COPD dFVC,% dFEV<sub>1</sub>,% 95 5.4% (Table 3, 4). 4.5%

Table 1. Characteristics of subjects between groups (I)

|                         | KNHANES*<br>(n=3,021)<br>Mean (5th~95th) | Community cohort <sup>†</sup><br>(n=1,543)<br>Mean (5th~95th) | COPD cohort <sup>‡</sup><br>(n=99)<br>Mean (5th~95th) | Total<br>(n=4,663)<br>Mean (5th~95th) |
|-------------------------|--|---|---|---------------------------------------|
| Height (cm)             | 162.8 (149.0~177.6)                      | 159.3 (146.5~173.5)   | 166.3 (159.0~175.0)                                   | 161.8 (147.9~176.5)                   |
| Weight (kg)             | 62.5 (47.1~81.3)                         | 62.5 (48.0~80.9)  | 64.0 (48.7~85.0)                                      | 62.5 (47.5~81.1)                      |
| Age (yr)                | 42.5 (22.0~67.0)                         | 54.0 (42.0~67.0)  | 63.9 (51.0~74.0)                                      | 46.8 (23.0~68.0)                      |
| FVC (L)                 | 3.9 (2.5~5.5)                            | 3.5 (2.4~4.9)   | 3.49 (2.2 ~4.9)                                       | 3.8 (2.4~5.4)                         |
| FEV <sub>1</sub> (L)    | 3.2 (1.9~4.6)                            | 2.7 (1.8~3.8)   | 1.6 (0.8~2.6)   | 3.0 (1.8~4.4)                         |
| FEV <sub>1</sub> % pred | 96.8 (74.1~116.6)                        | 93.8 (71.3~114.8)   | 51.5 (26.7~80.6)                                      | 94.9 (69.8~116.0)                     |
| dFVC (ml)               | 59.3 (4.0~167.0)                         | 57.4 (3.0~142.0)  | 58.6 (0.0~150.0)                                      | 58.6 (4.0~159.0)                      |
| dFVC (%)                | 1.6 (0.1~4.4)                            | 1.7 (0.1~4.5)   | 1.7 (0.0~3.9)   | 1.6 (0.1~4.4)                         |
| dFEV <sub>1</sub> (ml)  | 53.8 (4.0~152.0)                         | 50.8 (3.0~134.0)  | 27.6 (0.0~70.0)                                       | 52.2 (3.0~144.0)                      |
| dFEV <sub>1</sub> (%)   | 1.8 (0.1~4.9)                            | 2.0 (0.1~5.4)   | 1.9 (0.0~7.1)   | 1.8 (0.1~5.2)                         |

dFVC: the difference between the highest and second-highest FVC; dFEV<sub>1</sub>: the difference between the highest and second-highest FEV<sub>1</sub>; dFVC (%): dFVC / the highest FVC; dFEV<sub>1</sub> (%): dFEV<sub>1</sub> / the highest dFEV<sub>1</sub>; n: number.

\*Korean National Health and Nutritional Examination Survey, <sup>†</sup>A Community-based Cohort Study VI-Fishing village/Islands, <sup>‡</sup>Chronic Obstructive Pulmonary Disease Cohort.

Table 2. Characteristics of subjects between groups (II)

