Official ATS Technical Standards: Spirometry in the Occupational Setting

Online Supplement

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***co-chairs**

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METHODS TABLE

Panel assembly	Yes	No
• Included experts for relevant clinical and non-clinical disciplines	X	
• Included individual who represents the views of patients and society at large		X
• Included a methodologist with appropriate expertise (documented expertise in conducting systematic reviews to identify the evidence base and the development of evidence-based recommendations)	X	
Literature review		
• Performed in collaboration with librarian	X	
• Searched multiple electronic databases	X	
• Reviewed reference lists of retrieved articles	X	
Evidence synthesis		
• Applied pre-specified inclusion and exclusion criteria	X	
• Evaluated included studies for sources of bias	X	
• Explicitly summarized benefits and harms	X	
• Used PRISMA1 to report systematic review		X
• Used GRADE to describe quality of evidence		X

Generation of recommendations		
• Used GRADE to rate the strength of recommendations		**X**

SYSTEMATIC REVIEW

Questions

Four Questions were identified for systematic review

1) WHICH TRAINING REQUIREMENTS ARE NEEDED FOR PERFORMANCE OF SPIROMETRY IN THE OCCUPATIONAL SETTING?
2) IS THERE A DIFFERENCE IN RESULTS OR SAFETY BETWEEN OCCUPATIONAL SPIROMETRY TEST PERFORMANCE SITTING VS STANDING?
3) IS THERE A CORRECTION FACTOR THAT CAN BE PROVIDED FOR WORKERS IN NORTH AMERICA AND EUROPE OF ASIAN ETHNICITY?
4) WHAT IS THE LONGITUDINAL CHANGE IN SPIROMETRY THAT SHOULD BE TAKEN AS AN ACTION LEVEL IN OCCUPATIONAL SPIROMETRY?

For all questions, the search was limited to adults (19- 64 years), no limits were placed in the abstract search by language or study type except for the question 4, and the databases searched were Medline and Embase.

For each question a systematic review was performed with assistance from a medical librarian (Rouhi Fazelrad, and Viola Machel, University Health Network, Toronto) using Medline and EmBase with the search strategies as shown below, initially to 2009 and then extended to the end of April 2012, using the same search strategies. Additional relevant papers were added by the panel from review of references in the papers from the search or from personal knowledge of the literature. Abstracts were all screened by 2 panel members to identify those meeting inclusion criteria and full papers then obtained for data extraction by 2 panel members using the forms developed for each question (included below). Papers were then discussed by the full panel in a series of telephone conference calls, and consensus reached on those to include in evidence tables (Tables 1-4) in the main document.

Inclusion criteria, exclusion criteria, and search results

Question #1: Which training requirements are needed for performance of spirometry in the occupational setting?

Inclusion criteria were: spirometry testing; the study details included the type of person doing the testing (e.g. pulmonary function technologist); some comparison or analysis of the impact of training of the technician or some educational component; the outcome of quality of spirometry or other outcome. In addition, selected review articles were included to identify additional references.

Exclusion criteria were studies that did not include spirometry; included only patient training; or included only equipment quality control.

Search results to 2009: 1480 total abstracts were identified after removal of duplicates (681 Medline 799 Embase) of which 20 papers met the full criteria. From the extended search to the end of April 2012 (136 Medline, 944 Embase abstracts) an additional two papers were identified for a total of 22 papers, summarized inTable 1.

Question #2: Is there a difference in results or safety between occupational spirometry test performance sitting versus standing?

The search led to a total of 2865 abstracts: from Medline 2060 abstracts, with an additional 805 in EMBASE after excluding duplicates. From the 2865 abstracts initially identified, only 10 full papers were identified which met the following inclusion criteria: sitting and standing tests were performed in adults, on the same subjects, the outcome included spirometry (FEV_1 and FVC), and the abstract of the paper was in English. Three of these papers were excluded, as they were not in English, leaving 7 papers, summarized in Table 2. No additional papers suitable for inclusion were identified from the extended search to the end of April 2012 (292 Medline and 430 Embase abstracts).

Question #3: Is there acorrection value that can be provided for workers in North America and Europe of Asian ethnicity?

Inclusion criteria were: Race – Asian, Indian; abstract in English; population group – smokers and non-smokers; occupational cohorts were included if there was also a control group. Excluded were studies with only children; identified disease groups – e.g., COPD.

From the initial searches to 2009, a total of 515 abstracts were identified that met these criteria: 321 from the Medline search plus studies known to the panel members and an additional 194 from Embase after excluding duplicates. Studies of adult Asians and Indians living in the US, Canada, or Europe, including non-smokers and / or smokers were included. Studies of Asians in other countries and of disease groups such as COPD were then omitted, leaving 6 articles used for the evidence-based review. This increased by one additional article by the extended search to the end of April 2012 (459 Medline, 225 Embase abstracts) for a total of 7 articles, as summarized in Table 3.

Question #4: What is the longitudinal change inspirometry that should be taken as an action level in occupational spirometry?

Inclusion criteria were: at least 3 spirometry time points over at least 5 years; general population studies, or occupational cohorts that included either normal controls or low exposure group(s); smokers and non-smokers were included. Studies had to include an assessment of variability in FEV_1 decline. After the review was initiated, it became apparent that studies evaluating occupational cohorts where early measures of decline could be evaluated for ability to predict longer-term decline in individuals were useful, so these were also considered.

Exclusion criteria were: occupational cohorts without a control group (except studies where early measures of decline were evaluated for ability to predict longer-term decline in individuals, as noted for inclusion criteria); disease cohorts e.g. COPD; multiple studies of the same population – the study with the best methods were selected if there were several studies.

There were 814 total abstracts from the searches to 2009, excluding duplicates: Medline 585, Embase 229. Of these, 79 were selected for full paper review. When combined with results from the extended search to the end of April 2012 (95 Medline, 333 Embase abstracts), a total of 6 papers from 97 with full review completely fulfilled our criteria (summarized in Table 4).

Search strategies

Ovid MEDLINE(R) 1950 to August Week 2 2009

#	Searches	Results	Search Type
	Occupational Health Workers Segment		
1	exp Health Personnel/	300620	Advanced
2	(health* adj2 personnel*).mp.	98645	Advanced
3	(health* adj2 provid*).mp.	28025	Advanced
4	fieldworker*.mp.	174	Advanced
5	(field adj2 worker*).mp.	617	Advanced
6	(occupation* adj2 health*).mp.	44182	Advanced
7	personnel.mp.	208838	Advanced
8	(health* adj2 practitioner*).mp.	3495	Advanced
9	(health* adj2 worker*).mp.	18161	Advanced
10	(health* adj2 employ*).mp.	4717	Advanced
11	profession*.mp.	218413	Advanced
12	(staff or staffing).mp.	140855	Advanced
13	or/1-12	672632	Advanced
	Spirometry Segment		
14	exp Spirometry/	15468	Advanced
15	spiromet*.mp.	21201	Advanced
16	bronchospiromet*.mp.	819	Advanced

17	Respiratory Function Tests/	33305	Advanced
18	respiratory function test?.mp.	33663	Advanced
19	lung function test?.mp.	1943	Advanced
20	pulmonary function test?.mp.	5321	Advanced
21	Respiratory Therapy/	5155	Advanced
22	(respirat* adj2 therap*).mp.	7134	Advanced
23	"Work of Breathing"/	1653	Advanced
24	(work* adj2 breath*).mp.	2426	Advanced
25	bronchospirograph*.mp.	21	Advanced
26	spirograph*.mp.	624	Advanced
27	(breath* adj3 measur*).mp.	2762	Advanced
28	(incentive adj3 breath*).mp.	27	Advanced
29	exp Forced Expiratory Flow Rates/	8154	Advanced
30	(force* adj3 rate*).mp.	4672	Advanced
31	(force* adj3 capacit*).mp.	5964	Advanced
32	(force* adj3 volume*).mp.	21858	Advanced
33	(peak adj3 rate*).mp.	12406	Advanced
34	(flow* adj2 loop*).mp.	771	Advanced
35	fvc.mp.	6314	Advanced
36	fev1.mp.	13422	Advanced
37	fev6.mp.	27	Advanced
38	pefr.mp.	1566	Advanced
39	fivc.mp.	19	Advanced
40	triflo.mp.	13	Advanced
41	spirocare.mp.	1	Advanced
42	or/14-41	94567	Advanced
	Training Segment		
43	Teaching/	35472	Advanced

