Weight Gain and Longitudinal Changes in Lung Function in Steel Workers*

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Associations among dust exposure, smoking habits, and demographic factors and longitudinal changes of lung function were assessed among male steel workers. Cohort descriptive data analysis was conducted in 541 steel workers who had performed spirometry at least twice between 1982 and 1991 (mean follow-up, 6.1 years). The annual change (slope) in FVC, FEV_1, FEV_1/FVC%, and in body weight was determined by simple linear regression. The Pearson correlation coefficient between weight change and spirometry changes was calculated. Comparisons were also done in 75 pairs of steel workers matched by age, height, initial FEV_1, and smoking status, but whose FEV_1 declines differed by ≥60 mL/yr. The FEV_1 and FVC declined an average of 44 and 50 mL/yr, respectively, for the cohort as a whole. The FEV_1 and FVC declined 52 and 54 mL/yr for current smokers, 43 and 53 mL/yr for ex-smokers, and 36 and 43 mL/yr for nonsmokers, respectively. Increasing weight was highly correlated with accelerated decline in lung function ($p<0.0001$). In the matched pairs, mean slopes for FVC, FEV_1, and FEV_1/FVC ratio were −96 mL/yr, −95 mL/yr, and −0.40%/yr for the rapid decliners; and +5 mL/yr, +10 mL/yr, and +0.10%/yr for their partners ($p<0.0001$). Matched pair comparisons showed that the rapid decliners averaged a 4.313 kg weight gain, while their partners gained 1.044 kg during the follow-up period. The slope of weight gain was 0.708 kg/yr for rapid decliners and 0.191 kg/yr for comparison workers ($p<0.0036$). Weight gain, in addition to aging and cigarette smoking, was found to be associated with the longitudinal rate of decline in FVC, FEV_1, and FEV_1/FVC ratio.

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Key words: longitudinal analysis; lung function; matched pair; obesity; steel workers; weight gain

Abbreviation: BMI=body mass index

Longitudinal studies of ventilatory function have demonstrated that increasing age, dust exposure, and cigarette smoking are associated with greater rates of decline in function.[1] However, large unexplained differences in the rates of decline commonly exist among individual members in any given population. Multiple linear regression models developed to address the rate of lung function decline over time in a population showed that parameters such as gender, aging, smoking, and dust exposure explain only about 6 to 12% of the differences in the rates of decline among the members of the group (variance or R^2).[2-7] The reasons why some workers have an exaggerated rate of decline in lung function remain largely unexplained.

Obesity is associated with reduced lung volumes.[8-12] Several reports have evaluated weight gain and lung function over time, but not in dust-exposed cohorts (to our knowledge).[13,14] We analyzed the annual rate of change by simple linear regression in FVC, FEV_1, and FEV_1/FVC ratio, and demographic factors in 541 steel workers who had performed spirometry at least twice over a 5-year period between 1982 and 1991. The association among demographic parameters, smoking habits, years worked in dusty jobs, weight gain, and lung function decline was investigated using both cohort and matched pair analyses.

Materials and Methods

Cohort Data Analysis

Subject selection, spirometry procedures, and dust exposure assessment have been described in detail elsewhere.[7] Briefly,

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subjects were chosen from a total cohort of 1,171 medical records of steel mill workers obtained from the medical department of a steel company. These workers had participated in spirometry tests at least once from 1980 to 1991, and in some instances, as many as 12 times. Spirometry was performed with the subject in the standing position in the workplace by registered nurses who had completed a National Institute for Occupational Safety and Health-approved spirometry course. From the start of this study in April 1982 to its completion in September 1991, a water-filled survey spirometer with microprocessor (Eagle One; W.E. Collins; Braintree, Mass) was used and volume-time curves, accompanied by a computer printout of spirometry test values, were available. Curves from 3,587 spirometry tests were reviewed by at least two physicians for acceptability of effort, satisfactory start of test, presence of cough, air leak, or premature termination. A total of 152 tests (4.2%) without at least one acceptable curve were excluded.

Medical records were reviewed for the following: (1) demographic parameters—date of birth, sex, race, height, and weight; (2) smoking status—smoking category, cigarettes per day, years of smoking, and years since ceasing smoking; (3) spirometry indexes—FVC, FEV_1, and peak expiratory flow rate; and (4) job history—dates of employment, job description, and location.

