Interpreting Longitudinal Spirometry: Weight Gain and Other Factors Affecting the Recognition of Excessive FEV_1 Decline

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Background *Excessive FEV_1 loss in an individual or a group can reflect hazardous exposures and development of lung disease. However, multiple factors may affect FEV_1 measurements.*
Methods *Using medical screening data collected in 1884 chemical plant workers between 1973 and 2003, the influence of multiple factors on repeated measurements of FEV_1 was examined.*
Results *The FEV_1 level was associated with age, height, race, sex, cigarette smoking, changes in body weight, and spirometer model. After controlling for these factors, longitudinal FEV_1 decline averaged 23.8 ml/year for white males; an additional loss of 8.3 ml was associated with one pack-year smoking and 5.4 ml with a one pound weight gain. Depending on the spirometer model, FEV_1 differed by up to 95 ml.*
Conclusions *The study results provide quantitative estimates of the effect of specific factors on FEV_1, and should be useful to health professionals in the evaluation of accelerated lung function declines.* Am. J. Ind. Med. 52:782–789, 2009.

KEY WORDS: mass screening; excessive FEV_1 decline; spirometry; mixed model; longitudinal data

INTRODUCTION

Excessive loss of forced expiratory volume in one second (FEV_1) in an individual can be a useful early indicator of the development of lung disease, while differences in declines between occupational groups may suggest continuing workplace hazards. Persistent FEV_1 declines of 60–90 ml per year have recently been associated with subsequent increased mortality from respiratory and cardiovascular disease [Sircar et al., 2007]. Annual spirometry using professional standards is recommended for medical monitoring programs [Hankinson and Wagner, 1993; Townsend, 2000]. However, the reliable recognition of excessive longitudinal change in spirometry measurements is complicated by additional random and systematic variation, such as changes in weight, testing equipment, or procedures. Thus, the correct interpretation of serial FEV_1 measurements may depend on a number of variables in addition to test quality and methods [Glindmeyer et al., 1987; Buist and Vollmer, 1988; Lebowitz, 1996; Townsend, 2005].

Abbreviations: FEV_1, forced expiratory volume in one second; NIOSH, National Institute for Occupational Safety and Health; CDC, Centers for Disease Control and Prevention; ATS, American Thoracic Society; BMI, body mass index.

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This study aims to examine factors impacting the interpretation of FEV_1 declines, using 30 years of spirometry monitoring data, with the goal of assisting occupational professionals who utilize spirometry in recognizing and prioritizing respiratory health risks.

METHODS

Approval for performance of the study was received from the NIOSH Human Subjects Review Board. The data were obtained from an ongoing health monitoring program at a large chemical plant. Materials and methods have previously been reported [Wang et al., 2006].

Participants and Spirometry Testing

Spirometry was performed as part of the employee health monitoring program of a large chemical plant. A total of 1,884 participants with at least 5 valid results spanning 10 or more years between 1973 and 2003 were included in this analysis. Testing began in 1972 to comply with the first OSHA asbestos standard, and was scheduled annually, aside from the first 12 years, when spirometry was every 2 years for workers without asbestos exposure.

Testing was performed by trained nurse technicians at the on-site company medical department according to American Thoracic Society (ATS) standards current at the time of the test. In the years before professional standards were published, spirometry was supervised by academic researchers who were familiar with spirometry techniques and procedures. The head nurse spent 1 week training in spirometry at Tulane University; she then initiated the program and trained the other nurses. In 1978, the medical director collaborated with NIOSH in starting a NIOSH-approved spirometry course. Thereafter, all nurses were trained through that course. Quality was checked by the nurse technicians during testing, and reviewed by the medical director during the annual physical examination. Spirometry quality feedback was consistently provided to technicians by the head nurse and the medical director. Daily volume calibration checks were performed using a 3-L syringe. A leak check was also done each day prior to testing. Initially, spirometry results were all hand calculated using a back extrapolation time zero technique. Starting in 1978, software packages calculated results and provided quality feedback to the technicians. The testing posture was standing before March 1988; and was sitting afterward.

Four different models of volume spirometers were used in testing for various periods of time over the 30 years. Between 1973 and 1987, testing was performed with a Jones Pulmonaire spirometer with a Datamite microprocessor (Jones Instrument, Oak Ridge, IL). Between 1988 and 1996, testing was done using an InfoMed model 5100-0020 device. The NIOSH HF5 system with an Ohio rolling seal spirometer was used from 1997 to 2002, and an OMI (Occupational Marketing, Houston, TX) system since 2003.

