Table 1

Biometric characteristics (mean±SD) of control individuals and patients with work-related asthma.

	Control (n = 31)	Work-related asthma (n = 31)	p
Age (years)	51.0 ± 12.8	51.1 ± 12.9	ns
Body mass (kg)	70.5 ± 11.0	78.6 ± 14.8	$p<0.05$
Height (cm)	163.3 ± 7.2	164.2 ± 7.1	ns
BMI (kg/m^2)	25.9 ± 4.1	28.5 ± 6.3	$p<0.05$
Gender (M/F)	14 / 17	14 / 17	-

Table 2

Spirometric and plethysmographic characteristics of control individuals and patients with work-related asthma.

	Control (n = 31)	Work-related asthma before BD (n = 31)	Work-related asthma post BD (n = 31)
Spirometry			
FEV_1 (L)	2.8 ± 0.7	2.3 ± 0.6**	2.5 ± 0.7‡‡
FEV_1 (%)	93.1 ± 15.0	75.6 ± 19.2***	81.3 ± 17.4‡‡‡‡
FVC (L)	3.5 ± 0.8	3.1 ± 0.7	3.3 ± 0.8
FVC (%)	95.3 ± 15.1	84.1 ± 15.0**	86.6 ± 14.0‡‡
FEV_1/FVC	79.9 ± 6.7	72.6 ± 11.7*	76.4 ± 10.2‡
FEF 25-75%	2.9 ± 1.1	2.0 ± 1.1**	2.4 ± 1.2
FEF/CVF	0.7 ± 0.2	0.6 ± 0.3	0.7 ± 0.3
EPF	7.1 ± 1.8	5.5 ± 2.0**	5.7 ± 2.2
Plethysmography			
VC (L)	3.73 ± 0.6	2.95 ± 0.7***	3.16 ± 0.6
IC (L)	2.45 ± 0.6	2.69 ± 0.6*	2.93 ± 0.6‡
ERV (L)	1.31 ± 0.08	0.33 ± 0.2***	0.26 ± 0.2
TLC (L)	5.48 ± 0.9	5.27 ± 1.1	5.14 ± 1.3
TV (L)	-	0.86 ± 0.3	0.87 ± 0.2
RV (L)	1.7 ± 0.3	2.3 ± 0.8***	2.0 ± 0.9‡
RV/TLC	31.11 ± 3.1	43.8 ± 12.9***	39 ± 11.6‡
FRC	3.02 ± 0.35	2.86 ± 1.2	2.3 ± 1.0‡
TGV	-	3.2 ± 1.3	2.7 ± 1.26‡
RAW	1.38 ± 0.09	5.8 ± 5.2***	3.7 ± 3.1‡‡
SGAW	0.24 ± 0.02	0.12 ± 0.09***	0.16 ± 0.1‡

Data are mean ± SD; % = Percentage of the predicted values; *p<0.05 related to control group; **p<0.01 related to control group; ***p<0.001 related to control group; ‡p<0.05 related to pre-BD; ‡‡p<0.01 related to pre-BD.

Table 3

Oscillometric characteristics of control individuals and patients with work-related asthma and the effect of bronchodilator use.