Subjects were male steel workers with at least two valid spirometry tests and a follow-up interval of ≥4 years (n=541; 95% white). The average number of tests per worker was 4.5. Spirometry changes over the time of follow-up refer to the annual decline determined for each subject by simple linear regression using all available FVC, FEV_1, and FEV_1/FVC values against time. The weight was measured at the same time as spirometry, and yearly changes in weight were calculated for each worker based on linear regression of all available datapoints.

Dust exposure estimates were derived from a detailed job history and the recognition of dusty levels for each job location. Total years worked in dusty jobs was used as a surrogate for cumulative dust exposure. Each year of employment in the blast furnace sites, the sinter plant, in steelmaking, and in the continuous caster department was considered as a year employed in a dusty area. Each year spent working in operational services (*ie,* pipefitters, riggers, carpenters, fire fighters) was estimated as 50% time worked in a dusty area, while each year worked in the tin mill, in producing strip steel, in the sheet mill department, and in administration offices was not added to the sum of the years worked in dusty areas. The term "years in dusty job" is a combination of duration and level of exposure.

Descriptive cohort data analysis of longitudinal lung function decline stratified by age and smoking status was performed using group mean comparisons (analysis of variance). The Pearson correlation coefficient between weight change and lung function changes was also calculated.

Matched Pair Comparison

The 541 workers were grouped into cells according to age, height, initial FEV_1, and smoking status. All the individuals assigned to a cell were matched for all four variables: age at the midpoint of follow-up (±2.5 years), height (±2 cm), FEV_1 at baseline (±250 mL; nine groups between 2.0 and 6.5 L), and smoking status over the duration of the study (consistent current, former, or never-smokers). Workers whose smoking status changed during the study were excluded.

For each cell containing at least two individuals fully matched for all four variables (n=179), the worker with the greatest mean annual decline in FEV_1 was paired with the worker with the least mean annual decline. If this difference was ≥60 mL/yr, the pair was selected for further study. After a pair was selected, they were removed from the cell and the selection procedure repeated, until no more pairs with a difference in FEV_1 decline ≥60 mL/yr could be selected. This process resulted in 75 pairs (32 pairs of current smokers, 22 pairs of never-smokers, and 21 pairs of ex-smokers). The worker with the greater annual FEV_1 decline was defined as the rapid decliner.

A matched pair *t* test was used to test differences in demographic factors, dust exposure estimates, and cigarette smoking between rapid decliners and their partners.

RESULTS

Cohort Data Analysis

Table 1 displays the demographic characteristics and pulmonary function results in the 541 study subjects, stratified by smoking status at follow-up. The average age at the midpoint of follow-up approximated 40 years. The FEV_1 and FVC declined an average of 44 and 50 mL/yr, respectively, for the cohort as a whole. The FEV_1 and FVC declined 52 and 54 mL/yr for current smokers, 43 and 53 mL/yr for ex-smokers, and 36 and 43 mL/yr for nonsmokers, respectively. The difference in the rate of FEV_1 decline between current and nonsmokers was statistically significant ($p<0.0077$).

Figures 1 and 2 show the annual decline (slope) of FEV_1 and FVC by age and smoking status. The relationship between longitudinal spirometry decline and smoking habits was confirmed. Smokers lost more lung function than nonsmokers and ex-smokers in each age group during follow-up. A nonlinear relationship between aging and lung function was suggested. The rate of lung function decline appeared to accelerate in the age group of 25 to 30 years old, lessen between the ages of 30 and 40 years, and accelerate again at about age 40 years for smokers and ex-smokers, and age 45 years for nonsmokers.

The Pearson correlation coefficients for weight slope vs FEV_1 slope was −0.2410, ($p<0.0001$) and for weight slope vs FVC slope was −0.2755 ($p<0.0001$).

