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Gender difference in smoking effects on adult pulmonary function

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ABSTRACT: Data on 1,618 male and 1,669 female adults aged 40–69 yrs, from China in the Beijing Respiratory Health Study, were analysed to investigate the gender differences in effects of smoking on pulmonary function.

Smoking was characterized by total smoking-years, smoking status (former, transitional and constant), smoking type (cigarette, cigar and others). The effects of smoking on height-standardized forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were assessed by multiple regressions adjusting for age, education level, use of an indoor coal stove for heating, passive smoking, occupational dust and gas/fume exposure, and residence. Prediction equations were derived from nonsmoking asymptomatic subjects.

As compared to women, men had a much higher smoking prevalence (78 *vs* 35%) but a lower quitting rate (14 *vs* 23%). Female lifetime nonsmokers had greater mean percentage predicted lung function values than male lifetime nonsmokers, whilst female cigarette smokers had lower values than their male counterparts. In both sexes, the highest mean percentage predicted lung function values were found in lifetime nonsmokers, whilst the lowest values were found among former smokers, the second lowest among transitional smokers, and constant smokers actually had greater values than both former and transitional smokers. These findings were confirmed by sex-specific regression analyses. A global test on the interactions between smoking and sex was highly significant.

This study suggests that adverse smoking effects on pulmonary function were greater in women than in men. This gender difference in the effects of smoking on pulmonary function may be related, in part, to the gender difference in smoking prevalence in the population, creating an incomparability of the lifetime nonsmoker reference group between the two sexes. The inverse gradient of lung functions for former, transitional and constant smokers may be explained by the "healthy smoker effect".

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The findings concerning gender differences in effects of smoking on pulmonary function have been inconsistent. Several studies conducted in the US, Six Cities study [1, 2], Tucson, AZ, USA [3], and Los Angeles, CA, USA [4], and in Northern Italy [5], have shown that the deficits and accelerated rates of loss of pulmonary function associated with cigarette smoking were greater in men than in women. Other reports from US/Canada Three Cities study [6], Saskatchewan, Canada [7], Copenhagen, Denmark [8], seven French cities [9], and Vlagtwedde-Vlaardingen, The Netherlands [10] have suggested the opposite gender effect. Gender differences in smoking effects could be the result of several factors, ranging from the gender-related difference in airway geometry, inherently different susceptibility, different smoking behaviour, the gender-related difference in respiratory symptoms which may contribute to the condition of "being unhealthy", and differences in environmental and occupational exposures.

Studies have so far provided very limited insight into these speculated factors. Another possibility that has not been considered in previous studies is the incomparability of the reference groups between the two sexes. Most studies used lifetime nonsmokers as the reference group in estimating smoking effects, and the gender-specific smoking prevalence varied from study to study. In a given population, the proportion of unhealthy subjects among the lifetime nonsmokers is associated with smoking prevalence. The higher the smoking prevalence, the higher the proportion of unhealthy subjects among the lifetime nonsmokers. A high proportion of unhealthy subjects among the lifetime nonsmokers would produce a low lung function reference value for comparison, and thus underestimate the smoking effects.

One hypothesis proposed by this study is that the observed gender differences in smoking effect may be partially related to the differences in the proportion of

unhealthy lifetime nonsmokers in the reference groups between the two sexes, and the controversial findings on gender difference in previous studies may be attributed to the variation in direction and magnitude of gender difference in smoking prevalence from study to study.

The Beijing Respiratory Health Study, a community-based cross-sectional study in adults, provides an opportunity to further investigate the gender difference in the effects of smoking on pulmonary function. The data from this study, along with previously published data, are also used to test whether there is an association between gender difference in smoking prevalence and gender difference in smoking effect.