|                        | KNHANES*<br>(n=3,021) | Community cohort <sup>†</sup><br>(n=1,543) | COPD cohort <sup>‡</sup><br>(n=99) | Total<br>(n=4,663) |
|------------------------|-----------------------|--|------------------------------------|--------------------|
| Gender                 |                       |  |                                    |                    |
| Male                   | 1,419 (46.9%)         | 677 (43.9%)                                | 99 (100%)                          | 2,195 (47.1%)      |
| Female                 | 1,602 (53.1%)         | 866 (56.1%)                                | 0 (0%)                             | 2,468 (52.9%)      |
| Smoking status         |                       |  |                                    |                    |
| Non-smoker             | 1,169 (38.7%)         | 509 (33.0%)                                | 5 (5.1%)                           | 1,683 (36.1%)      |
| Smoker                 | 1,852 (61.3%)         | 1,034 (67.0%)                              | 94 (94.9%)                         | 2,980 (63.9%)      |
| Education              |                       |  |                                    |                    |
| <9 years               | 940 (31.2%)           | 914 (59.3%)                                | 45 (45.5%)                         | 1,899 (40.8%)      |
| 10~12 years            | 1,135 (37.6%)         | 453 (29.4%)                                | 31 (31.3%)                         | 1,619 (34.8%)      |
| >13 years              | 942 (31.2%)           | 174 (11.3%)                                | 23 (23.2%)                         | 1,139 (24.4%)      |
| FEV <sub>1</sub> / FVC |                       |  |                                    |                    |
| <0.7                   | 229 (7.6%)            | 189 (12.3%)                                | 99 (100%)                          | 517 (11.1%)        |
| ≥0.7                   | 2,792 (92.4%)         | 1,354 (87.7%)                              | 0 (0%)                             | 4,146 (88.9%)      |

dFVC: the difference between the highest and second-highest FVC; dFEV<sub>1</sub>: the difference between the highest and second-highest FEV<sub>1</sub>; dFVC (%): dFVC / the highest FVC; dFEV<sub>1</sub> (%): dFEV<sub>1</sub> / the highest dFEV<sub>1</sub>; n: number.

\*Korean National Health and Nutritional Examination Survey, <sup>†</sup>A Community-based Cohort Study VI-Fishing village/Islands, <sup>‡</sup>Chronic Obstructive Pulmonary Disease Cohort.

dFVC  
200 ml  
2.9%  
2.4%  
, 150 ml  
6.7%  
가 .  
5.3%  
가 .  
COPD  
200 ml  
200 ml  
1.9% 0.0%  
, 150 ml  
2.0%  
, 150 ml  
4.3%  
3.4% 0.0%  
3.0%  
가 (Table 5). dFEV<sub>1</sub>  
가 (Table 6).

dFVC  
dFVC,%  
dFEV<sub>1</sub>  
dFEV<sub>1</sub>,%

R<sup>2</sup> 3%  
(0.5~3.0%).

Table 3. Spirometry repeatability (2001 KNHANES)

|                        | Mean | SD   | Percentile |       |       |
|------------------------|------|------|------------|-------|-------|
|                        |      |      | Median     | 90th  | 95th  |
| dFEV <sub>1</sub> (ml) | 53.8 | 61.7 | 38.0       | 113.0 | 152.0 |
| dFEV <sub>1</sub> (%)  | 1.8  | 2.0  | 1.2        | 3.8   | 4.9   |
| dFVC (ml)              | 59.3 | 63.1 | 42.0       | 128.0 | 167.0 |
| dFVC (%)               | 1.6  | 1.8  | 1.1        | 3.4   | 4.4   |

dFVC: the difference between the highest and second-highest FVC; dFEV<sub>1</sub>: the difference between the highest and second-highest FEV<sub>1</sub>; dFVC (%): dFVC / the highest FVC; dFEV<sub>1</sub> (%): dFEV<sub>1</sub> / the highest dFEV<sub>1</sub>.

Table 4. Spirometry repeatability (Community and COPD Cohort)

|                        | Mean | SD   | Percentile |      |      |
|------------------------|------|------|------------|------|------|
|                        |      |      | Median     | 90th | 95th |
| dFEV <sub>1</sub> (ml) | 49.4 | 52.7 | 37         | 105  | 133  |
| dFEV <sub>1</sub> (%)  | 2.0  | 2.4  | 1.4        | 4.2  | 5.4  |
| dFVC (ml)              | 57.4 | 60.3 | 43.0       | 118  | 142  |
| dFVC (%)               | 1.7  | 2.2  | 1.3        | 3.6  | 4.5  |

dFVC: the difference between the highest and second-highest FVC; dFEV<sub>1</sub>: the difference between the highest and second-highest FEV<sub>1</sub>; dFVC (%): dFVC / the highest FVC; dFEV<sub>1</sub> (%): dFEV<sub>1</sub> / the highest dFEV<sub>1</sub>.