	Control (n = 31)	Work-related asthma before BD (n = 31)	Work-related asthma post BD (n = 31)
Resistive parameters			
R0 ($cmH_2O/L/s$)	2.7 ± 0.7	3.9 ± 1.8*	2.8 ± 1.1‡‡‡
Rm ($cmH_2O/L/s$)	2.6 ± 0.6	3.3 ± 1.3	2.5 ± 0.8‡‡‡
S ($cmH_2O/L/s^2$)	-8.9 ± 18.7	-66.0 ± 65****	-32.7 ± 43.5‡‡‡
R4 ($cmH_2O/L/s$)	2.6 ± 0.7	3.6 ± 1.5*	2.6 ± 0.9‡‡‡
R12 ($cmH_2O/L/s$)	2.4 ± 0.6	3.0 ± 1.1	2.3 ± 0.8‡‡‡
R20 ($cmH_2O/L/s$)	2.6 ± 0.7	2.8 ± 1.1	2.2 ± 0.8‡‡‡
R4-R20 ($cmH_2O/L/s$)	0.03 ± 0.3	0.7 ± 0.9****	0.3 ± 0.5‡‡
Reactive parameters			
Xm ($cmH_2O/L/s$)	0.4 ± 0.3	-0.4 ± 0.9****	-0.07 ± 0.6‡‡‡
Fr (Hz)	11.3 ± 1.5	20.0 ± 6.6****	17.2 ± 6.4‡
Cdyn (mL/cmH_2O)	18.8 ± 6.3	14.4 ± 5.8**	19.4 ± 6.1‡‡‡
Axt (cmH_2O/L)	8.7 ± 3.5	31.4 ± 30.1****	19.1 ± 22.0‡‡‡
Axi (cmH_2O/L)	6.2 ± 2.6	20.4 ± 20.4****	11.9 ± 12.6‡‡‡
Z4 ($cmH_2O/L/s$)	3.5 ± 0.9	5.0 ± 2.3*	3.6 ± 1.5‡‡‡

Data are means±SD. *p<0.05 related to control group; **p<0.01 related to control group; ***p<0.001 related to control group; ****p<0.0001 related to control group; ‡p<0.01 related to pre-BD; ‡‡p<0.001 related to pre-BD; ‡‡‡p<0.0001 related to pre-BD.

Table 4

Mean square errors (MSE) and relative distances (Rd) in the integer and fractional-order models studied in control individuals and patients with work-related asthma pre and post-bronchodilator use.

	MSEr ($cmH_2O/L/s$)	MSEx ($cmH_2O/L/s$)	MSEt ($cmH_2O/L/s$)	Rd (%)
Control				
eRIC	0.073±0.055	0.051±0.036	0.094±0.058	3.873±1.465
FrOr	0.083±0.131	0.055±0.041	0.109±0.130	3.900±1.590
WRA pre				
eRIC	0.214±0.892	0.237±0.469	0.367±0.991	3.363±1.098
FrOr	0.102±0.249	0.114±0.234	0.156±0.340	3.026±1.072*
WRA post				
eRIC	0.039±0.037	0.117±0.281	0.132±0.280	4.327±1.616
FrOr	0.043±0.049	0.088±0.163	0.105±0.166	5.509±6.432

* indicates a significantly small error in the evaluated models.

Table 5: Correlation analysis among traditional, eRIC, and fractional-order parameters, and the spirometric results. Significance was analyzed after Bonferroni correction. The significant associations are described in bold.