Prior to initiating this study, the authors evaluated spirometry data quality by examining hard copies of the spirometry volume-time tracings and flow-volume curves when available, and calculated repeatability using computer printouts from all the serial spirometry tests over the 30 years for a sample of 42 workers. We concluded that the overall quality of the testing was good and the database was acceptable for analysis.

Data Analysis

Statistical analysis was performed using the SAS® v9.0 software package (SAS®, version 9.0, 2002; SAS Institute, Inc., Cary, NC).

Longitudinal rate of change of FEV_1, often called "FEV_1 slope," was computed for each individual across the repeated measurements using simple linear regression. The resulting FEV_1 slope was then used as the outcome variable in the two-stage analysis comparing average slopes across the various groups of interest, including race, sex, age groups, and smoking categories. These group comparisons of FEV_1 slope were evaluated using *t*-tests or ANOVA. A linear mixed-effects model approach was also used to analyze the longitudinal spirometry data [Littell et al., 1996]. The health outcome variable was the repeated measurement of FEV_1. Multiple factors potentially affecting the measurements of FEV_1 were evaluated as fixed (time-independent) co-variables, including baseline age (Bage) and weight (Bwtlb), height, race, and sex. Also evaluated in the mixed-effects model were time-dependent co-variables, including the model of spirometer used, pack-years of smoking, and the change from baseline in body weight (difwt), with values recorded at the time of each test.

The major interest centered on the significance of the association between multiple factors and the changes in FEV_1 over time. Differences in longitudinal FEV_1 by race and sex were examined by including race–sex–time (interval since first test) interaction terms in the model. To examine differences in the association between weight gain and the decline in FEV_1 by race and sex, we also included the interaction term of race–sex–difwt in the model. The selection of the appropriate type of covariance structure was accomplished by considering the biological features of the outcome variable, and also by choosing the smallest Akaike's Information Criterion (AIC) after fitting models with alternative covariance structures [Burnham and Anderson, 1998]. The final MIXED model procedure was fitted using both RANDOM and REPEATED statements. It included an unstructured covariance to account for random variation between individuals in the intercept and slope (the longitudinal rate of change in FEV_1 obtained from the mixed models for repeated measurements), as well as a

TABLE I. Demographic and Spirometry Parameters at the Initial Examination by Sex (n = 1,884)

	Male, n = 1,721	Female, n = 163
Age (years)	35.0 (9.5, 18–62)[a]	31.0 (8.2, 19–53)
Year of birth	1,943 (11.5, 1,912–1,969)	1,948 (9.8, 1,924–1,969)
Height (inches)	69.9 (2.5, 58–79)	64.6 (2.3, 58–72)
Weight (pounds)	183.4 (28.4, 115–344)	148.8 (33.2, 95–268)
Race (ratio: white/black)	1,598:123	143:20
Smoking (pack-years)	7.8 (10.0, 0.0–62.7)	3.3 (7.0, 0.0–47.3)
Smoking (pack-years)[b]	12.9 (9.9, 0.1–62.7)	8.0 (9.1, 0.1–47.3)
FEV_1 (milliliters)	3,871 (661, 1,500–6,160)	2,886 (443, 1,800–4,720)
FVC (milliliters)	4.978 (721, 2,500–7,550)	3,597 (513, 2,375–5,680)
FEV_1/FVC (%)	77.8 (7.2, 45.5–99.0)	80.5 (7.7, 53.4–96.2)

[a]Values are mean (SD, range).
[b]Only ever smokers included (1,043 males and 67 females).

spatial power law structure, SP(POW), to account for serial correlation of FEV_1 measurements within individuals. This combination structure specifies an inter-subject random effect for differences between individuals, and a correlation structure within individuals that decreases with increasing time between measurements.

Two additional mixed models were performed, the first including only white males, and the second model including only non-smokers.