Methods

The Beijing respiratory health study was designed to investigate environmental and occupational exposures and their associations with chronic respiratory illnesses and pulmonary function. It consisted of a random sample of adults, 40–69 yrs of age, selected from three representative areas in Beijing. The methods of selection and characteristics of this population have been described previously [11, 12]. Briefly, the study sample was drawn from the 1982 National Census Records in the following three areas: Dongchen (residential area), Haidian (suburban area), and Shijinshan (industrial area), using a two-stage sampling method [13]. The population density (persons·km^{-2}) in the residential, industrial and suburban areas was 38,700, 17,500 and 900, respectively. The sample unit at the first stage is the administrative unit. At the second stage, it is the subject. Equal numbers of males and females were drawn from each area. Those who were outside the age range (40–69 yrs), dead, nonresident, resident in the study areas less than 5 yrs or less than six months in each year, or moved were excluded. Our age criteria was based on the following considerations: over 40 yrs of age, there is a significant increase in the prevalence of chronic obstructive pulmonary disease; over 70 yrs of age, it is difficult to obtain a satisfactory pulmonary function test. The survey was conducted between August 1 and September 30, 1986, a period with the lowest air pollution level and relatively stable temperatures (13 to 27°C, with a mean 22°C outdoor).

Current smokers were defined as those who responded positively to the question, "Do you now smoke?"; former smokers were those who responded negatively to this question but positively to, "Have you ever smoked at least one cigarette (or one cigar a week or an ounce of tobacco a month) for at least a year?". Current smokers were further classified as transitional smokers (those who responded affirmatively to the question, "Have you been cutting down your smoking over the past year?") and constant smokers (those with no change or with an increase in smoking amount). Subjects who smoked only cigarettes were defined as cigarette smokers; subjects who reported a history of cigar smoking were defined as cigar smokers; and hand-roll and/or pipe smokers were defined as other smokers. The presence of a coal stove for heating was used as a proxy for indoor air pollution. Subjects who were passively exposed to cigarette smoking at home were defined as passive smokers. Information on occupational exposure to dusts, and gases/fumes was collected using a modified version of the American Thoracic Society (ATS)-DLD questionnaire [12].

Pulmonary function measurements were performed in accordance with the ATS performance and reproducibility criteria [14]. Subjects performed vital capacity (VC) and forced vital capacity (FVC) manoeuvres on an electric auto-spirometer (AS-300, made by Minato Co., Japan), whilst in the standing position and wearing a noseclip, either at the central office or at home. A minimum of three acceptable measurements were performed. The maximum of three measurements was used for this analysis, because it was believed to be more reproducible than the mean [15], and the "best test" was the simplest and most practical result to record [16].

Forced expiratory volume in one second (FEV_1) and FVC measurements were standardized for height (ht) by dividing by ht^2 [11, 17] to adjust for body size. Such adjustment also makes pulmonary function more comparable between men and women. To confirm that the height-squared proportional model was appropriate for this data set, the observed lung functions were divided by various powers of height (ht, ht^2, and ht^3) and regressed to sex, age, education level, use of an indoor coal stove for heating, passive smoking, occupational dust and gas/fume exposure, and residence among nonsmoking and asymptomatic subjects. Then the residuals from each model were checked against height. It was found that the residuals from the ht and ht^3 standardized models were still significantly correlated with height ($p<0.001$), whereas residuals from the ht^2 standardized model were not ($p=0.48$), indicating that standardization by ht^2 is superior to that by ht or ht^3 in this sample.

The prediction equation was derived from nonsmoking and asymptomatic subjects (free from cough, phlegm, shortness of breath and wheeze) from this sample. The predictive models included sex, age, education level, use of an indoor coal stove for heating, passive smoking, occupational dust and gas/fume exposure, and residence. The mean percentage predicted (% pred) FEV_1 or FVC were compared by smoking status and by smoking type. Furthermore, multiple regression models were used to quantify smoking effect (E) whilst adjusting for other covariates. The basic model is as follow:

$$E(Y) = \beta_0 + \beta_1 \text{ smk-yrs} + \beta_2 \text{ transition} + \beta_3 \text{ constant} + \beta_4 \text{ cigar} + \beta_5 \text{ others} + \beta_x \text{ covariates}$$