	FEV_1 (L)	FEV_1 (%)	FVC (L)	FVC (%)	FEV_1/FVC	FEF (L)	FEF25-75 (%)	FEF25-75/CVF
Resistive								
R0	-0.33	-0.35	-0.13	-0.11	-0.46	-0.29	-0.44	-0.43
	ns	<0.05	ns	ns	<0.009	ns	<0.02	<0.02
Rm	-0.27	-0.27	-0.15	-0.12	-0.31	-0.30	-0.33	-0.29
	ns	ns	ns	ns	ns	ns	ns	ns
S	0.39	0.45	0.10	0.12	**0.65**	0.22	**0.58**	**0.62**
	<0.03	<0.02	ns	ns	**<0.0001**	ns	**0.0005**	**0.0001**
R4	-0.30	-0.31	-0.12	-0.08	-0.43	-0.28	-0.42	-0.40
	ns	ns	ns	ns	<0.02	ns	<0.02	<0.03
R12	-0.29	-0.29	-0.16	-0.14	-0.32	-0.31	-0.35	-0.30
	ns	ns	ns	ns	ns	ns	<0.05	ns
R20	-0.17	-0.13	-0.16	-0.10	-0.07	-0.31	-0.05	-0.43
	ns	ns	ns	ns	ns	ns	ns	<0.02
R4-R20	-0.32	-0.37	-0.01	-0.01	**-0.66**	-0.09	**-0.55**	**-0.64**
	ns	<0.04	ns	ns	**<0.0001**	ns	**<0.002**	**<0.0001**
Reactive								
Xm	0.47	**0.53**	0.22	0.24	**0.65**	0.24	**0.60**	**0.62**
	<0.007	**<0.003**	ns	ns	**<0.0001**	ns	**0.0002**	**0.0001**
Fr	**-0.51**	**-0.56**	-0.25	-0.32	**-0.63**	-0.34	**-0.66**	**-0.65**
	<0.003	**0.0008**	ns	ns	**0.0001**	ns	**<0.0001**	**<0.0001**
Cdyn	0.31	0.33	0.25	0.24	0.24	0.21	0.35	0.26
	ns	ns	ns	ns	ns	ns	ns	ns
Axt	-0.43	**-0.49**	-0.21	-0.24	**-0.57**	-0.23	**-0.52**	**-0.52**
	<0.02	**<0.005**	ns	ns	**0.0006**	ns	**<0.003**	**<0.003**
Axi	-0.44	**-0.49**	-0.20	-0.22	**-0.61**	-0,23	**-0.54**	**-0.55**
	<0.02	**<0.005**	ns	ns	**0.0002**	ns	**<0.002**	**<0.002**
Z4	-0.36	-0.39	-0.18	-0.16	-0.47	-0.25	-0.44	-0.42
	<0.05	<0.03	ns	ns	<0.008	ns	<0.02	<0.02
eRIC								
R	-0.05	0.008	-0.10	-0.02	0.11	-0.26	-0.01	0.08
	ns	ns	ns	ns	ns	ns	ns	ns

Rp	-0.37	-0.41	-0.10	-0.09	**-0.62**	-0.17	**-0.53**	**-0.59**
	<0.04	<0.02	ns	ns	**0.0001**	ns	**<0.002**	**0.0001**
Rt	-0.31	-0.31	-0.14	-0.09	-0.41	-0.28	-0.42	-0.40
	ns	ns	ns	ns	<0.03	ns	<0.02	<0.03
I	0.37	0.42	0.14	0.21	**0.54**	0.14	**0.48**	**0.53**
	<0.05	<0.02	ns	ns	**<0.002**	ns	**<0.006**	**<0.002**
C	0.24	0.30	0.13	0.17	0.28	0.14	0.37	0.33
	ns	ns	ns	ns	ns	ns	<0.04	ns
FrOr								
G	**-0.38**	**-0.35**	-0.30	-0.32	-0.14	-0.33	-0.28	-0.12
	<0.0026	**0.0058**	<0.02	<0.02	ns	<0.009	<0.026	ns
H	0.12	0.07	-0.11	0.00	0.16	013	0.15	0.15
	ns	ns	ns	ns	ns	ns	ns	ns
η	**-0.40**	-0.28	-0.32	-0.19	**-0.36**	-0.31	-0.34	-0.33
	<0.002	<0.03	<0.02	ns	**<0.004**	<0.02	<0.007	<0.009

FEV1: forced expiratory volume in the first second; FVC: forced vital capacity; FEF: forced expiratory flow between 25% and 75% of the FVC; %: percentage of the predicted values; G: damping factor; H: elastance; η: hysteresivity coefficient.

Table 6: Association among traditional, eRIC and fractional-order parameters and plethysmographic analysis. Significance was analyzed after Bonferroni correction. The significant associations are described in bold.