RESULTS

The study participants represented a middle-aged working population, and were 91% male and 92% Caucasian, with 35% current smokers, 24% ex-smokers, and 41% never smokers at the initial test. At the final test, there were 18% current smokers, 42% ex-smokers including 18% who quit smoking during follow-up. There were 21,819 pulmonary function measurements on 1,884 subjects (1,721 men and 163 women). The mean follow-up interval between each participant's first and last test was 18 years, ranging from 10 to 30 years, with an average of 12 valid spirometry results (range, 5–23). Table I shows the demographic characteristics and spirometry indexes at the time of the initial test. Demographic and spirometry indexes were similar between the 1,884 individuals included in the study and the 1,840 plant workers who did not meet entry criteria (mostly new employees or those who left the company after a short work tenure) (data not shown).

FEV_1 slope calculated by simple linear regression averaged −29.8 for white and −25.5 ml/year for black males ($P = 0.02$); and −23.2 for white and −21.7 ml/year for black females ($P = 0.76$), respectively. In males, smokers lost significantly more FEV_1 than ex- and non-smokers (FEV_1 slope = −36.5, −29.3, and −26.6 ml/year, respectively, $P < 0.0001$). Among females, comparisons of FEV_1 slopes by smoking groups (−26.8, −25.8, and −20.3 ml/year) were not statistically significant. Participants whose initial age was 35 and older lost significantly more FEV_1 than the groups with initial age 26–34, and 25 or younger (−32.9, −28.0, and −21.5 respectively, $P < 0.0001$). These differences by age at start of follow-up are consistent with a lung function plateau phase between ages 25 and 35.

The parameter estimates and P values obtained from the mixed-effects model analysis for the whole cohort are shown in Table IIA. The initial age and height were significantly related to the level of FEV_1, as were each of the models of spirometer used and the co-variables of weight gain and pack-years of cigarette smoking. Initial body weight did not influence FEV_1 ($P > 0.8$). Both the initial level and the longitudinal changes in FEV_1 differed significantly by race and sex. For white males, the parameter estimates indicate that a one year increase in initial age corresponded to an average 31.5 ml decrement in FEV_1 (age effect estimated cross-sectionally), while a one year increase in follow-up interval corresponded to an average 23.8 ml decline in FEV_1 (age effect estimated longitudinally), after controlling for initial age, height, race, sex, change in body weight, pack-years of smoking, and spirometer model.

The parameter estimates and P values obtained from the mixed-effects model analysis for white males only are shown in Table IIB; and for non-smokers only are shown in Table IIC. The parameter estimates from all three models were similar.

The study population as a whole gained an average of about 20 lbs over the 18 years of follow-up. At their initial test, about 37% of the workers had a body mass index (BMI[1]) $<25\,kg/m^2$, whereas at the final follow-up test, only about 14% of the workers had a BMI $<25\,kg/m^2$, and 46%, 35%, and 3.9% workers demonstrated Grades I, II, and III obesity (i.e., BMI = 25.0–29.9, 30.0–40.0, and $>40.0\,kg/m^2$),

[1] Participants' weight was recorded in pounds; we used the more familiar metric categories for BMI.

TABLE IIA. Parameter Estimates (in ml) From Fitting a Mixed-Effects Model to the Dataset of All FEV_1 Results*

	Sex	Race	Spirometer	Estimate	Standard error	*P*-value
Intercept (ml)				−1347.94	330.34	<0.0001
Initial age (Bage)				−31.51	1.22	<0.0001
Initial height (Bht)				94.19	5.00	<0.0001
Initial weight (Bwtlb)				−0.10	0.42	0.8048
Sex	Female			−654.18	46.66	<0.0001
Sex	Male			0.00	—	—
Race		Black		−483.62	42.68	<0.0001
Race		White		0.00	—	—
Spirometer			Jones	−94.86	16.50	<0.0001
Spirometer			InfMed	−43.60	14.43	0.0025
Spirometer			HF5	−40.47	13.38	0.0025
Spirometer			OMI	0.00	—	—
Smoking (pack-years)				−8.26	0.65	<0.0001
Weight gain (difwt)				−5.43	0.17	<0.0001
Time (interval, year)				−23.84	0.66	<0.0001
Race × sex × time	Female	Black		7.81	4.82	0.1051
Race × sex × time	Female	White		6.36	1.91	0.0009
Race × sex × time	Male	Black		6.31	1.91	0.0010
Race × sex × time	Male	White		0.00	—	—
Race × Sex × difwt	Female	Black		2.68	0.96	0.0051
Race × Sex × difwt	Female	White		1.73	0.55	0.0016
Race × Sex × difwt	Male	Black		0.95	0.52	0.0696
Race × Sex × difwt	Male	White		0.00	—	—

*Model variables included initial age in years (Bage), weight in pounds (Bwtlb), height in inches (Bht), race, and sex, as well as the time-dependent co-variables (values recorded at the time of each test) including interval since initial test in years (time), pack-years of smoking, and change in body weight in pounds from the baseline (difwt).

respectively [American Society for Clinical Nutrition, 1987].

