

Within-Session Variability as Quality Control for Oscillometry in Health and Disease

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Supplementary material

Table S1. Baseline FOT parameters using the ‘manual exclusion’ quality control method.

	Healthy	Asthma	COPD
Rrs5 (cmH ₂ O.s.L ⁻¹)	3.1±1.0	5.0±2.1*	5.1±1.8**
Z Score Rrs5	-0.4±3.1	1.2±1.2	1.9±1.2**
CoV(Rrs5) (%)	6.5±4.7	9.2±4.5	12.7±11.3
Xrs5.ex (cmH ₂ O.s.L ⁻¹)	-1.0±0.5	-2.9±2.8*	-4.7±4.5***
Xrs5.in-Xrs5.ex (cmH ₂ O.s.L ⁻¹)	-0.7±0.3	0.8±3.1	1.7±3.0**
Rrs5-19 (cmH ₂ O.s.L ⁻¹)	0.2±0.4	1.4±1.2**	1.7±0.8*****
AX (cmH ₂ O.L ⁻¹)	5.2±4.2	28.1±29.6*	38.7±32.4***
VT (L)	0.7±0.3	1.0±0.4	0.8±0.2

* P<0.05, *P<0.01, ***P<0.001, and ****P<0.0001 compared with health. AX: reactance area, CoV: coefficient of variation, ex: expiratory, in: inspiratory, Rrs5: resistance at 5Hz, Rrs19: resistance at 19 Hz, VT: tidal volume, Xrs5: reactance at 5 Hz.

Table S2. Baseline FOT parameters using the ‘combined’ quality control method.

	Healthy	Asthma	COPD
Rrs5 (cmH ₂ O.s.L ⁻¹)	3.1±1.0	4.9±2.0*	5.0±1.7**
Z Score Rrs5	-0.5±3.0	1.2±1.2	1.8±1.2**
CoV(Rrs5) (%)	6.7±4.7	9.8±5.7	12.6±11.2
Xrs5 (cmH ₂ O.s.L ⁻¹)	-1.3±0.5	-2.8±2.2	-3.9±3.0***
Xrs5.in-Xrs5.ex (cmH ₂ O.s.L ⁻¹)	-0.7±0.3	0.8±3.1	1.7±3.0**
Rrs5-19 (cmH ₂ O.s.L ⁻¹)	0.2±0.4	1.4±1.2***	1.7±0.8****
AX (cmH ₂ O.L ⁻¹)	4.3±2.9	28.4±30.1*	38.6±32.4***
VT (L)	0.7±0.3	1.0±0.4	0.8±0.2

* P<0.05, **P<0.01, ***P<0.001, and ****P<0.0001 compared with health. AX: reactance area, CoV: coefficient of variation, ex: expiratory, in: inspiratory, Rrs5: resistance at 5Hz, Rrs19: resistance at 19 Hz, VT: tidal volume, Xrs5: reactance at 5 Hz.

Table S3. Baseline FOT parameters using the ‘none’ quality control method.

	Healthy	Asthma	COPD
Rrs5 (cmH ₂ O.s.L ⁻¹)	3.1±1.0	4.9±2.0*	5.1±1.8**
Z Score Rrs5	-0.4±3.0	1.2±1.2	1.9±1.2**
CoV(Rrs5) (%)	6.6±4.6	9.8±5.4	12.6±11.3
Xrs5 (cmH ₂ O.s.L ⁻¹)	-1.3±0.5	-2.8±2.2	-3.9±3.0***
Xrs5.in-Xrs5.ex (cmH ₂ O.s.L ⁻¹)	-0.7±0.3	0.8±3.1	1.7±3.0**
Rrs5-19	0.2±0.4	1.4±1.2**	1.8±0.9****
AX (cmH ₂ O.L ⁻¹)	5.2±4.2	30.1±29.8**	38.7±32.4**
VT (L)	0.7±0.3	1.0±0.4	0.8±0.2

P<0.01, *P<0.001, and ****P<0.0001 compared with health. AX: reactance area, CoV: coefficient of variation, ex: expiratory, in: inspiratory, Rrs5: resistance at 5Hz, Rrs19: resistance at 19 Hz, VT: tidal volume, Xrs5: reactance at 5 Hz.