	VC (L)	IC (L)	ERV (L)	TV (L)	RV/TLC	FRC (L)	RV (L)	TLC (L)	TGV (L)	Raw	SGaw
Resistive											
R0	-0.36	-0.41	-0.09	-0.34	0.05	-0.20	0.03	-0.31	-0.20	0.35	-0.30
	<0.05	<0.03	ns	ns	ns	ns	ns	ns	ns	ns	ns
Rm	-0.39	-0.41	-0.14	-0.34	0.02	-0.25	-0.20	-0.37	-0.23	0.21	-0.17
	<0.03	<0.02	ns	ns	ns	ns	ns	<0.04	ns	ns	ns
S	0.22	0.30	-0.0005	0.25	-0.09	0.06	-0.004	0.09	0.09	**-0.57**	**0.51**
	ns	Ns	ns	ns	ns	ns	ns	ns	ns	**0.0007**	**<0.003**
R4	-0.37	-0.43	-0.08	-0.34	0.06	-0.19	-0.15	-0.32	-0.18	0.28	-0.28
	<0.04	<0.02	ns	ns	ns	ns	ns	ns	ns	ns	ns
R12	-0.39	-0.41	-0.12	-0.32	0.01	-0.25	-0.19	-0.37	-0.23	0.21	-0.20
	<0.03	<0.02	ns	ns	ns	ns	ns	ns	ns	ns	ns
R20	-0.43	-0.42	-0.18	-0.34	0.008	-0.28	-0.24	-0.44	-0.24	-0.02	0.03
	<0.02	<0.02	ns	ns	ns	ns	ns	<0.02	ns	ns	ns
R4-R20	-0.11	-0.23	0.08	-0.16	0.1	0.02	0.03	-0.008	-0.01	**0.52**	**-0.54**
	ns	ns	ns	ns	ns	ns	ns	ns	ns	**<0.003**	**<0.002**
Reactive											
Xm	0.26	0.29	0.03	0.22	-0.13	0.006	-0.01	0.09	0.02	**-0.58**	**0.49**
	ns	ns	ns	ns	ns	ns	ns	ns	ns	**0.0005**	**<0.006**
Fr	-0.38	-0.39	-0.06	-0.30	0.30	0.18	0.10	-0.04	0.13	0.40	-0.38
	<0.04	<0.03	ns	ns	ns	ns	ns	ns	ns	<0.03	<0.04
Cdyn	0.40	0.38	0.22	0.30	0.08	0.37	0.20	0.36	0.36	-0.30	0.24
	<0.03	<0.04	ns	ns	ns	<0.05	ns	<0.05	<0.05	ns	ns
Axt	-0.25	-0.28	-0.07	-0.24	0.07	-0.09	-0.04	-0.15	-0.09	**0.56**	-0.41
	ns	ns	ns	ns	ns	ns	ns	ns	ns	**0.0008**	<0.03
Axi	-0.22	-0.27	-0.05	-0.23	0.05	-0.09	-0.04	-0.13	-0.09	**0.59**	-0.46
	ns	ns	ns	ns	ns	ns	ns	ns	ns	**0.0004**	<0.008
Z4	-0.32	-0.36	-0.11	-0.30	0.02	-0.21	-0.13	-0.27	-0.20	0.44	-0.33
	ns	<0.05	ns	ns	ns	ns	ns	ns	ns	<0.02	<0.07
eRIC											
R	-0.37	-0.35	-0.20	-0.30	-0.05	-0.32	-0.30	-0.46	-0.28	-0.20	0.16
	<0.04	ns	ns	ns	ns	ns	ns	<0.008	ns	ns	ns

Rp	-0.21	-0.33	0.09	-0.23	0.10	-0.01	-0.009	-0.09	-0.03	**0.50**	-0.48
	ns	ns	ns	ns	ns	ns	ns	ns	ns	**<0.004**	<0.007
Rt	-0.38	-0.46	-0.04	-0.35	0.04	-0.19	-0.18	-0.34	-0.18	0.27	-0.27
	<0.04	<0.01	ns	<0.05	ns	ns	ns	ns	ns	ns	ns
I	0.10	0.09	-0.01	0.06	-0.25	-0.27	-0.14	-0.13	-0.25	-0.41	0.35
	ns	ns	ns	ns	ns	ns	ns	ns	ns	<0.02	<0.05
C	0.30	0.32	0.19	0.21	0.13	0.39	0.20	0.32	0.45	-0.41	0.37
	ns	ns	<0.04	ns	ns	<0.03	ns	ns	<0.02	<0.03	<0.04
FrOr											
G	-0.15	-0.16	-0.16	-0.20	-0.15	-0.34	-0.22	-0.25	-0.32	**0.53**	-0.31
	ns	ns	ns	ns	ns	ns	ns	ns	ns	**<0.003**	ns
H	-0.31	-0.31	-0.14	-0.27	0.07	-0.16	-0.07	-0.25	-0.13	0.36	-0.16
	ns	ns	ns	ns	ns	ns	ns	ns	ns	<0.05	ns
η	0.13	0.15	-0.16	-0.05	-0.19	-0.16	-0.08	0.03	-0.24	**0.53**	-0.34
	ns	ns	ns	ns	ns	ns	ns	ns	ns	**<0.003**	ns