Effects of weight gain on longitudinal FEV_1 were calculated by race and sex (see Table III), using the parameter estimates from the model shown in Table IIA to account for the other significant factors. For white males, a one pound increase in weight was associated with an average 5.4 ml loss in FEV_1. The impact of weight gain on lung function loss was greater in males than females, but did not differ significantly by race. To further explore the effect of weight

TABLE IIB. Parameter Estimates (in ml) From Fitting a Mixed-Effects Model to the Dataset of All FEV_1 Results for White Males Only*

	Sex	Race	Spirometer	Estimate	Standard error	*P*-value
Intercept (ml)				−1459.11	369.46	<0.0001
Initial age (Bage)				−31.92	1.34	<0.0001
Initial height (Bht)				95.96	5.63	<0.0001
Initial weight (Bwtlb)				−0.10	0.49	0.8322
Spirometer			Jones	−89.98	18.13	<0.0001
Spirometer			InfMed	−38.56	15.89	0.0152
Spirometer			HF5	−36.25	14.71	0.0139
Spirometer			OMI	0.00	—	—
Smoking (pack-years)				−8.25	0.71	<0.0001
Weight gain (difwt)				−5.44	0.17	<0.0001
Time (interval, year)				−23.77	0.69	<0.0001

*n = 1,598, number of observations = 1,598.

TABLE IIC. Parameter Estimates (in ml) From Fitting a Mixed-Effects Model to the Dataset of All FEV_1 Results for Non-Smokers Only*

	Sex	Race	Spirometer	Estimate	Standard error	*P*-value
Intercept (ml)				−1347.38	502.86	0.0075
Initial age (Bage)				−31.82	1.87	<0.0001
Initial height (Bht)				95.57	7.60	<0.0001
Initial weight (Bwtlb)				−0.31	0.62	0.6143
Sex	Female			−669.08	64.50	<0.0001
Sex	Male			0.00	—	—
Race		Black		−575.24	61.68	<0.0001
Race		White		0.00		—
Spirometer			Jones	−111.70	23.08	<0.0001
Spirometer			InfMed	−53.15	19.60	0.0067
Spirometer			HF5	−40.57	18.01	0.0243
Spirometer			OMI	0.00	—	—
Weight gain (difwt)				−5.60	0.25	<0.0001
Time (interval, year)				−23.52	0.95	<0.0001
Race × sex × time	Female	Black		6.88	5.46	0.2083
Race × sex × time	Female	White		4.77	2.36	0.0431
Race × sex × time	Male	Black		8.30	2.58	0.0013
Race × sex × time	Male	White		0.00	—	—
Race × Sex × difwt	Female	Black		3.05	1.13	0.0069
Race × Sex × difwt	Female	White		2.64	0.71	0.0002
Race × Sex × difwt	Male	Black		0.13	0.76	0.8657
Race × Sex × difwt	Male	White		0.00	—	—

*n = 774, number of observations = 9,443.

gain on FEV_1, an additional mixed-effects model with the addition of a dichotomous marker variable for overweight (BMI >25 kg/m^2, yes or no) was investigated. An interaction was evaluated in men and women regarding being overweight at the time of the spirometry test and the effect of weight gain on FEV_1. After controlling for the other significant factors in Table IIA, the effect of weight gain on FEV_1 was much greater for males who were overweight (BMI >25 kg/m^2 at the time of the test) compared to those who were not (−6.2 vs. −2.6 ml/lb, $P < 0.0001$). This difference was not noted in females (−3.6 vs. −3.4 ml/lb).

In addition, we compared FEV_1 slope between a group with the highest deciles of initial body weight (Bwtlb ≥ 220 lbs, n = 189) and the lowest deciles (Bwtlb ≤ 143 lbs, n = 192); on average, the FEV_1 decline was 9.2 ml/year greater in the group with the highest initial body weight (mean FEV_1 slope −31.5 vs. −22.5 ml/year, $P < 0.0001$).