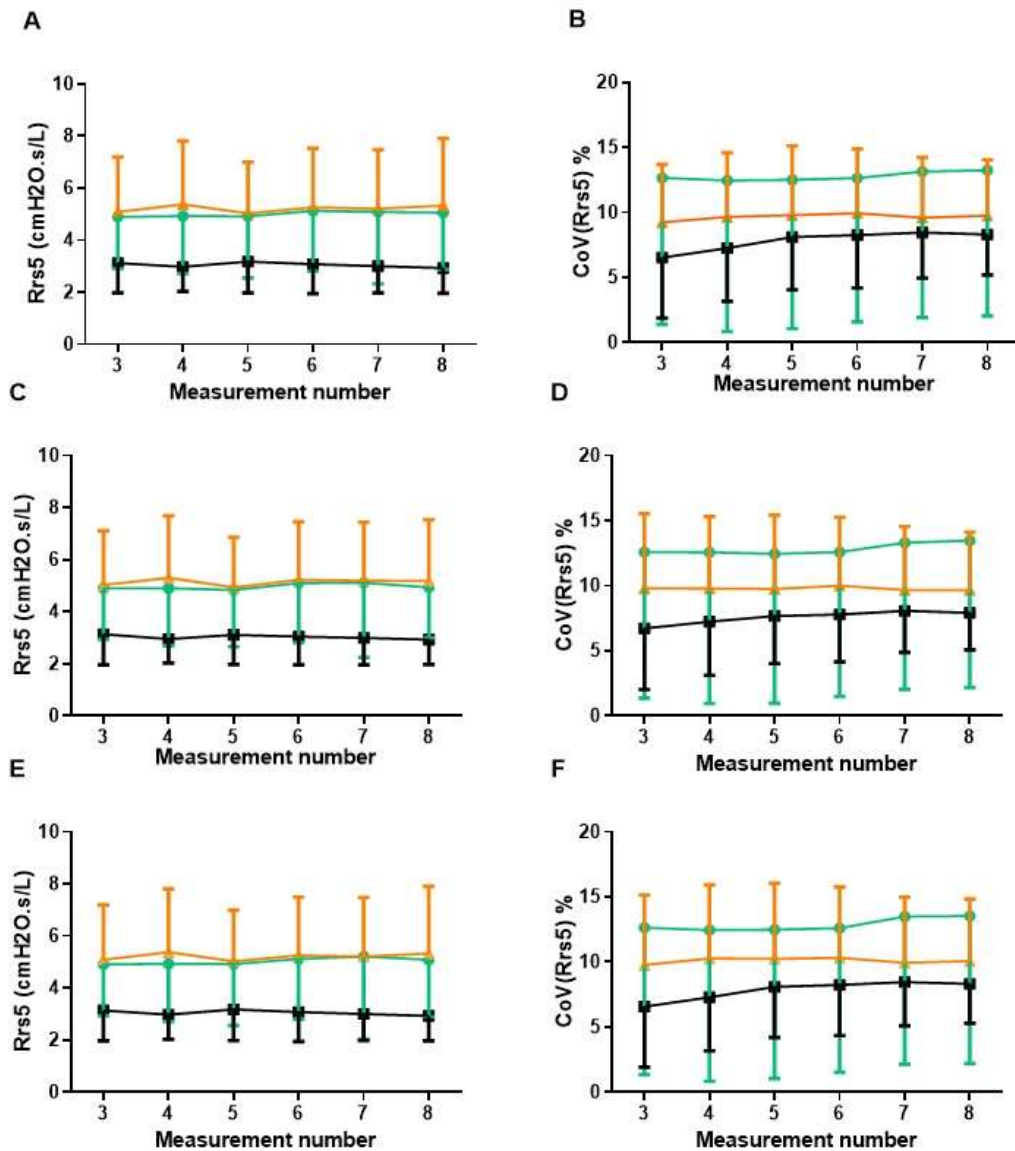


Figure S1. For all quality control methods, increasing the measurement number did not affect total Rrs5 and CoV(Rrs5). The mean Rrs5 and CoV(Rrs5) was calculated after 3-8 30 sec FOT measurements were carried on healthy individuals (black squares) and people with asthma (orange triangles) or COPD (green circles) after the ‘manual’ (A and B), ‘combined’ (C and D), or ‘none’ (E and F, respectively) quality control methods were used. (N=15 for all groups). CoV: coefficient of variation, Rrs5: total Rrs at 5 Hz.