where, E is expectation Y is pulmonary function standardized by ht^2; β_0 is the lung function for lifetime nonsmokers; β_1 is the change in pulmonary function per year history of smoking; β_2 is the difference in lung function between transitional smokers (1=transitional smokers, 0=otherwise) and former smokers, given smoking year and smoking type; β_3 is the difference in lung function between constant smokers (1=constant smokers, 0=otherwise) and former smokers, given smoking year and smoking type; β_4 is the difference in lung function between cigar smokers (1=cigar smokers, 0=otherwise) and cigarette smokers,

given smoking year and smoking status; β_5 is the difference in lung function between other smokers (1=other smokers, 0=otherwise) and cigarette smokers, given smoking year and smoking status; β_x is a vector of estimates for other covariates including age, education, use of an indoor coal stove for heating, passive smoking, occupational dust and gas/fume exposure, and residence.

Results

The initial sample consisted of 3,606 adults (1,762 men, 1,844 women), 40–69 yrs of age. Of these, 3,287 (91%) had acceptable pulmonary function measurements. Overall, 78% of men and 35% of women reported a history of smoking. Former, transitional, and constant smokers represented, respectively, 11, 15 and 52% of men, and 8, 9 and 18% of women. Among those who had smoked, cigarette smokers, cigar smokers, and other smokers (hand-roll, pipe), respectively, accounted for 61, 18 and 21% for men, and 75, 8 and 17% for women. Age, education, residence, use of a coal stove, and passive smoking were significantly associated with smoking status both for men and women (table 1). Prevalence of smoking appears to be inversely associated with education level both in men and women. More men than women reported occupational exposure to dust and gas/fume, whilst women were more likely than men to have low education, and to be exposed to passive smoking.

Figure 1 shows the mean percentage predicted FEV_1 by smoking status and by smoking type. As expected, lifetime nonsmokers had the largest mean percentage predicted value. However, it is noted that constant smokers had greater mean percentage predicted values than former and transitional smokers, in both sexes. The lowest mean percentage predicted values were observed among former smokers, and the second lowest among transitional smokers. Analysis of variance was performed to test the group differences, and the results were significant for smoking status and smoke type in both sexes. A similar trend was noted for FVC (data not presented). Some gender differences were also evident. For example, lifetime nonsmoking females appeared to have higher mean percentage predicted values than lifetime nonsmoking males. Female cigarette smokers appeared to have lower mean percentage predicted values than their males counterparts. In men, cigar smokers appeared to have lower FEV_1 than cigarette and other smokers. A dose-response relationship was observed when mean percentage predicted FEV_1 were plotted against total smoking-years (data not shown).

The association of prevalence of chronic respiratory symptoms, physician-diagnosed cardiovascular diseases and bronchitis with smoking was also examined, for men and women separately. As shown in table 2, former smokers had a two times higher prevalence of cardiovascular diseases and bronchitis than current smokers in men, and a similar trend was found in women, but of smaller magnitude. It is noted that in men lifetime nonsmokers had higher prevalence of cardiovascular diseases and bronchitis than current smokers, whilst in women lifetime nonsmokers had similar or lower prevalence than current smokers. This suggests that the male lifetime nonsmoker group contained a higher proportion of unhealthy subjects than the female lifetime nonsmoker group in this sample.