TABLE III. Estimated Effects (in ml) on Longitudinal FEV_1 of Follow-Up Time in Years and Weight Gain in Pounds, by Race and Sex, Calculated Using the Mixed Effects Model Parameters Listed in Table IIA

	Sex	Race	Spirometer	Estimate	Standard error	*P*-value
Race × sex × time	Female	Black		−16.03	4.81	0.0009
Race × sex × time	Female	White		−17.48	1.89	<0.0001
Race × sex × time	Male	Black		−17.53	1.91	<0.0001
Race × sex × time	Male	White		−23.84	0.66	<0.0001
Race × Sex × difwt	Female	Black		−2.76	0.94	<0.0001
Race × Sex × difwt	Female	White		−3.71	0.52	<0.0001
Race × Sex × difwt	Male	Black		−4.49	0.49	<0.0001
Race × Sex × difwt	Male	White		−5.43	0.17	<0.0001

DISCUSSION AND CONCLUSIONS

The accurate identification of individuals or groups experiencing excessive lung function losses from workplace exposures requires attention to multiple factors which may affect lung function test results [Becklake and White, 1993; Miller et al., 2005; Hnizdo et al., 2006]. Using results from 30 years of spirometry monitoring performed by the medical department staff of a large chemical plant, we sought to further define the contribution of several factors that may affect FEV_1 decline, and thereby facilitate the accurate interpretation of serial spirometry measurements. The FEV_1 measurements in the study workers were significantly affected by the initial age and height as well as change in body weight, and pack-years of smoking. Both the level and the longitudinal changes in FEV_1 differed significantly by race and sex. Among males (but not females), the impact of weight gain on FEV_1 loss was much greater in individuals who were overweight at the time of the test.

FEV_1 results obtained from different models of volume spirometers in this study differed on average by as much as 95 ml, or three to four times the mean annual longitudinal decline. These ''spirometer effects'' likely reflect many factors which change over time when longitudinal pulmonary function measurements are made in actual practice. The magnitude of the effect of spirometer type on FEV_1 measurements may be impacted by differences in technicians and methods used to perform the tests over the 30 years, as well as by differences in spirometer software measurement algorithms, automated feedback to the technician during testing, and calibration procedures used for each spirometer. Such variation is also found in flow-type spirometers, which exhibit systematic mean differences, as well as differences in measurement variability when spirometers from different manufacturers are compared [Jensen et al., 2007].

Cross-sectional and longitudinal estimates of age-related rate of decline in FEV_1 in various adult populations have been reported in numerous publications. Our results are generally consistent with previous reports [Camilli et al., 1987; Xu et al., 1995; Wang et al., 1996]. In the present study, a mixed model approach allowed us to estimate the cross-sectional and longitudinal age-effect on lung function simultaneously. The model results showed that cross-sectional (initial age) and longitudinal (interval between first and follow-up tests) estimates of age-related loss in FEV_1 for white males were 31.5 and 23.8 ml/year, respectively. Longitudinal estimates of age-related loss in FEV_1 differed by race and sex (see Table III), although the small sample size for black females should be considered in assessing the representativeness of the parameter estimates for that group. Some previous investigators have observed much smaller longitudinal declines than would have been predicted from cross-sectional analysis [Glindmeyer et al., 1982; Burrows et al., 1986]; while others have reported the opposite pattern [Dontas et al., 1984; Ware et al., 1990]. Divergent estimates of decline in FEV_1 have been explained by survey biases, including population characteristics, differences in techniques, instruments, statistical methods, or environments, and loss to follow-up [Xu et al., 1995]. Among industrial workers, it is possible that out-migration of individuals with the highest rates of FEV_1 decline, due to exposures, illnesses, or other factors, can result in a lower mean longitudinal decline among the individuals who remain and thus can be studied. We did not, however, find evidence for this effect in the current study: the mean FEV_1 decline in the study participants was actually greater than the decline observed among the 1,840 plant workers who did not meet study entry criteria, although this latter group was followed for a shorter time period.