44	teach*.mp.	123488	Advanced
45	(personnel* adj education*).mp.	52	Advanced
46	(education* adj2 technic*).mp.	287	Advanced
47	(education* adj2 techniq*).mp.	369	Advanced
48	(teach* adj2 method*).mp.	3949	Advanced
49	(train* adj2 activit*).mp.	1129	Advanced
50	(train* adj2 techniq*).mp.	770	Advanced
51	(train* adj2 technic*).mp.	1050	Advanced
52	exp Education/	502083	Advanced
53	educat*.mp.	493482	Advanced
54	workshop*.mp.	18908	Advanced
55	(parent* adj2 educat*).mp.	3615	Advanced
56	(train* adj2 program*).mp.	19065	Advanced
57	(educat* adj2 activit*).mp.	2460	Advanced
58	(train* adj2 requir*).mp.	2555	Advanced
59	Inservice Training/	14273	Advanced
60	(inservice* adj2 train*).mp.	14414	Advanced
61	(train* adj2 job).mp.	635	Advanced
62	(orient* adj2 program*).mp.	1282	Advanced
63	exp Students, Health Occupations/	34373	Advanced
64	(student? adj2 occupation?).mp.	1216	Advanced
65	(student? adj2 public health).mp.	157	Advanced
66	(student? adj2 premedical).mp.	203	Advanced
67	(student? adj2 nurse*).mp.	3065	Advanced
68	(student? adj2 medical).mp.	24948	Advanced
69	(student? adj2 pharmacy).mp.	963	Advanced
70	"Internship and Residency"/	27339	Advanced
71	(residenc* adj2 internship).mp.	27367	Advanced

72	ed.fs.	175635	Advanced
73	or/43-72	746832	Advanced
	Combined Results		
74	42 and 73 and 13	751	Advanced
75	limit 74 to ("all adult (19 plus years)" or "young adult (19 to 24 years)" or "adult (19 to 44 years)" or "young adult and adult (19-24 and 19-44)" or "middle age (45 to 64 years)" or "middle aged (45 plus years)" or "all aged (65 and over)")	240	Advanced
76	limit 74 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "newborn infant (birth to 1 month)" or "infant (1 to 23 months)" or "preschool child (2 to 5 years)" or "child (6 to 12 years)" or "adolescent (13 to 18 years)")	123	Advanced
77	76 not 75	68	Advanced
78	74 not 77	683	Advanced

EMBASE 1980 to 2009 Week 51

#	Searches	Results	Search Type
	Spirometry Segment		
1	spirometry/	10105	Advanced
2	spiromet*.mp.	13861	Advanced
3	bronchospirography/	7	Advanced
4	bronchospiromet*.mp.	13	Advanced
5	respiratory function test?.mp.	460	Advanced

6	lung function test/	14736	Advanced
7	pulmonary function test?.mp.	4768	Advanced
8	respiratory therapy.mp.	467	Advanced
9	respiratory therap*.mp.	1027	Advanced
10	*artificial ventilation/	11401	Advanced
11	(respirat* adj2 therap*).mp.	51593	Advanced
12	(work* adj2 breath*).mp.	1801	Advanced
13	spirograph*.mp.	1220	Advanced
14	(breath* adj3 measur*).mp.	3411	Advanced
15	(incentive adj3 breath*).mp.	26	Advanced
16	forced expiratory flow/	924	Advanced
17	(force* adj3 rate*).mp.	2299	Advanced
18	(force* adj3 capacit*).mp.	5520	Advanced
19	(force* adj3 volume*).mp.	25048	Advanced
20	breathing exercise/	1649	Advanced
21	(breath* adj3 exercise).mp.	4300	Advanced
22	(peak adj3 rate*).mp.	8109	Advanced
23	(flow* adj2 loop*).mp.	672	Advanced
24	fvc.mp.	5846	Advanced
25	fev1.mp.	15572	Advanced
26	fev6.mp.	39	Advanced
27	pefr.mp.	1359	Advanced
28	fivc.mp.	19	Advanced
29	triflo.mp.	15	Advanced
30	spirocare.mp.	3	Advanced
31	or/1-30	122212	Advanced
	Occupational Health Workers Segment		
32	exp health care personnel/	291163	Advanced

33	(health* adj2 personnel).mp.	44599	Advanced
34	(health* adj2 provid*).mp.	18146	Advanced
35	fieldworker*.mp.	109	Advanced
36	(field adj2 worker*).mp.	334	Advanced
37	(occupation* adj2 health*).mp.	32184	Advanced
38	occupational health/	13819	Advanced
39	personnel.mp.	86244	Advanced
40	(health* adj2 practitioner*).mp.	17214	Advanced
41	health practitioner/	15396	Advanced
42	(health* adj2 worker*).mp.	13111	Advanced
43	(health* adj2 employ*).mp.	11787	Advanced
44	medical profession/	11327	Advanced
45	profession*.mp.	120867	Advanced
46	(staff or staffing).mp.	58054	Advanced
47	or/32-46	453314	Advanced
	Training Segment		
48	teaching/	12624	Advanced
49	teach*.mp.	65732	Advanced
50	(personnel* adj2 education*).mp.	717	Advanced
51	(education* adj2 technic*).mp.	193	Advanced
52	(education* adj2 techniq*).mp.	633	Advanced
53	(teach* adj2 method*).mp.	3391	Advanced
54	(train* adj2 activit*).mp.	929	Advanced
55	(train* adj2 techniq*).mp.	1226	Advanced
56	(train* adj2 technic*).mp.	721	Advanced
57	exp education/	298294	Advanced
58	educat*.mp.	298322	Advanced
59	workshop/	4311	Advanced

60	workshop*.mp.	15744	Advanced
61	workshop*.mp.	15744	Advanced
62	(parent* adj2 educat*).mp.	4488	Advanced
63	training/	44428	Advanced
64	(train* adj2 program*).mp.	14917	Advanced
65	(educat* adj2 activit*).mp.	1629	Advanced
66	(train* adj2 requir*).mp.	2178	Advanced
67	in service training/	81	Advanced
68	(inservice* adj2 train*).mp.	112	Advanced
69	(train* adj2 job).mp.	387	Advanced
70	(orient* adj2 program*).mp.	718	Advanced
71	(student? adj2 occupation?).mp.	102	Advanced
72	(student? adj2 public health).mp.	188	Advanced
73	(student* adj2 premedical).mp.	50	Advanced
74	(student? adj2 medical).mp.	23054	Advanced
75	(student? adj2 pharmacy).mp.	1141	Advanced
76	(student? adj2 nurse*).mp.	543	Advanced
77	resident/	6102	Advanced
78	(residenc* adj2 internship).mp.	56	Advanced
79	quality control/	59876	Advanced
80	health care quality/	58244	Advanced
81	or/48-80	528976	Advanced
	Combined Results limited to adults, and humans		
82	31 and 47 and 81	1127	Advanced
83	limit 82 to (embryo <first trimester> or infant <to one year> or child <unspecified age> or preschool child <1 to 6 years> or school child <7 to 12 years> or adolescent <13 to 17 years>)	127	Advanced
84	limit 82 to (adult <18 to 64 years> or aged <65+ years>)	303	Advanced
85	83 not 84	83	Advanced

86	82 not 85	1044	Advanced
87	exp animals/ not (exp animals/ and exp humans/)	14366	Advanced
88	86 not 87	1044	Advanced

Searches for Question #2

Ovid MEDLINE(R) 1950 to July Week 4 2009

#	Searches	Results	Search Type
	Sitting vs. Standing Segment		
1	Posture/	48126	Advanced
2	postur*.mp.	69168	Advanced
3	(body adj2 position?).mp.	2373	Advanced
4	(body adj2 posture?).mp.	1054	Advanced
5	(sit* adj2 up*).mp.	7399	Advanced
6	(sit* adj2 straight).mp.	36	Advanced
7	(sit or sitting).mp.	13493	Advanced
8	(sit* adj2 erect).mp.	55	Advanced
9	(sit* adj2 position?).mp.	3988	Advanced
10	(sit* adj2 posture?).mp.	548	Advanced
11	((sit or sitting) adj2 value?).mp.	55	Advanced
12	(sit* adj2 spiromet*).mp.	13	Advanced
13	(stand or standing).mp.	45926	Advanced
14	(stand* adj2 position?).mp.	2808	Advanced
15	(stand* adj2 posture?).mp.	755	Advanced
16	((stand or standing) adj2 value?).mp.	114	Advanced