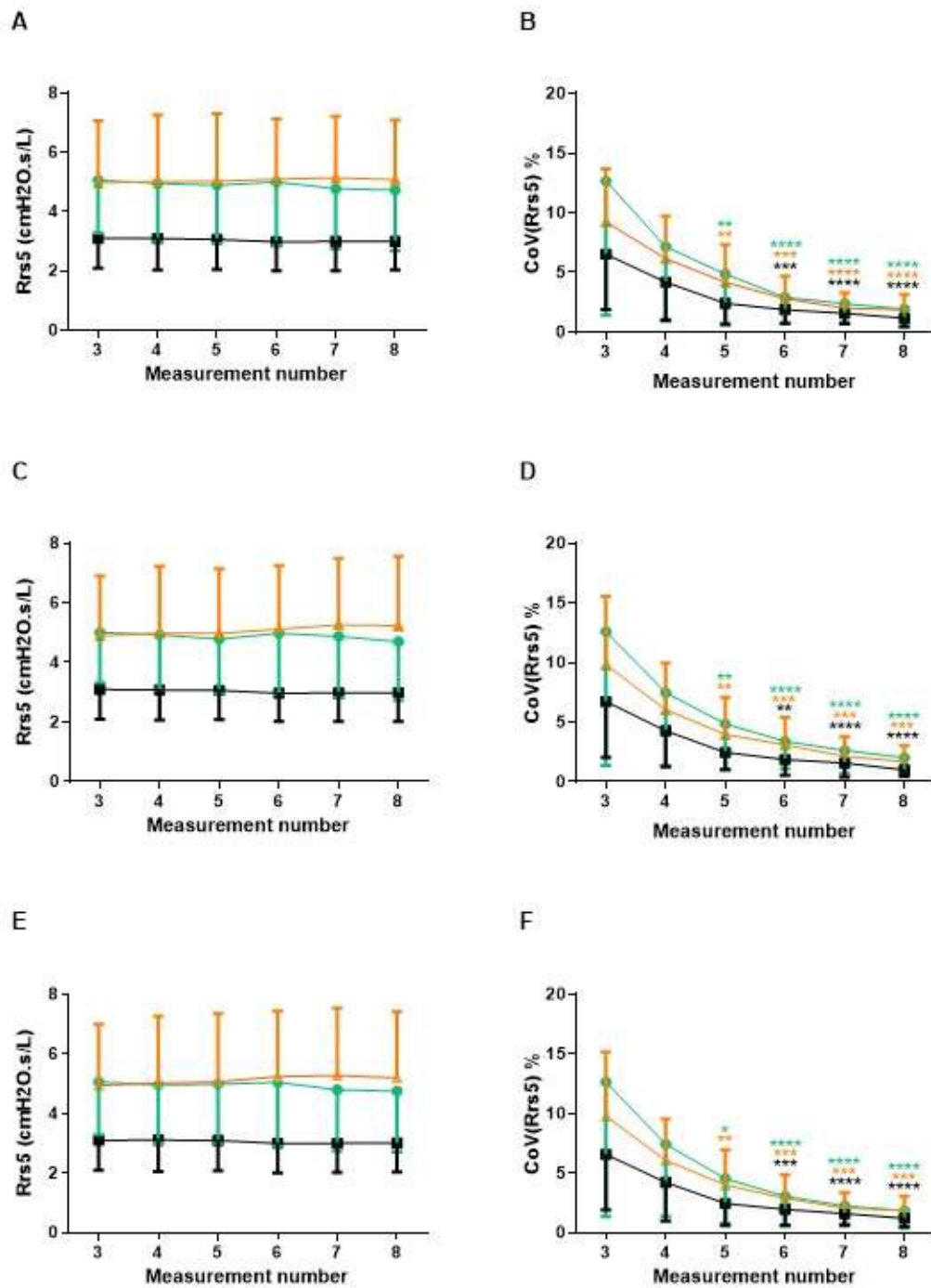


Figure S2. Increased measurement number allows for a decreased CoV(Rrs5) when the closest 3 measurements are selected. The mean Rrs5 and CoV(Rrs5) were calculated when the three closest of the 4-8 measurement were selected. Data from healthy individuals (black squares) and people with asthma (orange triangles) or COPD (green circles) then underwent further analysis for quality control using three different methods; ‘manual’ (A and B), ‘combined’ (C and D), or ‘none’ (E and F, respectively). N=15 for all groups * P<0.05, **P<0.01, ***P<0.001, and ****P<0.0001 compared with measurement 3 of the respective patient group. CoV(Rrs5): coefficient of variation, Rrs5: total Rrs at 5Hz.