FEV1: forced expiratory volume in the first second; FVC: forced vital capacity; FEF: forced expiratory flow between 25% and 75% of the FVC; %: percentage of the predicted values; G: damping factor; H: elastance; η: hysteresivity coefficient.

Table 7

Diagnostic accuracy (mean and 95% confidence interval) of the traditional FOT parameters in the diagnostic of respiratory abnormalities in patients with work-related asthma. Values considered adequate are described in bold.

	AUC	Se (%)	Sp (%)	Cut-off
R0	0.687	45.1	93.5	> 3.53
	0.556 - 0.799	27.3 - 64.0	78.6 - 99.2	
Rm	0.634	35.4	96.7	>3.54
	0.502 - 0.753	19.2 - 54.6	83.3 - 99.9	
R4	0.673	38.7	96.7	>3.70
	0.542 - 0.787	21.8 - 57.8	83.3 - 99.9	
R12	0.635	38.7	87.1	> 3.13
	0.503 - 0.753	21.8 - 57.8	70.2 - 96.4	
R20	0.513	100	12.9	> 1.49
	0.383 - 0.642	88.8 - 100.0	3.6 - 29.8	
S	**0.840**	67.7	80.6	≤-23.3
	0.745 - 0.934	48.6 - 83.3	62.5 - 92.5	
R4-R20	0.795	80.6	64.5	> 0.16
	0.673 - 0.887	62.5 - 92.5	45.4 - 80.8	
Xm	**0.826**	67.7	87.1	≤-0.03
	0.724 - 0.929	48.6 - 83.3	70.2 - 96.4	
Fr	**0.929**	74.2	100	>14.7
	0.835 - 0.979	55.4 - 88.1	88.8 - 100.0	
Cdyn	0.695	48.3	90.3	≤12.41
	0.565 - 0.806	30.2 - 66.9	74.2 - 98.0	
Axt	**0.875**	70.9	96.7	>13.56
	0.767 - 0.945	52.0 - 85.8	83.3 - 99.9	
Axi	**0.819**	80.6	67.7	>7.08
	0.701 - 0.906	62.5 - 92.5	48.6 - 83.3	
Z4	0.690	48.3	87.1	>4.54
	0.558 - 0.822	30.2 - 66.9	70.2 - 96.4	

Table 8

Diagnostic accuracy (mean and 95% confidence interval) of the eRIC and fractional-order parameters in the detection of respiratory alterations in patients with work-related asthma. Values considered adequate are described in bold.

	AUC	Se (%)	Sp (%)	Cut-off
eRIC				
R	0.514	74.2	41.9	≤2.87
	0.384 - 0.643	55.4 - 88.1	24.5 - 60.9	
Rt	0.703	41.9	96.7	>3.68
	0.574 - 0.813	24.5 - 60.9	83.3 - 99.9	
Rp	**0.838**	67.7	96.8	>0.80
	0.734- 0.942	48.6 - 83.3	83.3 - 99.9	
I	0.746	64.5	80.6	≤0.007
	0.619 - 0.848	45.4 - 80.8	62.5 - 92.5	
C	0.747	58.0	93.5	≤0.01
	0.621 - 0.849	39.1 - 75.5	78.6 - 99.2	
FrOr				
G	0.729	74.19	58.06	>13.53
	0.602 to 0.856	55.4 - 88.1	39.1 - 75.5	
H	**0.881**	83.87	90.33	<23.12
	0.785 to 0.978	66.3 - 94.5	74.2 - 98.0	
η	**0.970**	96.77 83.3 -	96.77 83.3 -	>0.658
	0.915 to 1.000	99.9	99.9	

AUC: area under the receiver-operator curve; Se: sensibility; Sp: specificity.