17	(stand* adj2 spiromet*).mp.	210	Advanced
18	((sit or sitting) adj2 (stand or standing)).mp.	1781	Advanced
19	(seat or seated).mp.	11432	Advanced
20	or/1-19	134604	Advanced
	Spirometry Segment		
21	exp Spirometry/	15429	Advanced
22	spiromet*.mp.	21112	Advanced
23	bronchospiromet*.mp.	819	Advanced
24	Respiratory Function Tests/	33181	Advanced
25	respiratory function test?.mp.	33537	Advanced
26	lung function test?.mp.	1930	Advanced
27	pulmonary function test?.mp.	5274	Advanced
28	Respiratory Therapy/	5141	Advanced
29	(respirat* adj2 therap*).mp.	7112	Advanced
30	"Work of Breathing"/	1651	Advanced
31	(work* adj2 breath*).mp.	2418	Advanced
32	bronchospirograph*.mp.	21	Advanced
33	spirograph*.mp.	623	Advanced
34	(breath* adj3 measur*).mp.	2755	Advanced
35	(incentive adj3 breath*).mp.	27	Advanced
36	exp Forced Expiratory Flow Rates/	8143	Advanced
37	(force* adj3 rate*).mp.	4655	Advanced
38	(force* adj3 capacit*).mp.	5907	Advanced
39	(force* adj3 volume*).mp.	21752	Advanced
40	(peak adj3 rate*).mp.	12366	Advanced
41	(flow* adj2 loop*).mp.	762	Advanced
42	fvc.mp.	6265	Advanced
43	fev1.mp.	13360	Advanced

44	fev6.mp.	26	Advanced
45	pefr.mp.	1562	Advanced
46	fivc.mp.	19	Advanced
47	triflo.mp.	13	Advanced
48	spirocare.mp.	1	Advanced
49	or/21-48	94168	Advanced
	Combined Search Results (limited to Adults and excluded letter and case report)		
50	49 and 20	2351	Advanced
51	letter/	660039	Advanced
52	case report.tw.	144688	Advanced
53	51 or 52	801722	Advanced
54	50 not 53	2330	Advanced
55	limit 54 to ("young adult (19 to 24 years)" or "young adult and adult (19-24 and 19-44)" or "middle age (45 to 64 years)" or "middle aged (45 plus years)" or "all aged (65 and over)")	1544	Advanced
56	limit 54 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "newborn infant (birth to 1 month)" or "infant (1 to 23 months)" or "preschool child (2 to 5 years)" or "child (6 to 12 years)" or "adolescent (13 to 18 years)")	580	Advanced
57	56 not 55	261	Advanced
58	50 not 57	2086	Advanced

EMBASE 1980 to 2009 Week 42

#	Searches	Results	Search Type
	Sitting vs. Standing Segment		
1	body position/	6848	Advanced
2	(body adj2 position?).mp.	7791	Advanced
3	sitting/	7483	Advanced
4	(sit* adj2 up*).mp.	7129	Advanced

5	(sit* adj2 straight).mp.	35	Advanced
6	(sit or sitting).mp.	15956	Advanced
7	(sit* adj2 erect).mp.	47	Advanced
8	(sit* adj2 position?).mp.	3552	Advanced
9	((sit or sitting) adj2 value?).mp.	56	Advanced
10	(sit* adj2 spiromet*).mp.	70	Advanced
11	standing/	8180	Advanced
12	(stand or standing).mp.	41164	Advanced
13	(stand* adj2 position?).mp.	2493	Advanced
14	((stand or standing) adj2 value?).mp.	94	Advanced
15	(stand* adj2 spiromet*).mp.	350	Advanced
16	(upright adj2 position?).mp.	1905	Advanced
17	((sit or sitting) adj2 (stand or standing)).mp.	2284	Advanced
18	(seat or seated).mp.	8212	Advanced
19	or/1-18	75904	Advanced
	Spirometry Segment		
20	spirometry/	9920	Advanced
21	spiromet*.mp.	13656	Advanced
22	bronchospirography/	7	Advanced
23	bronchospiromet*.mp.	13	Advanced
24	respiratory function test?.mp.	456	Advanced
25	lung function test/	14516	Advanced
26	pulmonary function test?.mp.	4716	Advanced
27	respiratory therapy.mp.	464	Advanced
28	respiratory therap*.mp.	1014	Advanced
29	*artificial ventilation/	11297	Advanced
30	(respirat* adj2 therap*).mp.	51542	Advanced
31	(work* adj2 breath*).mp.	1781	Advanced

32	spirograph*.mp.	1217	Advanced
33	(breath* adj3 measur*).mp.	3378	Advanced
34	(incentive adj3 breath*).mp.	26	Advanced
35	forced expiratory flow/	909	Advanced
36	(force* adj3 rate*).mp.	2283	Advanced
37	(force* adj3 capacit*).mp.	5446	Advanced
38	(force* adj3 volume*).mp.	24601	Advanced
39	breathing exercise/	1598	Advanced
40	(breath* adj3 exercise).mp.	4229	Advanced
41	(peak adj3 rate*).mp.	8058	Advanced
42	(flow* adj2 loop*).mp.	670	Advanced
43	fvc.mp.	5785	Advanced
44	fev1.mp.	15410	Advanced
45	fev6.mp.	38	Advanced
46	pefr.mp.	1354	Advanced
47	fivc.mp.	19	Advanced
48	triflo.mp.	15	Advanced
49	spirocare.mp.	3	Advanced
50	or/20-49	121230	Advanced
	Combined Results (limited to adults, and excluded letter and case report)		
51	50 and 19	1921	Advanced
52	letter/	442660	Advanced
53	case report/	1059060	Advanced
54	52 or 53	1411788	Advanced
55	51 not 54	1776	Advanced
56	limit 55 to (adult <18 to 64 years> or aged <65+ years>)	916	Advanced
57	limit 55 to (embryo <first trimester> or infant <to one year> or child <unspecified age> or preschool child <1 to 6 years>or	261	Advanced

	school child <7 to 12 years> or adolescent <13 to 17 years>)		
58	57 not 56	160	Advanced
59	55 not 58	1616	Advanced

Detailed results of searches for Question #3

Ovid MEDLINE(R) 1950 to August Week 1 2009

#	Searches	Results	Search Type
	Asian Segment		
1	exp Asian Continental Ancestry Group/	21129	Advanced
2	(asia* adj3 race*).mp.	236	Advanced
3	(asia* adj3 group*).mp.	18623	Advanced
4	(mongol* adj5 race*).mp.	55	Advanced
5	japanese*.mp.	62080	Advanced
6	korean*.mp.	10375	Advanced
7	chinese*.mp.	83668	Advanced
8	asian*.mp.	45218	Advanced
9	(asian* adj2 american*).mp.	4821	Advanced
10	(japanese* adj2 american*).mp.	1198	Advanced
11	(korean* adj2 american*).mp.	312	Advanced
12	(chinese* adj2 american*).mp.	732	Advanced
	Caucasian Segment		
13	European Continental Ancestry Group/	37958	Advanced
14	(europ* adj3 group*).mp.	41070	Advanced
15	white?.mp.	169016	Advanced
16	(caucas* adj3 race*).mp.	384	Advanced

17	(caucas* adj3 group*).mp.	927	Advanced
18	europ*.mp.	185893	Advanced
19	caucas*.mp.	29034	Advanced
20	(ethnic* adj2 differen*).mp.	8531	Advanced
21	(ethnic* adj2 background*).mp.	2415	Advanced
22	or/1-21	520833	Advanced
	Spirometry Segment		
23	exp Spirometry/	15464	Advanced
24	spiromet*.mp.	21191	Advanced
25	bronchospiromet*.mp.	819	Advanced
26	Respiratory Function Tests/	33298	Advanced
27	respiratory function test?.mp.	33656	Advanced
28	lung function test?.mp.	1942	Advanced
29	pulmonary function test?.mp.	5317	Advanced
30	Respiratory Therapy/	5155	Advanced
31	(respirat* adj2 therap*).mp.	7134	Advanced
32	"Work of Breathing"/	1651	Advanced
33	(work* adj2 breath*).mp.	2423	Advanced
34	bronchospirograph*.mp.	21	Advanced
35	spirograph*.mp.	624	Advanced
36	(breath* adj3 measur*).mp.	2760	Advanced
37	(incentive adj3 breath*).mp.	27	Advanced
38	exp Forced Expiratory Flow Rates/	8153	Advanced
39	(force* adj3 rate*).mp.	4670	Advanced
40	(force* adj3 capacit*).mp.	5955	Advanced
41	(force* adj3 volume*).mp.	21842	Advanced
42	(peak adj3 rate*).mp.	12404	Advanced
43	(flow* adj2 loop*).mp.	770	Advanced