Matched Pair Comparisons

Table 2 reveals that the 75 pairs were well matched by age, height, and baseline FEV_1 values. After matching, the pairs were found to have similar values for mean pack-years of smoking, years of work in dusty jobs, the average number of spirometry tests performed, the interval between first and last test, and body mass index (BMI) at both baseline and follow-up. Although body weight appears to be different at each time point, these differences do not achieve statistical significance. The initial percent predicted FVC was significantly higher in the rapid decliners than in the comparison group ($p=0.0466$). For the rapid decliners in these pairs, the mean

Table 1—*Characteristics of the Study Population by Smoking Sratus**

Smoking Status at Follow-up	Entire Cohort	Smokers		
		Current	Ex	Never
No.	541	203	175	163
Age at midpoint, yr	39.5 (7.8)	37.8 (6.6)	41.2 (8.1)	39.7 (8.4)
Mean height, cm	178.1 (6.9)	177.7 (7.5)	178.1 (6.9)	178.4 (6.3)
Years in a dusty job				
At baseline	14.3 (8.1)	13.3 (7.3)	15.7 (8.8)	14.2 (8.2)
At follow-up	20.5 (8.4)	19.4 (7.5)	21.7 (9.0)	20.5 (8.6)
Pack-years				
At baseline	14.4 (15.8)	20.6 (13.8)	20.6 (16.4)	0.0 (0.0)
At follow-up	18.0 (18.8)	28.9 (16.7)	22.2 (17.6)	0.0 (0.0)
Body weight, kg				
Baseline	86.943 (15.028)	84.082 (15.164)	87.851 (14.347)	89.576 (14.982)
Follow-up	90.802 (16.617)	87.261 (16.662)	92.981 (16.980)	92.936 (15.482)
Slope, kg/yr†	0.617 (1.189)	0.518 (1.099)	0.867 (1.330)	0.468 (1.103)
BMI				
Baseline, kg/m^2	27.4 (4.3)	26.6 (4.1)	27.7 (4.2)	28.2 (4.6)
Follow-up, kg/m^2	28.6 (4.8)	27.6 (4.2)	29.3 (4.9)	29.2 (4.7)
FVC				
Baseline	4.97 (0.85)	4.89 (0.79)	4.91 (0.82)	5.13 (0.92)
Baseline, % pred	97.2 (13.0)	95.4 (11.5)	97.0 (12.0)	99.8 (15.3)
Follow-up, L	4.62 (0.88)	4.54 (0.85)	4.55 (0.86)	4.81 (0.92)
Follow-up, % pred	93.8 (13.9)	91.7 (13.1)	93.2 (13.4)	97.0 (15.0)
Slope, L/yr†	−0.050 (0.058)	−0.054 (0.055)	−0.053 (0.061)	−0.043 (0.059)
FEV_1				
Baseline, L	3.95 (0.72)	3.87 (0.67)	3.92 (0.71)	4.07 (0.76)
Baseline, % pred	93.6 (13.9)	91.3 (12.7)	94.0 (13.3)	96.0 (15.6)
Follow-up, L	3.68 (0.75)	3.55 (0.72)	3.67 (0.74)	3.85 (0.77)
Follow-up, % pred	91.0 (15.3)	87.4 (14.4)	91.7 (14.5)	94.8 (16.2)
Slope, L/yr†	−0.044 (0.049)	−0.052 (0.045)	−0.043 (0.053)	−0.036 (0.049)
FEV_1/FVC				
Baseline, %	79.6 (7.0)	79.2 (7.5)	80.0 (7.3)	79.5 (5.9)
Baseline, % pred	96.0 (8.2)	95.4 (8.8)	96.7 (8.6)	96.0 (7.0)
Follow-up, %	79.6 (6.9)	78.3 (7.4)	80.6 (8.1)	80.1 (7.2)
Follow-up, % pred	96.8 (8.2)	95.0 (8.8)	98.2 (8.1)	97.5 (7.2)
Slope, %/yr†	−0.10 (0.78)	−0.22 (0.72)	−0.03 (0.084)	−0.03 (0.76)

*Smoking status given as determined at final follow-up testing; values are means (±SD); percent predicted values calculated based on Knudson et al.[25]

†Slope is defined as the change per year of weight and spirometry indexes, calculated by simple linear regression.

slopes of FVC, FEV_1, and FEV_1/FVC ratio were −96 mL/yr, −95 mL/yr, and −0.40%/yr, respectively, while for the comparison workers, the slopes were +5 mL/yr, +10 mL/yr, and +0.10%/yr. On average, rapid decliners lost 101 mL/yr in FVC, 105 mL/yr in FEV_1, and 0.50%/yr in FEV_1/FVC ratio more than the comparison workers. The FEV_1/FVC values at follow-up in the rapid decliners and in the comparison group were significantly different, with a lower value in the rapid decliners, reflecting a relative increase in airflow limitation.