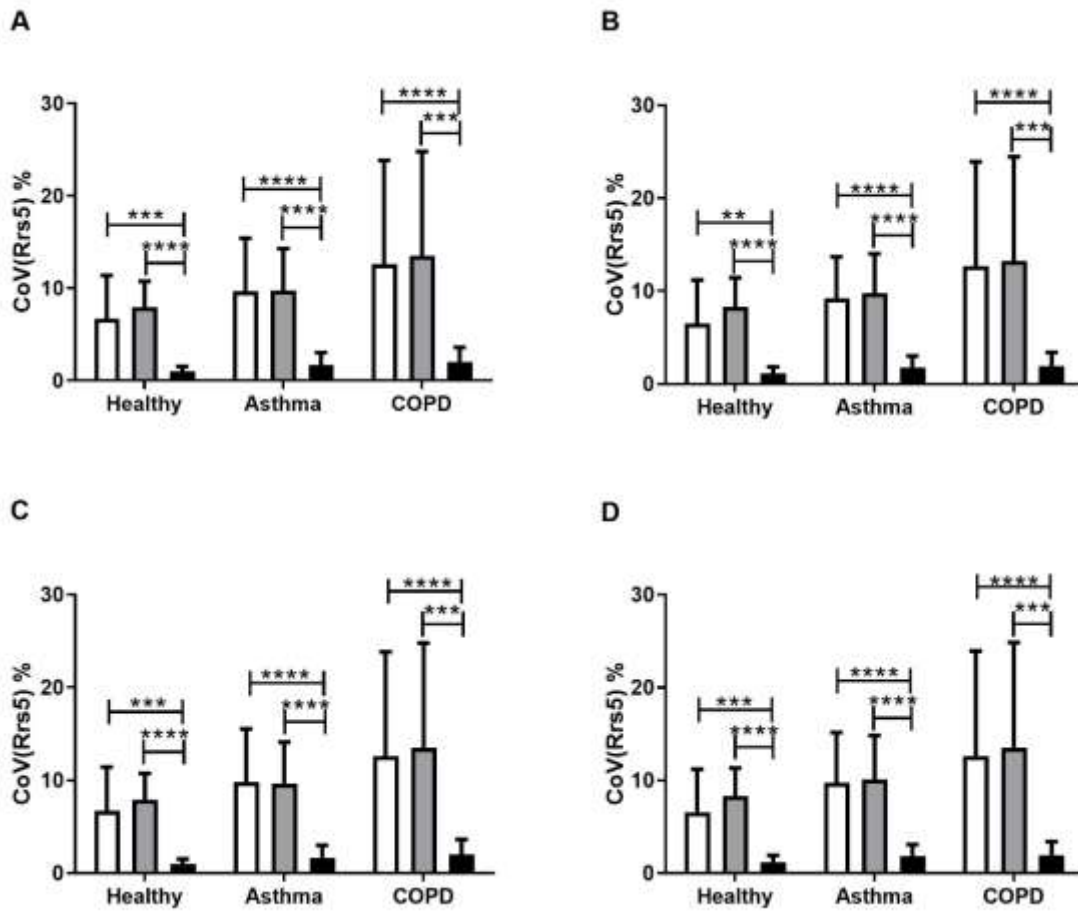


Figure S3. Selecting the closest three measurements decreases within-session variability compared to when consecutive measurements are used. Eight 30s FOT measurements were carried out on healthy, asthma, and COPD patients. The CoV(Rrs5) calculated from the first 3 consecutive measurements (white), or all 8 measurements (grey), was compared with the CoV(Rrs5) calculated from the 3 closest of 8 measurements (black). This analysis was carried out on data which had undergone quality control using the ‘SD-based’ (A), ‘manual’ (B), ‘combined’ (C), or ‘none’ method (D). N=15 for all groups; **P<0.01, ***P<0.001, and ****P<0.0001. CoV(Rrs5): coefficient of variation, Rrs5: total Rrs at 5Hz.