Table 1. – Sample characteristics by smoking status

		Smoking status					
		Men (n=1,618)			Women (n=1,669)		
		Lifetime NS (n=364) %	Former (n=178) %	Current (n=1,076) %	Lifetime NS (n=1,080) %	Former (n=138) %	Current (n=451) %
M,W* Age	40–49 yrs	37	22	37	49	20	33
	50–59 yrs	41	42	41	34	49	41
	60–69 yrs	23	36	22	17	32	26
M,W Education	>High school	21	6	5	5	0	2
	High school	39	41	33	29	5	10
	Primary school	30	42	42	27	30	31
	Illiterate	10	11	20	39	65	57
M,W Area	Dongchen	36	36	28	34	34	26
	Haidian	27	20	40	30	29	43
	Shijinshan	37	44	33	36	37	31
M,W Coal stoves	No	35	46	31	35	32	29
	Yes	65	54	69	65	68	71
Dust	No	66	57	61	73	72	71
	Yes	34	43	39	27	28	29
Gas/fume	No	74	77	76	84	83	87
	Yes	26	23	24	16	17	13
M,W Passive smokers	No	65	57	48	34	33	25
	Yes	35	43	52	66	67	75

M: men; W: women; Chi-squared test, p value <0.05 for men and women, respectively. NS: nonsmokers. High school: 7 to 12 yrs of education.