44	fvc.mp.	6308	Advanced
45	fev1.mp.	13418	Advanced
46	fev6.mp.	27	Advanced
47	pefr.mp.	1566	Advanced
48	fivc.mp.	19	Advanced
49	triflo.mp.	13	Advanced
50	spirocare.mp.	1	Advanced
51	or/23-50	94523	Advanced
	Race Corrections Segment		
52	(race* adj2 correct*).mp.	23	Advanced
53	(predict* adj2 equat*).mp.	3492	Advanced
54	(reference* adj2 equat*).mp.	194	Advanced
55	(correct* adj2 factor*).mp.	3457	Advanced
56	(bell adj2 correct*).mp.	9	Advanced
57	(race* adj2 norm*).mp.	111	Advanced
58	(race* adj2 value*).mp.	93	Advanced
59	(correct* adj2 predict*).mp.	4679	Advanced
60	(ethn* adj2 correct*).mp.	26	Advanced
61	(predict* adj2 value*).mp.	130745	Advanced
62	correct*.ab,ti.	280695	Advanced
63	or/52-62	406728	Advanced
	Combined Results (limited to all adults)		
64	22 and 63 and 51	403	Advanced
65	limit 64 to ("all adult (19 plus years)" or "young adult (19 to 24 years)" or "adult (19 to 44 years)" or "young adult and adult (19-24 and 19-44)" or "middle age (45 to 64 years)" or "middle aged (45 plus years)" or "all aged (65 and over)")	306	Advanced

EMBASE 1980 to 2009 Week 50

#	Searches	Results	Search Type
	Spirometry Segment		
1	spirometry/	10090	Advanced
2	spiromet*.mp.	13842	Advanced
3	bronchospirography/	7	Advanced
4	bronchospiromet*.mp.	13	Advanced
5	respiratory function test?.mp.	460	Advanced
6	lung function test/	14711	Advanced
7	pulmonary function test?.mp.	4761	Advanced
8	respiratory therapy.mp.	467	Advanced
9	respiratory therap*.mp.	1026	Advanced
10	*artificial ventilation/	11396	Advanced
11	(respirat* adj2 therap*).mp.	51588	Advanced
12	(work* adj2 breath*).mp.	1800	Advanced
13	spirograph*.mp.	1220	Advanced
14	(breath* adj3 measur*).mp.	3411	Advanced
15	(incentive adj3 breath*).mp.	26	Advanced
16	forced expiratory flow/	923	Advanced
17	(force* adj3 rate*).mp.	2297	Advanced
18	(force* adj3 capacit*).mp.	5514	Advanced
19	(force* adj3 volume*).mp.	25020	Advanced
20	breathing exercise/	1644	Advanced
21	(breath* adj3 exercise).mp.	4291	Advanced
22	(peak adj3 rate*).mp.	8109	Advanced
23	(flow* adj2 loop*).mp.	672	Advanced
24	fvc.mp.	5842	Advanced

25	fev1.mp.	15564	Advanced
26	fev6.mp.	39	Advanced
27	pefr.mp.	1359	Advanced
28	fivc.mp.	19	Advanced
29	triflo.mp.	15	Advanced
30	spirocare.mp.	3	Advanced
31	or/1-30	122133	Advanced
	Asian & Caucasian Segment		
32	exp asian/	26017	Advanced
33	(asia* adj3 race*).mp.	1945	Advanced
34	(asia* adj3 group*).mp.	1145	Advanced
35	(mongol* adj5 race*).mp.	194	Advanced
36	22urope22a*.mp.	62396	Advanced
37	22urope*.mp.	11102	Advanced
38	22urope22*.mp.	69592	Advanced
39	asian*.mp.	27002	Advanced
40	(asian* adj2 american*).mp.	2762	Advanced
41	(22urope22a* adj2 american*).mp.	941	Advanced
42	(22urope* adj2 american*).mp.	188	Advanced
43	(22urope22* adj2 american*).mp.	564	Advanced
44	exp 22urope22an/	25078	Advanced
45	(europ* adj3 group*).mp.	2687	Advanced
46	(caucas* adj3 race*).mp.	5878	Advanced
47	(caucas* adj3 group*).mp.	1004	Advanced
48	white?.mp.	131593	Advanced
49	22urope*.mp.	161255	Advanced
50	caucas*.mp.	35946	Advanced
51	(ethnic* adj2 differen*).mp.	19065	Advanced
52	(ethnic* adj2 background*).mp.	2068	Advanced
53	exp ethnic/ or racial aspects/	0	Advanced

54	exp race difference/	21889	Advanced
55	exp ethnic difference/	14936	Advanced
56	or/32-52	473053	Advanced
	Race Corrections Segment		
57	(race* adj2 correct*).mp.	15	Advanced
58	(race* adj2 norm*).mp.	3022	Advanced
59	(race* adj2 value*).mp.	87	Advanced
60	(predict* adj2 equat*).mp.	3011	Advanced
61	(predict* adj2 value*).mp.	51231	Advanced
62	(correct* adj2 factor*).mp.	3322	Advanced
63	(correct* adj2 predict*).mp.	4279	Advanced
64	(bell adj2 correct*).mp.	5	Advanced
65	exp reference value/	12156	Advanced
66	(reference* adj2 value*).mp.	17330	Advanced
67	(reference* adj2 equat*).mp.	193	Advanced
68	(ethn* adj2 correct*).mp.	26	Advanced
69	correct*.ab,ti.	222905	Advanced
70	or/57-69	292159	Advanced
	Combined Results (limited to all adults)		
71	31 and 56 and 70	443	Advanced
72	limit 71 to (embryo <first trimester> or infant <to one year> or child <unspecified age> or preschool child <1 to 6 years> or school child <7 to 12 years> or adolescent <13 to 17 years>)	119	Advanced
73	limit 71 to (adult <18 to 64 years> or aged <65+ years>)	292	Advanced
74	72 not 73	56	Advanced
75	71 not 74	387	Advanced
76	exp animals/ not (exp animals/ and exp humans/)	14366	Advanced
77	75 not 76	387	Advanced

Detailed results of searches for Question #4

Ovid MEDLINE(R) 1950 to October Week 5 2009

#	Searches	Results	Search Type
	Spirometry Segment		
1	exp Spirometry/	15786	Advanced
2	spiromet*.mp.	21667	Advanced
3	lung function test?.mp.	1993	Advanced
4	fev1.mp.	13677	Advanced
5	or/1-4	33744	Advanced
	Action Level Segment		
6	decline.mp.	96470	Advanced
7	loss.mp.	461437	Advanced
8	(act* adj2 level*).mp.	39430	Advanced
9	or/6-8	586272	Advanced
	Methodology		
10	exp Longitudinal Studies/	682390	Advanced
11	longitudinal.mp.	119242	Advanced
12	or/10-11	733402	Advanced
	Combined Results		
13	9 and 12 and 5	665	Advanced
14	limit 13 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "newborn infant (birth to 1 month)" or "infant (1 to 23 months)" or "preschool child (2 to 5 years)" or "child (6 to 12 years)" or "adolescent (13 to 18 years)")	148	Advanced
15	limit 13 to ("all adult (19 plus years)" or "young adult (19 to 24 years)" or "adult (19 to 44 years)" or "young adult and adult (19-24 and 19-44)" or "middle age (45 to 64 years)" or "middle aged (45 plus years)" or "all aged (65 and over)")	568	Advanced
16	14 not 15	55	Advanced
17	13 not 16	610	Advanced
18	exp animals/ not (exp animals/ and exp humans/)	3511449	Advanced

19	17 not 18	610	Advanced

EMBASE 1980 to 2009 Week 51

#	Searches	Results	Search Type
	Spirometry Segment		
1	exp spirometry/	10105	Advanced
2	spiromet*.mp.	13861	Advanced
3	lung function test?.mp.	15565	Advanced
4	lung function test/	14736	Advanced
5	fev1.mp.	15572	Advanced
6	or/1-5	36348	Advanced
	Action Level Segment		
7	decline.mp.	79966	Advanced
8	loss.mp.	381005	Advanced
9	(act* adj2 level*).mp.	34122	Advanced
10	or/7-9	485543	Advanced
	Methodology Segment		
11	longitudinal study/	20921	Advanced
12	follow up/	301675	Advanced
13	prospective study/	88183	Advanced
14	longitudinal.mp.	76286	Advanced
15	or/11-14	436257	Advanced
	Combined Results		
16	6 and 10 and 15	585	Advanced
17	limit 16 to (embryo <first trimester> or infant <to one year> or child <unspecified age> or preschool child <1 to 6 years> or school child <7 to 12 years> or adolescent <13 to 17 years>)	103	Advanced
18	limit 16 to (adult <18 to 64 years> or aged <65+ years>)	433	Advanced