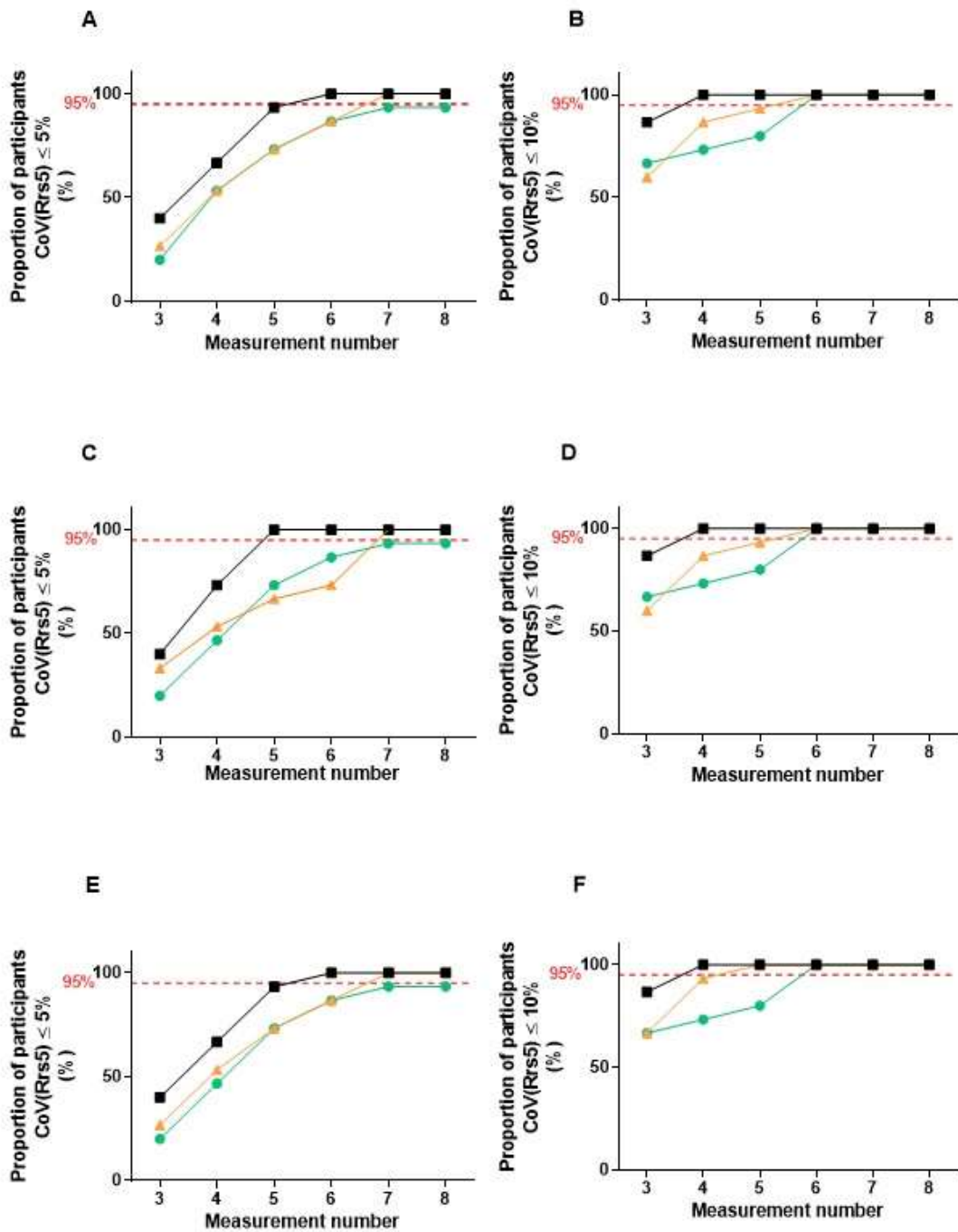


Figure S4. Across all quality control methods, individuals with airways disease show increased within-session FOT variability. For each quality control method, the number of measurements needed for 95% of the healthy (black squares), asthma (orange triangles), or COPD (green circles) populations to obtain a CoV(Rrs5) of $\leq 5\%$ or $\leq 10\%$, when the closest 3 measurements were selected from 4-8 measurements. The ‘manual’ (A and B), ‘combined’ (C and D), ‘none’ methods (E and F, respectively) were used (N=15 for all groups). CoV: coefficient of variation, Rrs5: total Rrs at 5 Hz.