On average, the rapid decliners gained 4.313 kg while the comparison workers gained 1.044 kg over the follow-up period. The slope of weight gain for rapid decliners was 0.708 kg/yr and 0.191 kg/yr for the comparison workers. Rapid decliners gained 0.517 kg/yr more (the difference in weight slope) than the comparison workers ($p=0.0036$).

Table 3 shows that there is a relatively large proportion of overweight workers. Approximately one fourth and one third of the paired subjects had a BMI ≥30 kg/m^2 (<25 kg/mg^2 is considered normal[15]) at baseline and follow-up, respectively.

Discussion

Numerous epidemiologic studies have explored the risk factors associated with the decline of lung function in workers. Longitudinal studies have documented accelerated losses in lung function in relation to aging, dust exposure, and cigarette smoking. However, why certain workers experience accelerated rates of lung function decline (rapid decliners) in association with industrial exposures remains largely unexplained. Factors that may be responsible

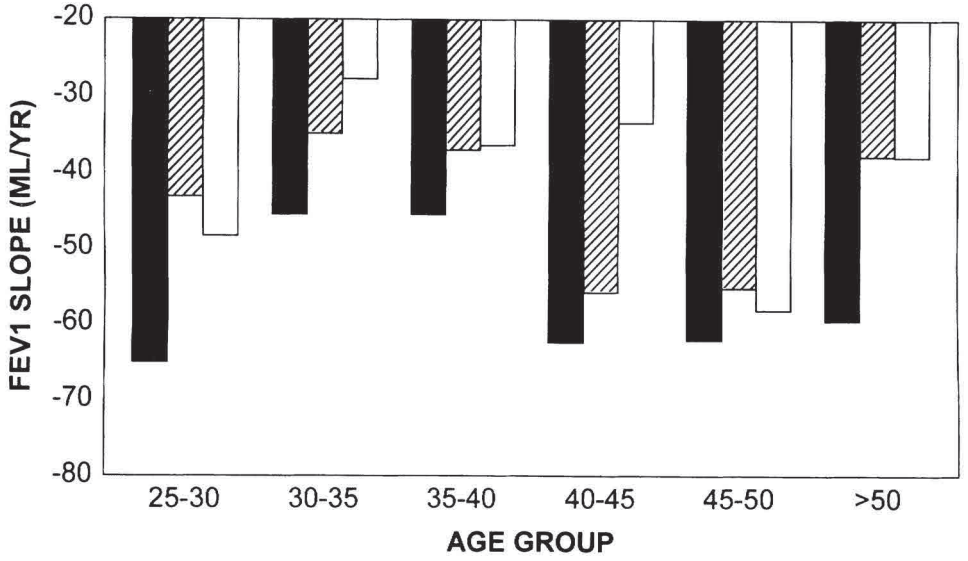

FIGURE 1. This figure represents the longitudinal decline of FEV_1 by age at midpoint of survey and the smoking status at the final survey. The number of observations in each of the six age groups beginning in the 25 to 30-year-old age group to >50 age group for current smokers is 14, 73, 52, 27, 26, and 11; for former smokers, 9, 43, 33, 31, 26, and 33; and for never-smokers, 10, 59, 30, 24, 16, and 24, respectively. In this and Figure 2, the black bar represents average annual rate of decline (slope) in FEV_1 for current smokers, the hatched bar for former smokers, and the white bar for never-smokers.

for the development of airways obstruction include host susceptibility, a family history of atopy, childhood illnesses, obesity and excessive weight gain, intercurrent respiratory infection, environmental exposures outside of the workplace, socioeconomic status, and airways responsiveness; additional factors that are not yet accounted for may play a role in determining the rate of lung function decline.