19	17 not 18	48	Advanced
20	16 not 19	537	Advanced
21	exp animals/ not (exp animals/ and exp humans/)	14366	Advanced
22	20 not 21	537	Advanced

EVIDENCE TABLES

Appendix Table E1: References for Technician Training

Author/ Year	Population/ setting	Subjects / Study Groups	Study design (with respect to evaluating impact of training)	Training	Key findings	Other comments
Bellia 2000 (1)	Spirometry performed on patients enrolled in Italian S.A.R.A multicenter study of resp health in elderly	Spirometry performed by PFT techs	Case series	Initial tech training with 15 h of lectures and workshops, written/practical examination, then ongoing central QC and feedback, site visits if needed, electronic feedback from spirometer, meeting to review performance at 1yr	# of tests performed by a center was related to the reproducibility of tests; ATS criteria for 3 acceptable curves was 84% of patients with hx of asthma or COPD; and 82% of patients with no hx resp disease	Similar approach to Lung Health Study
Borg 2010 (2)	Spirometry performed on primary care practice patients of rural Australian health facilities	Spirometry performed by nurses and physiotherapists. Quality compared to that of spirometry performed by experienced respiratory health scientist.	Case series. Prospective (comparison nurses/physiotherapists vs. respiratory scientist) and retrospective(record reviews of nurses & physiotherapists, no controls).	A 2-day, 14-hour training course in spirometry by experienced respiratory scientists. Then observation of performance and retrospective review of 10 spirometry records at 5, 7, and 9 months. Feedback, further education as required.	ATS criteria met by trainee: 5 mo – 40%; 7 mo – 67%; 9 mo – 87%. Respiratory scientist: 87%, 93%, and 100%. Record reviews of spirometry for ATS criteria and selecting correct test: 37%, 60%, and 58% at 5, 7, and 9 months.	The 2-day training course was not enough to assure quality spirometry. Observation of performance and feedback helped them to improve.
Burton 2004 (3)	Spirometry performed on 141 customers of Australian pharmacies	Spirometry performed by pharmacists (n= 9)	Case series.	Initial training 3-4 hours verbal/practical; then weekly feedback visits	66% curves meeting 3 ATS acceptability criteria; 86% of acceptable tests had 2 reproducible blows. Overall 57% acceptable tests	Raises issue of challenges in the outpatient setting, even with technician training
Den Otter 1997 (4)	Spirometry performed on general practice patients in the Netherlands	Spirometry performed by practice assistants (n=17), each video-taped performing spirometry on 3 patients	Case series.	“ received training and regular refresher courses” Videos reviewed by 7 experienced PFT techs and evaluated for 20 items	FVC maneuver demonstrated to patient only 11.2% of time. Quality of encouragement to patient adequate 13.5% of time.	Illustrates technical problems but no detail provided on type of training
Eaton 1999 (5)	Spirometry performed on patients of primary care practices in New Zealand	Spirometry performed by physicians and nurses in participating practices	Randomized controlled trial. 301 primary care practices invited to participate; 119 accepted; 30 randomly selected and randomized to 2 study arms (“trained” or “usual”) of 15 practices each	“Trained” = 2 h workshop at 0 and 12 weeks; “Usual” = no training until 12 weeks; followed until 16 weeks	13.5% (trained) vs. 3.4% (usual) had 3 acceptable blows and 2 reproducible blows; 33% (trained) vs. 12.5% (usual) had 2 acceptable blows. Differences resolved after training of usual group	Usual cause of failure was short blows. Better results with training

Appendix Table E1: References for Technician Training						
Author/ Year	**Population/ setting**	**Subjects / Study Groups**	**Study design (with respect to evaluating impact of training)**	**Training**	**Key findings**	**Other comments**
Enright 2008 (6)	Spirometry performed on patients of WTC medical monitoring program, 6 institutions, 12,000 tests	Spirometry performed by PFT techs	Case series.	"trained at...inception of project", written manual of procedures. Electronic feedback from spirometer. Review of tests and feedback from study director.	More than 80% of tests met ATS criteria for quality	Similar to Lung Health Study.
Enright 1991 (7)	Spirometry performed on 5887 adult cigarette smokers participating in Lung Health Study	Spirometry performed by 20 PFT techs.	Case series. Some component of before-and-after (before-after retraining and before-after implementing monitoring and feedback)	Combination of measures. Initial 16 h hands-on training & workshop. Electronic feedback from spirometer. Re-training when quality declined at 6 mo. Central QC and feedback.	Re-training at 6 months improved quality. Best impact with central monthly QC monitoring and feedback. 99.6% had 2 best FEV_1 matching 5% or 200 ml.	Early influential study. Documents that combination of interventions led to high quality results in epidemiology study.
Enright 2010 (8)	Spirometry performed on 13,599 WTC workers volunteers in medical screening program	Spirometry performed by 16 PFT techs	Case series.	Initial training. Electronic feedback from spirometer. Monthly QC review and feedback by study director.	80% tests were grade A or B ($\geq$ 3 acceptable maneuvers, 2 best FEV_1 and FVC within 200 ml)	Mutliple regression analysis showed some technicians better or worse than others
Hankinson 1991 (9)	Spirometry performed on 6486 participants in NHANES III Study, ages 8 to 90, the general US population	Spirometry performed by PFT techs	Case series.	1 week training (NIOSH course), pilot study, spirometer electronic and central QC feedback, field visits by Sr. tech for observation and feedback	95.4% $\geq$ 2 acceptable curves with FEV_1 and FVC within 200 ml (200 ml felt to be a better criteria than 5% for short people)	Early and influential study. Approach parallels Lung Health Study with similar findings.
Kunzli 1995 (10)	Spirometry performed on healthy, non-smoking Swiss adult participants in the SAPALDIA study	Spirometry performed by 23 PFT techs at 8 centers	Case series. 13-20 participants evaluated by each PFT tech at each center to evaluate technician, team, center and device effect.	Initial training in 3 day workshop. 2 months of practice prior to onset SAPALDIA. Electronic feedback from spirometer. Ongoing evaluation of studies and feedback.	No systematic differences between techs; group mean differences were 0.5-2.9% for FVC and 0.2-2.5% for FEV_1 across the 8 teams. One device identified with 10% lower FVC values.	Suggests uniform results can be obtained with a combination of training interventions.
Latzke-Davis 2011 (11)	Spirometry performed on patients in U.S. outpatient practices (20 pediatric, 15 family med, 2 intern med) with EasyOne spirometer or participated in research.	Spirometry performed by practice personnel. Each practice had a spirometry coach (usually a medical assistant or registered nurse) and a test interpreter (usually an MD).	Randomized controlled trial. Intervention (CD-ROM training) or control (no special training). Quality of spirometry (A or B vs. C, D, or F) was compared between the 20 intervention vs. 19 control practices that provided usable data.	Interpreter and coach in intervention practices viewed multimedia CD-ROM entitled "Spirometry Fundamentals™: A Basic Guide to Lung Function Testing," a70-min tutorial with an interactive delivery involving video, audio, animation, and text.	A or B quality was achieved in 19.4% of 537 sessions submitted by control practices; and 20.9% of 943 sessions submitted by intervention practices. Pediatric practices had A or B quality in 25.5% of studies vs. 14.6% in non-pediatric practices.	Viewing the CD-ROM did not improve the quality of spirometry.