Table S4. Comparison of different quality control methods

FOT parameter	Healthy				Asthma				COPD			
	Standard deviation	Manual exclusions	Standard deviation + manual exclusions	No quality control	Standard deviation	Manual exclusions	Standard deviation + manual exclusions	No quality control	Standard deviation	Manual exclusions	Standard deviation + manual exclusions	No quality control
Rrs5 (cmH ₂ O.s.L ⁻¹)	3.1±1.0	3.1±1.0	3.1±1.0	3.1±1.0	4.9±2.0*	5.0±2.1*	4.9±2.0*	4.9±2.0*	5.0±1.7**	5.1±1.8**	5.0±1.7**	5.1±1.8**
CoV(Rrs5) (%)	6.7±4.7	6.5±4.7	6.7±4.7	6.6±4.6	9.7±5.7	9.2±4.5	9.8±5.7	9.8±5.4	12.6±11.2	12.7±11.3	12.6±11.2	12.6±11.3
Z Score Rrs5	-0.5±3.0	-0.4±3.1	-0.5±3.0	-0.4±3.0	1.2±1.2	1.2±1.2	1.2±1.2	1.2±1.2	1.8±1.2**	1.9±1.2**	1.8±1.2**	1.9±1.2**
Rrs5.in (cmH ₂ O.s.L ⁻¹)	3.1±1.1	3.1±1.1	3.1±1.1	3.1±1.1	4.5±1.9*	4.5±1.9*	4.5±1.9*	4.5±1.9*	4.2±1.1	4.2±1.1	4.2±1.1	4.2±1.1
CV(Rrs5.in) (%)	9.7±5.6	9.7±5.6	9.7±5.6	9.7±5.6	11.8±10.8	11.8±10.8	11.8±10.8	11.8±10.8	14.1±10.3	14.1±10.3	14.1±10.3	14.1±10.3
Rrs5.ex (cmH ₂ O.s.L ⁻¹)	3.1±1.0	3.1±1.0	3.1±1.0	3.1±1.0	5.2±2.3**	5.2±2.3**	5.2±2.3**	5.2±2.3**	5.4±1.8**	5.4±1.8**	5.4±1.8**	5.4±1.8**

CoV(Rrs5.ex) (%)	6.5±4.1	6.5±4.1	6.5±4.1	6.5±4.1	12.5±6.5	12.5±6.5*	12.5±6.5*	12.5±6.5*	15.3±15.3	15.2±15.4	15.3±15.3	15.2±15.4
Xrs5 (cmH ₂ O.s.L ⁻¹)	-1.3±0.5	-1.3±0.5	-1.3±0.5	-1.3±0.5	-2.8±2.2	-2.8±2.2	-2.8±2.2	-2.8±2.2	-3.9±3.0** *	-3.9±3.0**	-3.9±3.0***	-3.9±3.0***
CoV(Xrs5) (%)	8.3±5.9	8.4±5.6	8.2±5.5	8.6±6.0	14.0±12.2	13.1±10.3	14.0±12.2	13.9±12.3	13.8±12.1	14.1±12.1	13.8±12.1	14.0±12.1
Xrs5.in (cmH ₂ O.s.L ⁻¹)	-1.6±0.7	-1.6±0.7	-1.6±0.7	-1.6±0.7	-2.1±1.7	-2.1±1.7	-2.1±1.7	-2.1±1.7	-2.9±1.6*	-2.9±1.6*	-2.9±1.6*	-2.9±1.6*
CoV(Xrs5.in) (%)	9.9±5.0	9.9±5.0	9.9±5.0	9.9±5.0	51.8±150.8	51.8±150.8	51.8±150.8	51.8±150.9	12.1±7.4	12.1±7.3	12.1±7.4	12.1±7.3
Xrs5.ex (cmH ₂ O.s.L ⁻¹)	-1.0±0.5	-1.0±0.5	-1.0±0.5	-1.0±0.5	-2.9±2.8*	-2.9±2.8*	-2.9±2.8*	-2.9±2.8*	-4.7±4.5** *	-4.7±4.5***	-4.7±4.5***	-4.7±4.7***
CoV(Xrs5.ex) (%)	11.3±7.2	11.3±7.2	11.3±7.2	11.3±7.2	20.7±12.2	20.7±12.2	20.7±12.2	20.7±12.2	17.8±19.5	17.7±19.5	17.8±19.5	17.7±19.5
Xrs5.in- Xrs5.ex (cmH ₂ O.s.L ⁻¹)	-0.7±0.3	-0.7±0.3	-0.7±0.3	-0.7±0.3	1.0±3.1	0.8±3.1	0.8±3.1	0.8±3.1	1.7±3.0**	1.7±3.0**	1.7±3.0**	1.7±3.0**
Rrs19 (cmH ₂ O.s.L ⁻¹)	2.9±0.9	2.9±1.0	2.9±0.9	2.9±0.9	3.6±1.1	3.5±1.1	3.6±1.1	3.5±1.1	3.3±1.2	3.3±1.2	3.3±1.2	3.3±1.2
CoV(Rrs19) (%)	4.9±4.1	5.6±4.0	5.0±4.1	5.6±4.0	5.6±4.3	6.5±4.0	5.7±4.3	6.8±3.8	9.8±7.3	9.8±7.3	9.8±7.2	9.9±7.1