In the mixed model analysis, the weight gain parameter is derived from the measured changes (in both FEV_1 and weight) for individual participants over the time interval between the date of the initial spirometry and the date of each follow-up test. The parameter estimate for weight gain can be interpreted to reflect the reduction in FEV_1 associated with a one pound weight gain, with both changes occurring over the same time interval. After adjustment in the model for other significant factors, the FEV_1 effect attributed to a one pound weight gain in this study (Table IIIA) was −5.4 ml per lb for white and −4.5 for black males respectively—very similar to our previous study of 475 steel workers (−4.7 ml per lb) [Wang et al., 1996]. In fact, the impact of weight gain on longitudinal FEV_1 observed in males in this study (4.5–5.4 ml per lb or 9.9–11.9 ml per kg) is also similar to values reported in several other longitudinal lung function studies (9.6–11.5 ml per kg) [Wise et al., 1998; Carey et al., 1999; Chinn et al., 2005]. The magnitude of the adverse effect of weight gain on FEV_1 was significantly less among women; it was −3.7 ml per lb for white and −2.8 for black female study participants. In part, the smaller effect of weight gain in women may be explained simply by lung size—the mean initial FEV_1 in females was 25% less than in males. However, the effect of weight on lung function is thought to reflect the distribution of adiposity as well as lean body mass, which differ systematically with age and between males and females [Chen et al., 1993; Harik-Khan et al., 2001; Thyagarajan et al., 2008].

Accounting for the effect of these multiple factors can facilitate the recognition of respiratory hazards in similarly exposed groups. For example, among the 1,884 participating workers in this study, we used a random effects model approach to identify 119 (6.3%) individuals (''rapid decliners'') whose FEV_1 slope showed a significant ($P < 0.05$) decline, after adjusting for all the significant co-variables (see Table IIA) [Fitzmaurice et al., 2004]. Using the limited data available from the study participants' employment histories, a group of 122 individuals worked more than 10 years in areas with potential exposures to multiple chemicals; while a group of 120 workers with similar tenure had no known potential exposure to workplace respiratory hazards. The proportion of "rapid decliners" in the exposed group ($n = 15$, 12.3%) was five times greater than in the putatively non-exposed group ($n = 3$, 2.5%). This difference was statistically significant by Chi-square test ($P = 0.0037$, OR = 5.5 and CI of 1.5–19.4). Thus, even with very limited occupational exposure data, evidence of a potential adverse effect of workplace hazards was detectable when the multiple factors were taken into account.

A limitation of this study is that no detailed information was available to the investigators regarding the participants' respiratory symptoms and illnesses, or potentially harmful occupational exposures. However, the parameter estimates presented in Tables IIA and III reflect quantitative observations regarding the effects of weight gain and cigarette smoking on longitudinal changes in FEV_1. These estimates, taken with previous reports, further characterize the expected magnitude of these effects, and should thus be useful to occupational professionals during the interpretation of individual spirometry declines. A second limitation should be noted. The testing posture was changed from standing to sitting in March 1988; closely coinciding with the change from the Jones Pulmonaire/Datamite. In the analysis, the effect of changing test posture on FEV_1 may have been attributed to the Pulmonaire spirometer. Test posture appears to have little effect on FEV_1 among obese individuals [Gudmundsson et al., 1997]. However, any effect of standing posture is expected to result in a slightly larger FEV_1, suggesting that the average spirometer effect of −94 ml could have been larger if the effect of that spirometer were not confounded with test posture. A third limitation relates to the modification of professional recommendations during the course of the study. ATS recommendations in 1994 included tightening of repeatability criteria from 5% to 200 ml. We examined this effect by adding additional variables in the mixed model, but saw no effect on FEV_1 measurements or overall study results from the change in ATS guidelines after 1994.

In summary, the results of this study confirm that multiple factors may affect the interpretation of longitudinal changes in lung function. Lung function was influenced by age, height, weight gain, pack-years of smoking, and the model of spirometer used. When testing is performed on different spirometry models over time, these results suggest that care must be taken in the interpretation of longitudinal changes. Weight gain resulted in a mean decline in FEV_1 of 10–12 ml/kg in males, which appears to be a consistent finding across a number of studies. Declines in FEV_1 associated with weight gain were greater in men than women, and in overweight compared to normal weight males. The parameter estimates presented in Tables II and III should be useful to health professionals interpreting longitudinal lung function changes in middle-aged populations, whether in the workplace or other settings. When health professionals identify individuals with excessive FEV_1 declines using serial spirometry, accounting for the anticipated effects of weight gain, smoking, and other factors should facilitate identification of ongoing hazards and initiation of appropriate interventions.

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