Appendix Table E1: References for Technician Training						
Author/ Year	**Population/ setting**	**Subjects / Study Groups**	**Study design (with respect to evaluating impact of training)**	**Training**	**Key findings**	**Other comments**
Malstrom 2002 (12)	Spirometry performed on participants in 6 Phase III randomized clinical trials at 232 sites in 31 countries.	Spirometry performed by PFT technicians at the study sites. 2532 adults 336 children.	Case series.	0.5-2 days initial training, certified after demonstrating adequate performance, spirometer electronic feedback, central QC and feedback, retraining if needed	79 % of subjects had a mean FEV_1 quality of A or B across the trial (3 or more acceptable blows and reproducible for best 2 blows within 200ml)	Quality improved with time as study participants and technicians gained experience
Perez-Padilla 2008 (13)	Spirometry performed on 5315 Latin American participants in PLATINO study	Spirometry performed by PFT techs in 5 Latin American cities	Case series.	Initial 2-day training similar to NIOSH course, practice prior study, spirometer electronic feedback, QC and feedback from local supervisor and central review site	89% met 2005 ATS/ERS criteria	Similar combination as Lung Health Study
Schermer 2003 (14)	Spirometry performed on patients with COPD in the Netherlands; 338 in 1st yr and 332 in 2nd yr	Spirometry performed by general practitioners and practice assistants in general practices and techs in PFT laboratories	Prospective, cross-sectional study comparing individual subjects' quality of spirometry between 4 PFT laboratories vs. 61 general practices	GP personnel received 2x 2.5 hour training sessions, 1 month apart. Feedback from spirometers included real-time flow curves, and time of exp. and inspiratory flow, but no quality prompts.	FEV_1 reproducibility 1st year 84% labs and 82% offices, 2nd year 82% in both (within 5% or 200 ml). However GP values were consistently higher than lab values	A high level of success can be achieved in GP clinics. However, absolute values may be somewhat different from labs
Schermer 2011 (15)	Spirometry performed on patients of 19 family practices in the Netherlands	Spirometry performed by nurses working in family practices participating in the study 9 intervention practices (490 tests analyzed), 10 control practices (645 tests analyzed)	Randomized, cluster controlled comparison of spirometry over 1 year in intervention vs.control practices. Primary outcome was proportion of tests with $\geq$2 acceptable blows and repeatable FEV_1 and FVC.	Nurses attended a 2.5 hour baseline workshop, didactic and practical. Intervention nurses only also watched a CD-ROM (same as Latzke-Davis 2011) and submitted up to 25 tests every 2 to 2.5 months for expert review and feedback reports.	The rate of adequate tests was 32.9% in the intervention and 29.8% in the control group. Over time, the intervention group improved, with 43.3% and 34.1% adequate in intervention and control groups respectively in the last study period.	Authors note, "In the course of 1 year, we observed a small and late effect of e-learning and repeated feedback on the quality of spirometry."
Silverman 2007 (16)	Spirometry performed on 620 US patients with acute asthma in 20 emergency departments	Spirometry performed by RNs, physician assistants, and research assistants	Case series.	Half-day group training, followed by half-day training session at individual study site. Feedback from electronic spirometer and central QC site.	By 1 hour after arrival, 90% of acute asthma patients had FEV_1 reproducibility within 10% and 96.4% had 2 or more acceptable curves.	Patients with severe airway obstruction were initially less likely to meet quality goals.
Stoller 1997 (17)	Spirometry performed on 1129 adult participants in a US A1AT registry	Spirometry performed by PFT technicians at 37 centers	Case series.	0.5 day course, monthly quality reports to centers, remedial phone call and training if needed, site visits. Variety of equipment used.	Rates of reproducibility for FEV_1 were $\geq$ 95% for pre and post BD studies (criteria the greater of 5% of largest FEV_1 or 100 ml)	Using multiple measures was effective in A1AT patient population

Appendix Table E1: References for Technician Training						
Author/ Year	**Population/ setting**	**Subjects / Study Groups**	**Study design (with respect to evaluating impact of training)**	**Training**	**Key findings**	**Other comments**
Stoller 2002 (18)	Spirometry performed on inpatients receiving bedside spirometry in a US tertiary care hospital (Cleveland Clinic)	Bedside spirometry performed by respiratory therapists	Case series, , compared quality of spirometry after training vs. retrospective data collected by auditing 20 spirometry tests performed before the training initiative.	Initial 1 hour training in person or videotape. Review of spirogram printouts (volume-time, flow-volume). Central review and feedback with suggestions for improvement.	ATS-based criteria. 15% acceptable tests before intervention vs. 63.5% after intervention ($p < 0.001$).	Significant improvement after limiting spirometry to core group of trained respiratory therapistsand providingfeedback
Townsend 1986 (19)	Spirometry performed on participants in the US Multiple Risk Factor Intervention Trial (MRFIT)	Spirometry performed by PFT techs at 6 clinics participating in the study	Case series.	Techs watched film, reviewed manual, certification and re-certification annually based on testing of 3 non-MRFIT subjects, central QC with regular review and feedback	Examples of clinics' FEV_1 and FVC reproducibility reports ranged from 90.4% to 98.7% (criteria within 200 ml)	Set of interventions put into place after problems early in MRFIT. Early example of measures later used in the Lung Health Study and NHANES.
Upton 2000 (20)	Spirometry performed on 2294 participants ages 30-59 in a British population cohort study (Renfrew-Paisley family study)	Spirometry performed by 5 nurses	Case series; some results are shown before-and-after feedback and refresher training	16 hours training over 3 weeks; electronic real time feedback from spirometer; central review, problems identified week 14, feedback provided on week 15, refresher training 2 weeks later	Overall 84.5% with 3 acceptable curves and 2 reproducible maneuvers. 4.9% improvement occurred after feedback and retraining.	Multivariate analysis shows participant and technical characteristics predicted unacceptable FEV_1, variable FEV_1& FVC. Participant characteristics predicted unacceptable FVC.
Walters 2008 (21)	Spirometry performed on patients of Australian general practices. Patients were over 35 yr old and had histories of ever having smoked regularly	Spirometry performed by practice personnel (GP physicians or practice nurses/assistants); or, in addition, by visiting nurses trained in spirometry who visited for two 3-hour sessions per week	Randomized, prospective trial comparing the impact of visiting spirometry nurses (4 intervention practices) vs. no visiting spirometry nurses (4 control practices)	At all clinics, 2-hour training was provided to GP physicians and other nominated staff on spirometry and on Global Obstructive Lung Disease criteria for diagnosing COPD. Spirometer used in study provided electronic feedback on quality.	531 spirometry tests performed in intervention group; 87 in control group. Rate of A or B quality spirometry ($\geq$ 3 acceptable blows and reproducible for best 2 blows within 200ml) was 76.4% intervention vs 43.7% control group, $p < 0.0001$.	Spirometry was performed more frequently and with better quality when general practices were visited by well-trained, experienced travelling nurses as opposed to relying on usual clinic staff
Yawn 2007 (22)	Spirometry performed on patients in family practices in the USA >7 yr old with asthma or COPD	Spirometry performed by practice personnel assigned to perform the test.	Case series.	Family physicians and those assigned to perform spirometry took 2 day spirometry training session on performance. Also received electronic feedback from spirometers	71% tests considered adequate for interpretation based on ATS/ERS criteria	Primary purpose of study was to assess the impact of spirometry on management, not training on performance

Appendix Table E1: References for Technician Training						
Author/ Year	**Population/ setting**	**Subjects / Study Groups**	**Study design (with respect to evaluating impact of training)**	**Training**	**Key findings**	**Other comments**

Abbreviations
AIAT: alpha-1 antitrypsin
BD: bronchodilator
CD-ROM: compact disk that functions as read-only memory
COPD: chronic obstructive pulmonary disease
FEV_1: forced expiratory volume in 1 second
GP: general practice
H: hour
Hx: history
MRFIT: Multiple Risk Factor Intervention Trial
NHANES: National Health and Nutrition Examination Survey
PLATINO: Latin American Project for the Investigation of Obstructive Lung Diseases
PFT: pulmonary function test
QC: quality control
Resp: respiratory
SAPALDIA: Swiss study on air pollution and lung disease in adults
S.A.R.A.: salute respiratoria nell'Anziano (Respiratory Health in the Elderly)
Tech: technician
Yr: year
WTC: World Trade Center

<table>
<tr><th colspan="5">Appendix Table E2: References for Standing vs. Sitting Position</th></tr>
<tr><th>Reference</th><th>Population/ Setting</th><th>Number Subjects</th><th>Study Design*</th><th>Key Findings</th></tr>
<tr><td>Fiz, 1991(23)</td><td>Healthy non-smokers, Spain. Not obese: mean age 27, mean wt 172 lb</td><td>15 men</td><td>Randomized cross-over clinical trial</td><td><table>
<tr><th></th><th>Sit (Mean)</th><th>Stand (Mean)</th><th></th></tr>
<tr><td>FVC</td><td>**6.06** L</td><td>6.03 L</td><td>NS</td></tr>
<tr><td>FEV_1</td><td>5.01 L</td><td>**5.02** L</td><td>NS</td></tr>
</table></td></tr>
<tr><td>Gudmundsson 1997(24)</td><td>Obese, mean BMI 39, mean age 45 subjects having spiro at PFT lab and were asked to participate</td><td>50
32 women 18 men</td><td>Randomized cross-over clinical trial</td><td>FVC +.06 L standing, $p<0.05$;
FEV_1 + .03 L $p>0.05$
Post-bronchodilator PFTs.
Analyzed results from the curve with max FEV_1+FVC</td></tr>
<tr><td>Lalloo 1991(25)</td><td>Healthy, non-obese