Rrs19.in (cmH ₂ O.s.L ⁻¹)	2.9±1.0	2.9±1.0	2.3±1.0	2.9±1.0	3.5±1.1	3.5±1.1	3.5±1.1	3.5±1.1	3.1±1.1	3.1±1.1	3.1±1.1	3.0±1.1
CoV(Rrs19.in) (%)	7.4±4.0	7.4±4.0	7.4±4.0	7.4±4.0	5.9±4.0	5.9±4.0	5.9±4.0	5.9±4.0	8.3±8.0	8.3±7.9	8.3±8.0	8.3±7.9
Rrs19.ex (cmH ₂ O.s.L ⁻¹)	2.9±0.9	2.9±0.9	2.9±0.9	2.9±0.9	3.5±1.1	3.5±1.1	3.5±1.1	3.5±1.1	3.2±1.4	3.4±1.4	3.4±1.4	3.4±1.4
CoV(Rrs19.ex) (%)	5.7±4.3	5.7±4.3	5.7±4.3	5.7±4.3	7.6±4.5	7.6±4.5	7.6±4.5	7.6±4.5	10.4±8.4	10.7±8.1	10.4±8.4	10.7±8.1
Rrs5-19	0.2±0.4	0.2±0.4	0.2±0.4	0.2±0.4	1.4±1.2**	1.4±1.2**	1.4±1.2***	1.4±1.2**	1.7±0.8** *	1.7±0.8*** *	1.7±0.8*** *	1.8±0.9*** *
AX (cmH ₂ O.L ⁻¹)	5.2±4.2	5.2±4.2	4.3±2.9	5.2±4.2	28.1±29.6 *	28.1±29.6*	28.4±30.1*	30.1±29.8* *	38.7±32.4 ***	38.7±32.4* **	38.6±32.4* *	38.7±32.4* *
VT (L)	0.7±0.3	0.7±0.3	0.7±0.3	0.7±0.3	1.0±1.2	1.0±0.4	1.0±0.4	1.0±0.4	0.8±0.2	0.8±0.2	0.8±0.2	0.8±0.2
Measurements for a CoV≤5%	5	6	5	5	8	7	7	6	Never	Never	Never	Never
Measurements for a CoV≤10%	4	4	4	3	5	6	6	4	6	6	6	5

* compared with healthy in the same quality control method

Table S5. Within-session CoV in health, asthma and COPD in a larger, previously-described dataset

	Healthy (n=31)	Asthma (n=53)	COPD (n=36)
CoV Rrs5			
Median	5.8	7.1	6.5
IQR	4.5-7.2	5.0-9.2	4.4-8.4
5th – 95th centile	2.6-12.5	3.2-13.3	2.9-17.8
CoV Xrs5			
Median	8.4	10.9	9.5
IQR	7.0-10.8	8.1-13.3	6.5-14.6
5th – 95th centile	4.6-15.6	4.2-32.7	3.7-34.4

Median, interquartile range (IQR) and 5th-95th centiles calculated from three, manually quality-controlled measurements within a session for each participant. Details of the dataset have been previously published (Rutting et al, Eur Respir J 2021 Mar 25:2004318)