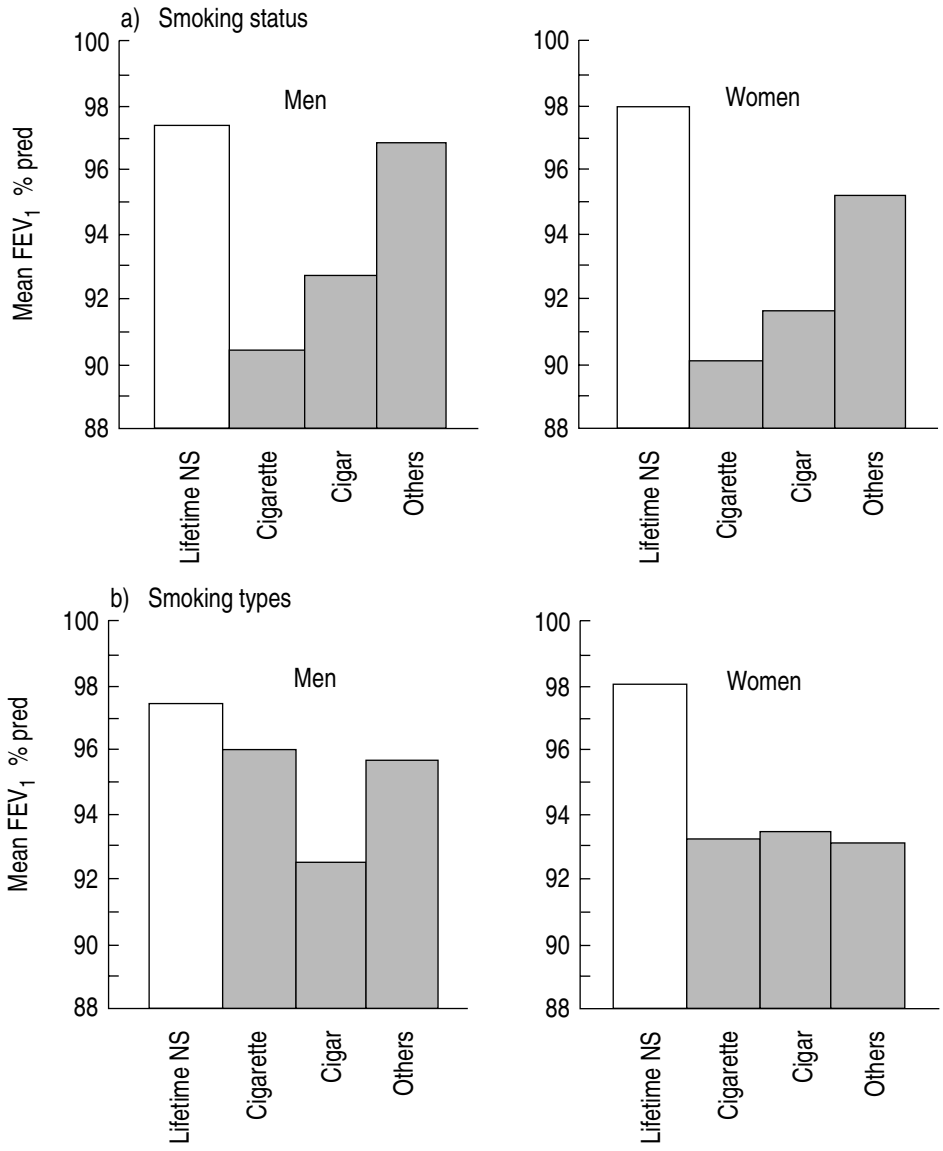

Fig. 1. – Sex-specific mean percentage predicted values of height-adjusted FEV_1 and FVC by a) smoking status and b) smoking types. FEV_1: forced expiratory volume in one second. Note that FEV_1 axis does not start at zero.

Table 2. – Prevalence of cardiovascular and respiratory illness by sex and smoking status

Smoking status	Men		Women	
	%	Ratio	%	Ratio
Physician-diagnosed cardiovascular diseases				
Current	12.4	ref	17.0	ref
Former	25.8	2.1	27.6	1.6
Lifetime NS	15.6	1.3	17.6	1.0
Physician-diagnosed bronchitis				
Current	17.3	ref	28.4	ref
Former	34.9	2.0	32.7	1.2
Lifetime NS	21.4	1.2	19.2	0.7
Respiratory symptoms*				
Current	47.2	ref	53.4	ref
Former	51.2	1.1	44.2	0.8
Lifetime NS	37.5	0.8	38.7	0.7

ref: reference group; NS: nonsmoker. *: presence of either cough, phlegm, shortness of breath or wheeze.

Results from sex-specific multiple regression analyses are presented in table 3. As compared to lifetime non-smokers, the estimated reductions in height-adjusted FEV_1 were 2.3 and 1.4 $ml \cdot m^{-2}$ per smoking year, respectively, for men and women, and the effects were highly significant. Significant reductions associated with smoking year were also observed for FVC in both sexes. After taking smoking-years and smoking type into account, male transitional and constant smokers had a significantly higher level of FEV_1 and FVC than former smokers. Female transitional smokers had a similar level of FEV_1 and FVC to former smokers, whilst constant smokers had a higher level of FEV_1 and FVC than former smokers (only significant for FVC). Controlling for smoking year and smoking status, male cigar smokers had additional deficits in FEV_1 (-25.6 $ml \cdot m^{-2}$) and in FVC (-17.5 $ml \cdot m^{-2}$) in comparison with cigarette smokers, whilst other smokers had less deficit than cigarette smokers. However, the differences were not statistically significant. Among women, no significant difference in lung function was found by smoking type.

Table 3. – Estimated effects of smoking on FEV_1 and FVC

Smoking variables	Men		Women	
	Coeff.	SEM	Coeff.	SEM
FEV_1 ml·m^{-2}				
Years	-2.3	0.5	-1.4	0.5
Transitional	42.1	19.5	-0.0	19.6
Constant	82.3	16.3	25.5	16.2
Cigar	-25.6	15.7	-7.5	27.7
Others	23.3	15.1	2.8	20.3
FVC ml·m^{-2}				
Years	-1.8	0.6	-1.1	0.5
Transitional	53.7	20.9	9.1	21.1
Constant	99.9	17.5	42.4	17.4
Cigar	-17.5	16.8	-0.1	29.9
Others	40.1	16.2	-0.1	21.8

The basic model is as follows:

$$E(Y) = \beta_0 + \beta_1 \text{ smk-yr} + \beta_2 \text{ transition} + \beta_3 \text{ constant} + \beta_4 \text{ cigar} + \beta_5 \text{ others} + \beta_x \text{ covariates}$$

where, E: expectation; Y: pulmonary function standardized by height^2; β_0: lung function for lifetime nonsmokers; smk-yr: total smoking year; transition: 1=transitional smokers, 0=otherwise; constant: 1=constant smokers; 0=otherwise; cigar: 1=cigar smokers; 0=otherwise; other: 1=other smokers, 0=otherwise; covariates including age, education, use of an indoor coal stove for heating, passive smoking, occupational dust and gas/fume exposure, and residence. FEV_1: forced expiratory volume in one second; FVC: forced vital capacity.