Table 5. Numbers of subjects meeting different repeatability criteria

| Repeatability criteria | KNHANES*<br>3,021 (100%) | Community cohort <sup>†</sup><br>1,543 (100%) | COPD cohort <sup>‡</sup><br>99 (100%) |
|------------------------|--------------------------|---|---------------------------------------|
| dFVC                   |                          |   |                                       |
| < 200 ml               | 2,933 (97.1%)            | 1,512 (98.0%)                                 | 97 (98.0%)                            |
| ≥ 200 ml               | 88 (2.9%)                | 31 (2.0%)                                     | 2 (2.0%)                              |
| dFVC                   |                          |   |                                       |
| < 150 ml               | 2,818 (93.8%)            | 1,476 (95.7%)                                 | 96 (97.0%)                            |
| ≥ 150 ml               | 203 (6.7%)               | 67 (4.3%)                                     | 3 (3.0%)                              |

dFVC: the difference between the highest and second-highest FVC.

\*Korean National Health and Nutritional Examination Survey, <sup>†</sup>A Community-based Cohort Study VI-Fishing village/Islands, <sup>‡</sup>Chronic Obstructive Pulmonary Disease Cohort.

Table 6. Numbers of subjects meeting different repeatability criteria

| Repeatability criteria | KNHANES*<br>3,021 (100%) | Kangwha<br>1,543 (100%) | COPD cohort <sup>†</sup><br>99 (100%) |
|------------------------|--------------------------|-------------------------|---------------------------------------|
| dFEV <sub>1</sub>      |                          |                         |                                       |
| < 200 ml               | 2,948 (97.6%)            | 1,513 (98.1%)           | 499 (100.0%)                          |
| ≥ 200 ml               | 73 (2.4%)                | 30 (1.9%)               | 0 (0.0%)                              |
| dFEV <sub>1</sub>      |                          |                         |                                       |
| < 150 ml               | 2,861 (94.7%)            | 1,490 (96.6%)           | 99 (100.0%)                           |
| ≥ 150 ml               | 160 (5.3%)               | 53 (3.4%)               | 0 (0.0%)                              |

dFEV<sub>1</sub>: the difference between the highest and second-highest FEV<sub>1</sub>.

\*Korean National Health and Nutritional Examination Survey, <sup>†</sup>Chronic Obstructive Pulmonary Disease Cohort.

Table 7. Linear regression models predicting higher spirometry variability

|                        | Male | Height*<br>(cm) | Age <sup>†</sup><br>(years) | Weight <sup>‡</sup><br>(kg) | Smoker | Edu.1 <sup>§</sup> | Edu.2 <sup>  </sup> | FEV <sub>1</sub> /FVC<br>< 0.7 | 1994 ATS<br>criteria | R <sup>2</sup> (%) <sup>¶</sup> |
|------------------------|------|-----------------|-----------------------------|-----------------------------|--------|--------------------|---------------------|--------------------------------|----------------------|---------------------------------|
| dFVC (ml)              | NS   | NS              | 0.18                        | 0.28                        | NS     | NS                 | NS                  | 17.62                          | 5.16                 | 1.6%                            |
| dFVC (%)               | NS   | -0.02           | 0.01                        | 0.008                       | NS     | NS                 | NS                  | 0.55                           | 0.13                 | 2.9%                            |
| dFEV <sub>1</sub> (ml) | NS   | NS              | -0.27                       | NS                          | NS     | NS                 | NS                  | NS                             | NS                   | 0.54%                           |
| dFEV <sub>1</sub> (%)  | NS   | -0.02           | NS                          | NS                          | NS     | NS                 | NS                  | 0.51                           | NS                   | 1.6%                            |

dFVC: the difference between the highest and second-highest FVC; dFEV<sub>1</sub>: the difference between the highest and second-highest FEV<sub>1</sub>; dFVC (%): dFVC / the highest FVC; dFEV<sub>1</sub> (%): dFEV<sub>1</sub> / the highest dFEV<sub>1</sub>; NS: not a statistically significant factor.