Vitalograph bellows spirometer</td><td>94
41 men and 53 women</td><td>Randomized cross-over clinical trial</td><td><table>
<tr><th>Females</th><th>Stand – Sit (Mean)</th><th></th></tr>
<tr><td>FVC</td><td>+0.02 L</td><td>NS</td></tr>
<tr><td>FEV_1</td><td>+0.04 L</td><td>p<.001</td></tr>
</table>
<table>
<tr><th>Males</th><th>Stand – Sit (Mean)</th><th></th></tr>
<tr><td>FVC</td><td>0 L</td><td>NS</td></tr>
<tr><td>FEV_1</td><td>0.10 L</td><td>NS</td></tr>
</table></td></tr>
<tr><td>Lin 2005(26)</td><td>Sitting in a wheelchair, upright vs. standing Spinal Cord Injury (SCI) patients</td><td>40
22 men and 18 women</td><td>Randomized cross-over clinical trial.</td><td><table>
<tr><th></th><th>Sit (Mean)</th><th>Stand (Mean)</th><th></th></tr>
<tr><td>FVC</td><td>4.13L</td><td>**4.26** L</td><td>p<0.001</td></tr>
<tr><td>FEV_1</td><td>3.31L</td><td>**3.42** L</td><td>P=0.001</td></tr>
</table></td></tr>
<tr><td>Pierson 1976(27)</td><td>Random community sample, Colorado</td><td>235</td><td>Cross-over clinical trial</td><td>FVC 3.93 L stand vs. 3.97 L sit ($p<0.01$)
FEV_1 2.93 L stand vs. 2.96 L sit ($p<0.05$) FEV_1/VC ns
All subjects stood first, sat second</td></tr>
<tr><td>Razi 2007(28)</td><td>Obese, BMI>30, Asthmatics vs. controls Iran
No info on participation rate</td><td>49 asthmatic
51 non-asthmatic
all obese</td><td>Cross-over clinical trial</td><td>Asthmatics:FVC: sit 3.04 L; stand 3.03 L; FEV_1: sit 2.38 L; stand 2.40 L.
Non-asthmatics:FVC: sit 3.68 L; stand 3.72 L;FEV_1: sit 3.17 L; stand 3.21 L;$p > 0.5$ for all comparisons
Testing order and whether pre or post bronchodilator results analyzed not specified. Analyzed results from the curve with max FEV_1+FVC</td></tr>
<tr><td>Townsend 1984(29)</td><td>Middle age employed men, MRFIT participants, age 42-61. All asked participated.
68 subjects FEV_1/FVC > 0.70
22 subjects FEV_1/FVC $\leq$ 0.70
Collins spirometer</td><td>90 men</td><td>Cross-over clinical trial
Alternated test posture order within groups</td><td><table>
<tr><th></th><th>Sit (Mean)</th><th>Stand (Mean)</th><th></th></tr>
<tr><td>FVC</td><td>4.21L</td><td>**4.27** L</td><td>p<0.001</td></tr>
<tr><td>FEV_1</td><td>3.10L</td><td>**3.17** L</td><td>p<0.001</td></tr>
</table>
<table>
<tr><th></th><th>Test 1 (Mean)</th><th>Test 2 (Mean)</th><th></th></tr>
<tr><td>FVC</td><td>4.22L</td><td>**4.27** L</td><td>p<0.01</td></tr>
<tr><td>FEV_1</td><td>3.11L</td><td>**3.16** L</td><td>p<0.001</td></tr>
</table>
Significant effect of test order also observed, with second test FEV_1 and FVC greater than first test.</td></tr>
</table>

Abbreviations
FEV_1: forced expiratory volume in 1 second
FVC: forced vital capacity

MRFIT: Multiple Risk Factor Intervention Trial
* randomized refers to test posture order randomized for each subject

Appendix Table E3: References for Asian Predicted Values					
Reference	**Population and Setting**	**Number Subjects**	**Study Design**	**Key Findings**	**Comments**
Fulambarker 2004(30)	Healthy non-smoking Asian-Indian immigrants to USA, born in India. Chicago area. Mean age men 40 yrs Mean age women 40 yrs	366 226 men 137 women	Cross-sectional study. Comparison to published studies, Caucasian reference values.	Compared to Caucasians, Indian men: FEV_1: 16-23% lower; FVC 20-24% lower. Indian women: FEV_1: 21-26% lower; FVC 25-28% lower	Only Indian born immigrants, no Chinese, Korean, or other Asians. Authors generated reference equations for spirometric values.
Hankinson 2010(31)	Participants from the Multi-Ethnic Study of Atherosclerosis (MESA) Lung Study, excluded if smoking, obesity, or serious medical problem. 60% women. Mean age 65 yrs	1068 270 white 201 African-American 245 Hispanic 343 Asian-Americans	Cross-sectional studywith white control group. Also comparison to NHANES III reference values.	Asian-Americans significantly lower FVC and FEV_1 than whites. A correction factor for Asian-Americans of 0.88 seems more appropriate than 0.94 currently recommended.	70% of the Asian subjects were of Chinese origin. Non-Mexican Hispanics had lower FVC and FEV_1 than Mexican Hispanics.
Korotzer 2000(32)	Healthy non-smoking physicians and medical students in US of European or Asian descent. Mean age 28 yrs. 50% female.	80 40 Asian descent 40 European descent	Cross-sectional study with control group (European descent)	FEV_1: 7% lower (range 4-11%) for Asian-American than European-American physicians and medical students.	Young physicians. No difference for diffusing capacity
Lin 1999(33)	Healthy non-smoking adults from bilateral Filipino ancestry in US, recruited from around San Diego Mean age 37 yrs	224 121 men 103 women	Cross-sectional study. Comparison to Crapo reference values.	FEV_1 and FVC: 15% lower (range 12-21%) than whites when using Crapo reference values.	Authors recommend 0.85 correction factor for Filipino subjects when using Crapo reference equation.
Marcus 1988(34)	Healthy non-smoking Asian-Indian immigrants to USA, born in India. Chicago area. Mean age men 40 yrs Mean age women 40 yrs	1490 men selected from 8,006 men in original cohort	Cross-sectional study, within prospective cohort study. Comparison to published studies.	Prediction equations for FEV_1 for Japanese-American men were compared to published prediction equations. Values for FEV_1 were between higher Caucasian and lower African-American values.	Only Japanese-American men in Honolulu Heart Program.
Massey 1986(35)	Healthy non-smoking Japanese-Americans men from Japan-Hawaii Cancer Study, their wives, friends, in Oahu.Mean age 49 yrs 50% women.	118 men and women Control group: 36 Caucasian s	Cross-sectional studywith control group, also comparison to published studies.	Younger Japanese in Oahu spirometric values closer to Caucasians (Crapo predicted); older Japanese more like native Japanese, lower spirometric values.	Japanese in Hawaii anthropometric and spirometry values closer to Caucasians than Japanese in Japan.
Sharp 1996 (36)	Healthy non-smoking men with acceptable FEV_1 selected from Honolulu Heart Program survivors: Japanese ancestry born 1900 -1919, on Oahu in 1965, alive forfollow-up 1991	528 men selected from 3,076 with acceptable spirometry.	Cross-sectional study, comparison to published Caucasian reference values. Also prospective cohort study to assess	Prediction equations for FEV_1& FVC were 5-7% and 9-12% lower for Japanese-American men, compared to Caucasian reference values from the Cardiovascular Health Study.	Elderly Japanese-Americans men. Decline in FEV_1 over mean 22.6 yrs in these subjects was similar to other studies: 28 to 33ml/year.

	to 1993. Mean age 77 yrs (71 to 90 yr)	Follow-up Marcus 1988.	FEV_1decline.			Abbreviations

Abbreviations
FEV_1: forced expiratory volume in 1 second
FVC: forced vital capacity
NHANES: National Health and Nutrition Examination Survey
Cardiovascular Health Study: Observational study of risk factors for cardiovascular disease in adults 65 years or older.