The mean slopes of the FVC, FEV_1, and FEV_1/FVC ratio for the comparison workers were +5 mL/yr, +10 mL/yr, and +0.10%/yr, respectively. We recognize that ventilatory function is not expected to improve over time in this age group. We consider these small increases in the mean values of spirometry indexes to reflect several possibilities. These may be due to a "learning effect," biological variability (*eg*, the participant may have lung function testing in the morning compared to the afternoon, in

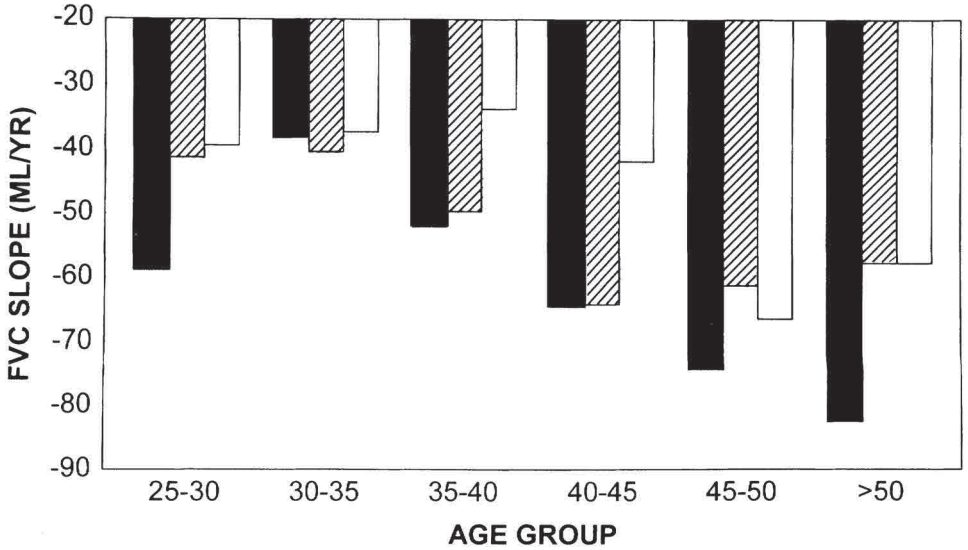

FIGURE 2. This figure represents longitudinal decline of FVC by age at midpoint of survey and the smoking status at the final survey.

Table 2—*Comparisons for 75 Matched Pairs*

	Rapid Decliners Mean (±SD)	Comparison Group Mean (±SD)	p Value*
Age at midpoint, yr	38.1 (7.6)	38.0 (7.7)	0.5636
Mean height, cm	178.8 (6.1)	178.7 (5.8)	0.8492
No. of tests	4.6 (1.4)	4.3 (1.5)	0.2174
Years of follow-up	5.8 (1.4)	5.9 (1.5)	0.7065
Years in a dusty job			
At baseline	12.4 (7.9)	12.8 (7.3)	0.6690
At follow-up	18.1 (8.3)	18.7 (7.9)	0.5608
Pack-years			
At baseline	12.9 (13.5)	13.5 (16.2)	0.7534
At follow-up	16.5 (16.2)	16.3 (17.9)	0.9511
Body weight, kg			
Baseline	86.761 (14.664)	88.623 (13.302)	0.3192
Follow-up	91.074 (15.573)	89.667 (14.710)	0.4925
Slope, kg/yr†	0.708 (1.208)	0.191 (1.158)	0.0036
BMI			
Baseline, kg/m^2	27.1 (4.1)	27.7 (3.7)	0.2946
Follow-up, kg/m^2	28.5 (4.4)	28.1 (4.1)	0.4945
FVC			
Baseline, L	5.13 (0.80)	5.02 (0.80)	0.0866
Baseline, % pred	98.7 (11.9)	95.9 (12.1)	0.0466
Follow-up, L	4.57 (0.92)	5.01 (0.79)	0.0001
Follow-up, % pred	90.8 (14.8)	99.1 (11.8)	0.0001
Slope, L/yr†	−0.096 (0.061)	0.005 (0.051)	0.0001
FEV_1			
Baseline, L	4.04 (0.64)	4.04 (0.67)	0.8965
Baseline, % pred	94.3 (12.1)	93.3 (11.5)	0.2780
Follow-up, L	3.51 (0.72)	4.07 (0.67)	0.0001
Follow-up, % pred	85.2 (15.0)	98.2 (12.0)	0.0001
Slope, L/yr†	−0.095 (0.048)	0.010 (0.039)	0.0001
FEV_1/FVC			
Baseline, %	79.1 (6.2)	80.8 (6.6)	0.0819
Baseline, % pred	95.3 (7.3)	97.3 (7.7)	0.0878
Follow-up, %	77.3 (6.2)	81.5 (4.8)	0.0001
Follow-up, % pred	93.8 (9.1)	98.9 (5.7)	0.0001
Slope, %/yr†	−0.40 (0.78)	0.10 (0.72)	0.0001

*p value obtained from paired *t* test.
†Slope is defined as the change per year of weight and spirometry indexes, calculated by simple linear regression.

the fall as opposed to the spring, or in association with a mild viral illness), measurement variability (*eg*, different technicians with better or worse coaching styles), or a combination of these. Furthermore, some workers may even have lost weight.