\*1 cm increase in height, <sup>†</sup>1 year increase in age, <sup>‡</sup>1 kg increase in weight, <sup>§</sup>10 years ≤ educational period ≤ 12 years, <sup>||</sup>educational period ≥ 13 years, <sup>¶</sup>the total variance explained by the model.

(Table 7).

| 고찰  | ATS  | 가  | dFVC                   | dFEV <sub>1</sub>    | 가      |
|---|--|--|------------------------|----------------------|--------|
| 1994 ATS <sup>2</sup><br>dFVC가 200 ml<br>ml | dFEV <sub>1</sub><br>, 200                           | Enright <sup>3</sup>                           | 20                     | 90                   | 18,000 |
| 2005 ATS/ERS<br>dFVC가 150 ml                | dFEV <sub>1</sub><br>1.                              | 1994   | dFVC                   | dFEV <sub>1</sub>    | 가      |
| ATS <sup>2</sup>                            | 가  | dFEV <sub>1</sub>                              | 가                      | 2005 ATS/ERS         | 150 ml |
| 2005 ATS/ERS                                | 가  | dFEV <sub>1</sub>                              | dFVC                   | dFEV <sub>1</sub>    | 가      |
| 4,663 ERS                                   | 가 167 ml,  | 2005 ATS/<br>dFVC 95                           | 가                      | 가                    | 가 가    |
| COPD  | 가 142 ml<br>가 152 ml,                                | dFEV <sub>1</sub> 95<br>COPD 가                 | 가                      | COPD                 | 가      |
| 133 ml                                      | 2005 ATS/ERS   | COPD   | dFVC                   | dFEV <sub>1</sub>    | COPD   |
| dFVC dFEV <sub>1</sub> 1994                 | ATS  | dFVC dFEV <sub>1</sub><br>Enright <sup>3</sup> | 가                      | Enright <sup>3</sup> | 가      |
| 1994 ATS<br>dFVC 95<br>150 ml               | 가 180 ml, dFEV <sub>1</sub> 95                       | Enright <sup>3</sup>                           | Humerfelt <sup>8</sup> | 30                   | 46     |
| dFVC dFEV <sub>1</sub> 95                   | 가  | COPD   | 45,000<br>9.5%         | 가                    | 가      |
| 가   | 가  | COPD   | 864<br>6.8%(59 )가      | 가                    | 가      |
| 가   | FVC FEV <sub>1</sub><br>Hankinson <sup>4</sup> 6,500 | 가  | 가                      | Enright <sup>3</sup> | 가      |

Enright<sup>10</sup> 65 85 5,201 ATS/ERS (Table 3, 4, 7),  
6%, 3%, FEV<sub>1</sub>, FVC, Enright  
65 497 가 Bellia<sup>6</sup> 65 FVC<sup>3</sup>  
638 2005 ATS/ERS  
, 6 가 , FEV<sub>1</sub> 가 ,  
, FVC 가 연구배경: 2005 ATS/ERS  
가 . Enright<sup>3</sup> ,  
방 법: , COPD ,  
4,663 dFVC dFEV<sub>1</sub> , 1994  
ATS 2005 ATS/ERS  
가 가  
R<sup>2</sup> 0.5~  
3.0% dFVC dFEV<sub>1</sub> 결 과: 95% 150  
ml . 1994 ATS  
dFVC dFEV<sub>1</sub> 가 가  
3,4,8 .  
가 dFVC가 가 ,  
FEV<sub>1</sub> FVC 6  
가 가  
Enright<sup>3</sup> FEV<sub>1</sub> 가  
COPD 9,12 .  
FEV<sub>1</sub> FEV<sub>1</sub> 감사의 글

(A040153).

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