Appendix Table E4: Selected References for Evaluating Longitudinal Spirometry (Loss of FEV1) in Workers					
Reference	**Population / Setting**	**Subjects**	**Study Design**	**Key Findings**	**Other Comments**
Hnizdo 2005(37)	Surveillence spirometry data from 11 industrial plants	3130 workers with ≥3 spirometry tests over ≥ 5 yrs	Retrospective cohort.	Plant-specific variability in pairwise within-person SD of FEV_1; precision of FEV_1 measurements impacts the duration of follow up needed to identify a “true” excess rate of decline in an individual.	Method described to evaluate longitudinal FEV_1 data precision. The ability to detect “abnormal” values of decline in FEV_1 depends on the data precision.
Hnizdo 2006(38)	Surveillence spirometry data from 11 industrial plants	1786 men with ≥ 5 spirometry tests over 5 yrs	Retrospective cohort.	Comparedthe effectiveness (sensitivity, specificity, and positive predictive value) of 3 different methods to estimate LLD in predicting “true” FEV_1 decline (> 60 ml/yr &> 90 ml/yr) using data over different years of follow-up (1 to 8 years).	The LLD method using FEV_1 data precision had higher sensitivity and similar specificity over years 1 through 5, compared to 15% method, to detect excessive decline FEV_1.
Hnizdo 2007 (39)	Surveillance spirometry data from 4 programs: 2 industrial plants, firefighters, and the Lung Health Study	1021 plant workers > 1600 firefighters and 5597 smokers with early COPD	Retrospective cohort	Provides methods for calculating absolute and relative LLD of FEV_1using pair-wise estimates of within person variation to assess program quality.	In a good-quality monitoring program, LLD of ~10% for excessive annual decline FEV_1can be achieved in normals; LLD of 15% for asthma or COPD subjects seems appropriate.
Hnizdo 2012 (40)	Surveillance spirometry data from 3 programs: firefighters, paper pulp mill workers, and construction workers	965 Firefighters 1631 Pulp-mill workers 460 Construction workers with ≥ 4 spirometry tests over> 8 yrs	Retrospective cohort	Various methods to identify excessive FEV_1 decline (> 90 ml/yr) evaluated. Thresholds determined by LLD and 15% (plus expected decline)methods both achieved clinical usefulness after ~ 4-5 yrs follow up. Regression slope required generally ≥ 7 yrs to predictexcessive FEV_1 decline.	The thresholds for decline based on LLD method and 15% (plus expected decline) are similar with within-person variation (program data precision) of 6%. LLD method can be more sensitive with better quality spirometry program (less data variability).
Johnsen 2010 (41)	Workers at 15 Norwegian smelters with varying exposure levels	2620 employees, 878 in lowest exposure group, 80% men, age ~40, ~40% never smokers. Yearly spirometry for 5 yrs	Prospective cohort	Mean follow-up 3.5 yrs. Annual decline in FEV_1 for anon-smoking employee in the lowest tertile exposure group was 26.6 ml/yr.	Similar annual FEV_1 decline as other studies. Findings relative to unexposed subjects limited by inclusion of production workers with low exposure in the lowest exposure group.
McKay 2011 (42)	Refractory ceramic fiber (RCF) workers at 5 locations. Lowest exposure group ≤ 15 fiber-months/cc	Lowest exposure group: 470 men; 191 women, mean age 38 yrs. Spirometry every 1 to 3 yrs for 7-10 years	Prospective cohort	Modeled FEV_1 decline. Lowest exposure group (ml/yr): Age 30: -30; Age 40: -29; Age 50: -42; Age 60: -44. FEV_1 decline increased with smoking, initial weight, and weight gain.	Study notes that "lung function declines with age are non-linear and accelerate in older age groups who also have the longest duration of exposure".
Hnizdo 2011 (43)	Construction workers in worksite wellness program	1224 workers with ≥ 5 yrs follow-up. Spirometry every 3 yrs, ≥ 2 tests in 5 yrs	Retrospective cohort	SPIROLA software used to evaluate FEV_1decline. Mean FEV_1 decline was 47 ml/yr, associated with smoking, increased BMI (especially BMI >35). 8.3% had moderate airflow obstruction. Interventions identified.	Use of spirometry in worksite wellness program. Of 53 workers with excessive decline FEV_1, 74% met ATS guidelines, 20.8% had "quality issues that could potentially affect interpretation."

Abbreviations:
LLD – longitudinal limits of decline
FEV_1: forced expiratory volume in 1 second
yr: year
BMI: Body mass index
SPIROLA: Spirometry Longitudinal Data Analysis program developed by NIOSH

Appendix Table E5: Selected References for Evaluating Longitudinal Spirometry (Loss FEV_1) in the General Population					
Reference	**Population /Setting**	**Subjects / Study Groups**	**Study Design**	**Key Findings**	**Other Comments**
Burchfiel 1996(44)	Japanese-Americans, general population, Hawaii, USA	4451 men 45 - 68 yrs, mean age 54 yrs Spirometry at: baseline, 2 yrs, 6 yrs	Retrospective Cohort	Rates FEV_1 decline Never smokers: 22 ml/yr Active smokers: 34 ml/yr Total population: 26 ml/yr	Continued smoking, pk-years, wheezing, coronary heart disease, alcohol intake, and leanness all independent predictors of rapid FEV_1decline
Burrows 1986(45)	White, non-Mexican, Tucson, AZ, USA Healthy non-smokers	466: 158 men, 308 women Mean follow-up 9.6yrs, Average 5.2 spirometry tests per subject	Retrospective cohort	Equations for ΔFEV_1 related to (age * ht^2). Decline accelerates with greater age. Apparent onset decline 36.3 yrs for men and 36.7 yrs for women.	Survey biases critical. Cautioned that their equations should not be considered generalizable.
Fletcher 1977(46)	Random sample of men (mostly skilled manual or clerical) working in West London, England	1136 men (792 with sufficient follow-up spirometry over 8 years for analysis) aged 30-59 103 non-smokers spirometry q 6 months	Prospective cohort	FEV_1 declines continuously. Sudden large falls rare. Rate accelerates with age. Nonsmokers (and many smokers) lose FEV_1 slowly. Some "susceptible" more rapid decline. Smoking cessation can return rate of decline to normal. Mean rate FEV_1 decline in non-smokers: 36 ml/yr	Landmark study. Early advocate of using greatest FEV_1 rather than mean of several FEV_1s obtained during a spirometry session.
Kohansal 2009 (47)	Subset of population-based Framingham offspring cohort, never-smokers with at least two valid spirometry tests (out of 4 offered over 26 yrs).	4391 participants met inclusion criteria. 1578 never smokers. Mean age at entry -23 yrs. 666 men, 912 women. Median follow –up 23 yrs.70% participants had $\geq$ 3 spirometry tests, 48% had 4.	Retrospective cohort	Never smokers: Mean FEV_1 in men increased up to a peak at age 23 yrs. Mean FEV_1 in women was at a plateau until about age 40 yrs. Annual rate of decline for males (19.6 ml/yr) was slightly but not significantly greater than females (17.6 ml/yr).	Method to estimate FEV_1rate of decline: "calculated in each participant by dividing the difference in milliliters between measurements obtained in the first and last availablespirometry in each individual, out of a maximum of four…by the time (yrs) between these measurements…"
Siedlinski 2009 (48)	Two Dutch general population cohorts (Doetinchem [D] cohort and Vlagtwedde-Vlaardingen [VV] cohort)	1152 in D cohort, 47% men, median age 54 yrs last visit, 32% never-smokers, 3 spirometry in 10yrs; 1390 in VV cohort, 51% men, median age 52 yrs last visit, 32% never-smokers, 7 spirometryin 25yrs.	Retrospective cohort	D cohort: rate FEV_1 decline 26.2 ml/yr VV cohort: rate FEV_1decline 20.8 ml/yr	Primary purpose was to assess the impact of gene polymorphisms on level of FEV_1 and rate of FEV_1 decline. Data showed that the polymorphisms affected level of FEV_1, but not rate of decline.
Lee 2010 (49)	Systematic review 47 studies different smoking groups	28 studies 19 studies men At least 2 yrs follow-up. mean follow-up 11 yrs	Systematic review	Mean rates FEV_1 decline Never-smokers: 29.2 m./yr Ex-smokers: 27.6 ml/yr Continuing smokers: 40.1 ml/yr	In smokers FEV_1 decline related to number of cigarettes smoked / day.
Abbreviations: FEV_1: forced expiratory volume in 1 second yr: year					

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