Finally, regression analysis combining both men and women was performed to provide a global test on the interactions of smoking with sex on pulmonary function. The female-smoking product term, the difference in smoking effects between mean and women, was significant for both FEV_1 (-26.2±12.6 ml·m^{-2}) and FVC (-37.4±13.6 ml·m^{-2}), indicating a greater smoking effect among women than among men.

Discussion

Published data on gender differences in the effect of smoking on pulmonary function have been controversial. The findings from this study suggest that adverse smoking effects on pulmonary function in general were greater among female smokers than among male smokers, which is consistent with studies conducted in three US/Canada cities [6], Saskatchewan, Canada [7], Copenhagen, Denmark [8], seven French cities [9], and Vlagtwedde-Vlaardingen, The Netherlands [10]. In contrast, other studies including The US Six Cities study [1, 2], Tucson, AZ, USA [3], Los Angeles, CA, USA [4], and Northern Italy [5] have shown opposite effects. Whilst a number of factors related to the gender difference have been speculated, including biological, behaviour, environmental and occupational factors, one possibility that has not been considered in previous studies is the incomparability of the reference groups between the two sexes. In most previous studies, lifetime nonsmokers were used as the reference group in estimating the effects of smoking on pulmonary function. Given that all the other factors are the same across different populations or gender, the reference values alone could affect the estimates of smoking effects. The incomparability of reference values may result from the difference in proportion of "unhealthy" subjects in the lifetime nonsmoker reference group across populations or gender. The higher the proportion of "unhealthy subjects", the lower the reference values, and the more likely that the smoking effects are underestimated. As there is a relative fixed proportion of "unhealthy lifetime nonsmokers" in a population, the higher the smoking prevalence, the higher the proportion of "unhealthy lifetime nonsmokers" in the lifetime nonsmoker reference group. Therefore, comparison of smoking effects across different populations and between genders may be biased, unless the comparisons are adjusted for smoking prevalence. Such bias could be substantial when almost all of the lifetime nonsmokers are "unhealthy lifetime nonsmokers" in one sex, whilst "unhealthy lifetime nonsmokers" are only a small fraction of all the lifetime nonsmokers in another sex due to a very low smoking prevalence. Our data and other data published previously support this hypothesis. In our sample, males had a higher smoking prevalence than females. The notion that the male lifetime nonsmokers had a lower mean percentage predicted lung function, and a relatively higher prevalence of physician-diagnosed cardiovascular diseases and bronchitis (as compared to current smokers) suggests that the male lifetime nonsmoker group contained a higher proportion of "unhealthy subjects" than their female counterparts. Furthermore, as shown in table 4, the studies reporting greater smoking effects among women all had a low percentage of lifetime nonsmokers in men (15–25%). In contrast, studies reporting a greater effect among males all had a relatively high prevalence of male lifetime nonsmokers (27–38%). We therefore conclude that the observed gender difference in smoking effects may be partially attributed to the incomparability of the lifetime nonsmoker reference group between the two sexes. This hypothesis may also help to explain the conflicting findings on gender differences in smoking effects on pulmonary function across previous studies.

Numerous studies have shown that the number of cigarettes smoked has a linear effect on pulmonary function level and rate of loss [19, 20]. Due to the cross-sectional nature, cumulative smoking pack-years could not be determined in this study. Instead, smoking years was used in the regression analyses. Consistent with previous reports, this study demonstrated a linear association between smoking years and reduced level of FEV_1 and FVC.