Impairment in lung function has been observed in obese subjects.[8-12] However, the effect of weight gain on longitudinal changes of lung function has been only rarely reported. An important finding in this study is the association between weight gain and longitudinal decline of FEV_1, FVC, and FEV_1/FVC ratio. Body weight and BMI, both at baseline and follow-up, did not differ significantly between the two matched groups, yet rapid decliners gained significantly more weight than their comparison workers over an average of 6.2 years. This is consistent with a similar matched pair analysis of data from the US National Study of Coal Workers' Pneumoconiosis, which evaluated potential risk factors in miners for clinically important declines in FEV_1.[16] In that report, 344 pairs were entered into the analysis, and excessive weight gain was one of the risk factors for the rapid decline of lung function. Rapid decliners gained 3.72 kg more weight than their matched partners over an average of 11 years of follow-up ($p<0.001$).

Weight gain in those already overweight may be relatively more important in determining lung function decline than weight gain in those of normal body weight.[7,14] The preponderance of overweight workers may have affected the importance of weight gain on lung function in this population. In the matched pair comparison, weight gain explained the differences in rate of decline between the rapid decliners and the comparison workers. In the longitudinal survey,[7] a multiple regression model was developed to explore the risk factors associated with longitudinal decline of FEV_1; weight gain as an independent variable explained approximately half (6%) of the total variance (12%).

Obesity is recognized to be associated with changes in pulmonary mechanics, particularly when extreme.[8-12] Decreases in various lung volumes have been observed in obese subjects. Airway closure at the lung bases and the increased work of breathing may affect gas exchange at rest and exercise, although the diffusing capacity is usually normal or increased with simple obesity. Severe obesity may result in hypoxia, hypoventilation, cor pulmonale, and right heart failure. In contrast, mild obesity is generally believed to have little effect on ventilatory lung function.[17] In this report, weight gain over time was more important than body weight on the effect of longitudinal changes of lung function. Weight gain affected the FEV_1 more than FVC. The annual rate of decline in FEV_1/FVC ratio was steeper for rapid decliners ($p<0.0001$). This implies that weight gain may affect airflow and lung volumes.

Results from National Health and Nutrition Examination Surveys revealed an increasing number of overweight US adults.[18] From 1988 to 1991, 33.4% of US adults 20 years of age or older were estimated to be overweight (with overweight being defined as a BMI $\geq$27.8 for men and $\geq$27.3 for women). Factors such as dietary knowledge, attitudes, and practices, physical activity levels, and perhaps social, demographic, and health behavior factors are likely responsible for increases in the prevalence of overweight. Activity level has been associated with weight in male health professionals.[19]

We are aware that there is a potential for selection bias when health effects are measured only among those who participate in a screening program and

Table 3—*Distribution of BMI by Classification of Obesity* at Baseline and Follow-up for 75 Pairs*

BMI Range, kg/m^2	Grade of Obesity*	Rapid Decliners		Comparison Group	
		Baseline, No. (%)	Follow-up, No. (%)	Baseline, No. (%)	Follow-up, No. (%)
<25.0	0	25 (33.3)	15 (20.0)	15 (20.0)	17 (22.7)
25.0-29.9	1	33 (44.0)	36 (48.0)	41 (54.7)	36 (48.0)
30.0-40.0	2	16 (21.3)	23 (30.7)	19 (25.3)	21 (28.0)
>40.0	3	1 (1.3)	1 (1.3)	0 (0.0)	1 (1.3)

*The classification of obesity (grade 0, 1, 2, 3) is based on the Panel Summary Statement on "Energy, Obesity, and Body Weight Standards."[15]

information regarding the health of nonparticipants is unavailable. In this matched pair nested case-control study, it is our opinion that selection bias is likely to be less in a longitudinal survey than in a cross-sectional survey. Workers who may not be a part of a one-time screening process might well be included in a longitudinal study. We allowed workers to be included if they performed at least two tests over at least 4 years. Allowing this flexible criteria for participation may have lessened the bias, particularly if this is compared to workers who would be included only if they participate each year. We could also postulate that those screened every year, when such a program was not required, might be excessively concerned regarding their health. Such a strict requirement for participation might also bias the study. Furthermore, the mean years of participation (nearly 6 years) in both groups allowed a reasonable chance to measure an effect attributable to the workplace environment on the worker's health.