Table 9

Area under the receiving operator curve (mean and 95% confidence interval) of the traditional FOT parameters in the identification of the bronchodilator response in patients with work-related asthma. Values considered adequate are described in bold.

	AUC	Se (%)	Sp (%)	Cut-off
R0	0.699	74.1	58.0	> 2.72
	0.570 - 0.829	55.4 - 88.1	39.1 - 75.5	
Rm	0.694	83.8	51.6	>2.39
	0.563 - 0.825	66.3 - 94.5	33.1 - 69.8	
R4	**0.708**	93.5	38.7	>2.00
	0.580 - 0.835	78.6 - 99.2	21.8 - 57.8	
R12	0.690	64.5	70.9	> 2.46
	0.558 - 0.822	45.4 - 80.8	52.0 - 85.8	
R20	0.691	74.1	61.2	> 2.20
	0.558 - 0.824	55.4 - 88.1	42.2 - 78.2	
S	0.686	77.4	51.61	≤-19.9
	0.554 - 0.817	58.9 - 90.4	33.1 - 69.8	
R4-R20	0.677	61.2	70.9	> 0.30
	0.542 - 0.813	42.2 - 78.2	52.0 - 85.8	
Xm	0.629	45.1	87.1	≤-0.35
	0.489 - 0.768	27.3 - 64.0	70.2 - 96.4	
Fr	0.634	51.6	77.4	>19.5
	0.494 - 0.773	33.1 - 69.8	58.9 - 90.4	
Cdyn	**0.706**	58.0	87.1	≤14.3
	0.574 - 0.837	39.1 - 75.5	70.2 - 96.4	
Axt	0.697	51.6	83.8	>18.6
	0.566 - 0.828	33.1 - 69.8	66.3 - 94.5	
Axi	0.665	61.29	64.52	≤9.10
	0.530 to 0.800	42.2 – 78.2	45.4 – 80.8	
Z4	**0.726**	74.1	61.2	>3.36
	0.601 - 0.851	55.4 - 88.1	42.2 - 78.2	

Table 10

Diagnostic accuracy (mean and 95% confidence interval) of the eRIC and fractional-order parameters in the detection of respiratory effects of bronchodilator use in patients with work-related asthma. Values considered adequate are described in bold.

	AUC	Se (%)	Sp (%)	Cut-off
eRIC				
R	0.678	67.7	67.7	≤2.1
	0.544 - 0.813	48.6 - 83.3	48.6 - 83.3	
Rt	0.664	93.6	32.2	>2.59
	0.529 - 0.799	78.6 - 99.2	16.7 - 51.4	
Rp	0.546	29.0	96.7	>1.81
	0.400 - 0.693	14.2 - 48.0	83.3 - 99.9	
I	0.518	29.0	83.8	≤0.003
	0.372 - 0.663	14.2 - 48.0	66.3 - 94.5	
C	0.651	58.0	77.4	≤0.01
	0.513 - 0.790	39.1 - 75.5	58.9 - 90.4	
FrOr				
G	0.660	61.29	64.52 45.4	≤14.65
	0.528 to 0.775	42.2 - 78.2	- 80.8	
H	0.645	74.19 55.4 -	61.29 42.2 -	≤16.81
	0.513 to 0.763	88.1	78.2	
η	0.505	58.06 39.1 -	58.06 39.1 -	≤0.93
	0.375 to 0.634	75.5	75.5	

AUC: area under the receiver-operator curve; Se: sensibility; Sp: specificity.