Recent studies in the US and other western countries showed that the level of FEV_1 in former smokers was lower than in lifetime nonsmokers but higher than in current smokers [1, 3, 4]. However, earlier studies in which voluntary quitting smoking rate was low, showed that the level of FEV_1 in former smokers was generally the lowest [5, 21, 22]. Our analysis is consistent with these earlier studies. An argument similar to the healthy smoker effect, albeit more complex and speculative, can

Table 4. – Percentage of lifetime nonsmokers, percentage of former smokers in those subjects who had smoked, and effects of smoking and former smoking on FEV_1 level or rate of loss of FEV_1

Studies	% Lifetime nonsmokers			% Former smokers		Smoking effect	Effects of ex-smoking†	
	M	F	F/M	M	F		M ml·yr^{-1}	F ml·yr^{-1}
Present study	22	65	3.0			M < F		
Three Cities study [6]+ US/Canada	19	40	2.1			M < F		
Saskatchewan, Canada [7]	25	46	1.8			M < F		
Copenhagen, Denmark [8]	15	31	2.1	28	19	M < F	-2, 2	-2, 0
Seven French Cities [9]	25	72	3.1			M < F		
Netherlands study [10]	11	45	4.1			M < F		
Six Cities study, USA [1]	27	51	1.9			M > F		
Six Cities study, USA [2]	27	51	1.9	46	31	M > F	-4	1
Tucson, AZ, USA [3]	28	42	1.5	37	31	M > F	-2	-1
Los Angeles, USA [4]	38	56	1.5	43	59	M > F	-4	-4
Italy study [5]	32	66	2.1			M > F		
Boston, USA [18]	47			22			4	

+: FEV_1/FVC was used in the report. M: male; F: female. †: effect on rate of loss of FEV_1, negative indicates a reduction in the decline. For further abbreviations see legend to table 3.

be applied to former smokers. Former smokers can be divided into those who quit because they are sick, "unhealthy quitters", and those who quit because they want to, "normal quitters". The "unhealthy quitters" are expected to have a lower level of pulmonary function than the "normal quitters". The percentage of "unhealthy quitters" among all former smokers will increase with age, and with amount and duration of smoking. The percentage of "normal quitters" may be influenced by health education, anti-smoking campaigns, and social/cultural factors. We hypothesize that, to the extent that a higher smoking cessation rate reflects a higher proportion of "normal quitters", the pulmonary function level in former smokers will be low if the smoking cessation rate is low in a population, or vice versa. With this hypothesis, studies showing that former smokers had a higher level of pulmonary function than current smokers should have a higher smoking cessation rate, whilst studies showing former smokers had a lower level should have a lower smoking cessation rate. The results obtained from our study and several other large longitudinal studies (table 4) are consistent with this hypothesis. In our sample, former smokers accounted for only 14 and 22%, respectively, of males and females who had ever smoked. In China, because of a lack of public awareness of the health hazards of smoking and the benefits of quitting, the smoking prevalence is very high. Many smokers are not motivated to quit, until they are ill and forced to do so by their doctors. A survey in China conducted by WENG *et al*. [23] found that the smoking cessation rate was only 4.8%, and 68% of those who quit did so due to illness. As shown in table 4, the studies with the greatest recovery of FEV_1 in former smokers (-4 ml·yr^{-1}) had a higher percentage of former smokers (43–59%). In contrast, the studies reporting an increased decline in former smokers (4 ml·yr^{-1}) had a lower percentage of former smokers (22%). The studies showing a similar rate of decline between former and lifetime nonsmokers (-2 to 2 ml·yr^{-1}) had a moderate smoking cessation rate (19–37%).

Another interesting finding in this study concerns transitional smokers, and has not been reported in previous studies. We found that pulmonary function level in transitional smokers was somewhere between that of former smokers and constant smokers. In China, many smokers reduce their smoking amount after a doctor diagnosis of a smoking-related disease, and quit completely when these diseases progress to a more severe stage. This analysis provides additional evidence for the "unhealthy quitters" hypothesis. It also indicates the necessity to separate transitional smokers from current smokers in the analysis of the effects of smoking on respiratory health, because they may represent two heterogeneous groups.

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