We also recognize that individuals may have low lung values and progress at a rapid rate (the so-called horse-racing effect) or begin at relatively high values and have a relatively rapid rate of decline (a phenomenon described as "regression towards the mean"). We have guarded against these biases by matching individuals for baseline FEV_1. In Table 2, the baseline FEV_1 for the rapid decliners and for the comparison group was not different. We reviewed the curves, not knowing whether a worker would be a member of the comparison group or a rapid decliner and used the same criteria for accepting the spirometry curves in both groups. We have no justifiable reason to think that the values are spurious in either group.

Potential confounders could include a cigarette smoking habit, change in this smoking habit over the length of the study, years in a dusty job at baseline and/or follow-up, or the presence of an underlying medical condition that may be associated with a sedentary lifestyle and weight gain. Since data from the unchanging smoking history and the years in a dusty job were similar (Table 2), we do not consider these to be confounders. We cannot be sure that those with an accelerated rate of lung function decline were free of medical illnesses, yet the presence of an illness would not detract from the relationship between weight gain and the loss of FEV_1 unless the illness was highly correlated with weight gain. Because of the way that we randomly enrolled workers into the study, the manner in which matching criteria were used to determine whether a worker fits into the comparison group or "rapid" decliner category, as well as the recognition that these men are blue-collar workers who work every day, we have no reason to think that this is the case. Weight gain appears to be an independent determinant for an accelerated decline in FEV_1.

There may be numerous explanations for weight gain. In the present study, we have no data that attribute weight gain to such common explanations as poor fitness with lack of exercise or dietary indiscretions. These steel workers were active and employed at the time when these lung function tests were performed. Many in this group were often required to undertake manual labor. Overall, this group would be considered to be healthy workers. Further study to better understand the reason for weight gain in this population might be helpful.

Weight is frequently measured, but rarely considered, when modeling longitudinal lung function changes. Because this feature has not been well described, the impact of weight gain on FEV_1 and FVC over time is of interest. Weight gain may influence changes in lung function observed over time. Other factors such as host susceptibility factors, airway hyperresponsiveness, childhood respiratory illnesses, and socioeconomic status have been suggested to affect rates of decline in lung function.[20-24] In investigations of dust-exposed workers, these factors are frequently not determined, yet may explain some of the unexplained variance.

Finally, it is somewhat surprising that in the matched-pair analysis, accelerated declines in lung function were not associated with years worked in dusty areas. We are aware that respiratory exposures in a steel mill may include asbestos, metal-working fluids, carbon dust, and irritant gases, among others.

We acknowledge that direct measurements of exposure were not available and years worked in dusty jobs was used as a surrogate of estimated exposures. This approach has the potential to result in large variability or misclassification in exposure estimates, and therefore reduce the ability to detect the exposure-related health effects. However, based on our previous work,[7] we think that our method of assigning exposures is reasonable. In a previous report on this population, dust exposures were related to the level of lung function in a cross-sectional analysis, with a stronger effect at baseline (about 10 mL additional loss in FEV_1 related to each year of employment in a dusty job [p=0.008]) than at follow-up (about 5 mL/yr worked in dusty jobs [p=0.077]); whereas, in the longitudinal analysis, the relationship between years worked in a dusty job and the annual rate of decline in FEV_1 was weak, and similar to the longitudinal findings in this matched pair analysis. The reasons for this are unclear, but may be related to improvements in the workplace that lessened dust exposures or nonlinear rates of lung function decline.

In summary, weight gain was found to be associated with longitudinal decline in lung function in a middle-aged and relatively overweight working population. The rate of FEV_1 decline exceeded the rate of FVC decline, implying that weight gain may be relevant in understanding airways obstruction in rapid decliners in the dust-exposed population. When attempting to understand the reasons for the rate of change in longitudinally determined lung function in working populations, it seems reasonable to address the effect of changes in weight as a potential explanation for some of the otherwise unexplained variances in lung function. Further study needs to be undertaken to show the strength of this relationship in other populations, and the pattern and biological mechanisms for this relationship.

References

1 Oxman AD, Muir DCF, Shannon HS, et al. Occupational dust exposure and chronic obstructive pulmonary disease. Am Rev Respir Dis 1993; 148:38-48

2 Love RG, Miller BG. Longitudinal study of lung function in coal-miners. Thorax 1982; 37:193-97

3 Kauffmann F, Drouet D, Lellouch J, et al. Occupational exposures and 12-year spirometric changes among Paris area workers. Br J Ind Med 1982; 39:221-32

4 Attfield MD. Longitudinal decline in FEV_1 in United States coalminers. Thorax 1985; 40:132-37

5 Seixas NS, Robins TG, Attfield MD, et al. Longitudinal and cross sectional analyses of exposure to coal mine dust and pulmonary function in new miners. Br J Ind Med 1993; 50:929-37

6 Graham WGB, Weaver S, Ashikaga T, et al. Longitudinal pulmonary function losses in Vermont granite workers—a reevaluation. Chest 1994; 106:125-30

7 Wang ML, McCabe L, Hankinson JL, et al. Longitudinal and cross sectional analyses of lung function in steel workers. Am J Respir Crit Care Med 1996; 153:1907-13

8 Cotes JE, Gilson JC, John C. Effects of inactivity and a gain in weight upon lung function and indices of submaximal exercise. J Physiol 1966; 188:36P-8P

9 Enright PL, Kronmal RA, Higgins M, et al. Spirometry reference values for women and men 65 to 85 years of age—cardiovascular health study. Am Rev Respir Dis 1993; 147:125-33

10 Zerah F, Harf A, Perlemuter L, et al. Effects of obesity on respiratory resistance. Chest 1993; 103:1470-76

11 Jenkins SC, Moxham J. The effects of mild obesity on lung function. Respir Med 1991; 85:309-11

12 Bedell GN, Wilson WR, Seebohm PM. Pulmonary function in obese persons. J Clin Invest 1958; 37:1049-60

13 Schoenberg JB, Beck GJ, Bouhuys A. Growth and decay of pulmonary function in healthy blacks and whites. Respir Physiol 1978; 33:367-93

14 Bande J, Clement J, Van De Woestijne KP. The influence of smoking habits and body weight on vital capacity and FEV_1 in male air force personnel: a longitudinal and cross-sectional analysis. Am Rev Respir Dis 1980; 122:781-90

15 1987 American Society for Clinical Nutrition (panel summary statement). Energy, obesity, and body weight standards. Am J Clin Nutr 1987; 45:1035-47

16 Wang ML, Petsonk EL, Attfield MD, et al. Miners with clinically important declines in FEV_1: analysis of data from the US national coal study. Appl Occup Environ Hyg 1996; 11:989-95

17 Bates DV. Respiratory function in disease. 3rd ed. Philadelphia: WB Saunders, 1989; 100-02

18 Kuczmarski RJ, Flegal KM, Campbell SM, et al. Increasing prevalence of overweight among US adults—the National Health and Nutrition Examination Surveys, 1960 to 1991. JAMA 1994; 272:205-11

19 Ching LYH, Willett WC, Rimm EB, et al. Activity level and risk of overweight in male health professionals. Am J Public Health 1996; 86:25-30

20 Burrows B, Knudson RJ, Lebowitz MD. The relationship of childhood respiratory illness to adult obstructive airway disease. Am Rev Respir Dis 1977; 115:751-60

21 Burrows B. An overview of obstructive lung diseases. Med Clin North Am 1981; 65:455-71

22 Burrows B. Airways obstructive diseases: pathogenetic mechanisms and natural histories of the disorders. Med Clin North Am 1990; 74:547-60

23 Enterline PE, Lainhart WS. The relationship between coal mining and chronic nonspecific respiratory disease. Am J Public Health 1967; 57:484-95

24 Morgan WKC. Industrial bronchitis. Br J Ind Med 1978; 35:285-91

25 Knudson RJ, Lebowitz MD, Holberg CJ. Changes in the normal maximal expiratory flow-volume curve with growth and aging. Am Rev Respir Dis 1983; 127:725-34