

Compensation as a Risk Factor for Lung Cancer in Smokers Who Switch from Nonfilter to Filter Cigarettes

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Abstract: The likelihood of increasing the number of cigarettes per day (cpd), a common method of compensation, in smokers switching from nonfilter to filter cigarettes, was examined in newly diagnosed and histologically confirmed lung cancer cases including all cell types; 1,242 lung cancer cases and 2,300 sex and age matched hospital controls were interviewed in 20 hospitals from nine United States cities between 1969 and 1984.

The mean increase in cpd for lung cancer cases was about twice that of controls. Using switchers who did not increase cpd as the referent group, there was a linear dose-response relationship be-

tween the odds of lung cancer and increasing level of compensation. The odds ratio increased from 1.19 to 2.37 in males and from 1.66 to 3.83 in females corresponding to increases of 1-10 to 21+ cpd after switching.

Findings from this study suggest that increasing cpd after switching to filter cigarettes is an important risk factor for lung cancer that needs to be emphasized in epidemiologic studies. Proponents of the idea that switching cigarettes is of some benefit, should also advocate that individuals who continue smoking should avoid compensation after switching. (*Am J Public Health* 1989; 79:188-191.)

Introduction

Epidemiologic studies have shown a reduced risk for lung cancer among smokers who switch from nonfilter to filter cigarettes relative to those who continue smoking nonfilter cigarettes.¹ On the basis of this finding it has often been recommended that people who are unwilling or unable to give up smoking should switch to filter cigarettes. The tar intake per day after switching to filter cigarettes will be reduced if smokers continue to smoke the same or fewer numbers of cigarettes per day (cpd). In this paper the term "switchers" stands explicitly for smokers who switched from nonfilter to filter cigarettes. The ways by which switchers attempt to compensate for the reduction in nicotine are by increasing cpd or altering their puff frequency, puff duration, puff rate, and interpuff interval² exposing themselves to higher quantities of gas and particulate cigarette smoke constituents.³ This study focuses on compensation in switchers who increase cpd among lung cancer cases and controls. The main questions of interest were: Is there a differential pattern of increase in cpd between cases and controls? Is there an increase in risk for lung cancer in switchers who increase cpd compared to those who do not?

Methods

The cases and controls in this study were interviewed between 1969 and 1984, in 20 hospitals in nine US cities, as part of a hospital-based ongoing study of smoking-related cancers.⁴ In the original study, cases were patients with newly diagnosed and histologically confirmed tobacco-related cancers and controls were hospitalized patients with an admitting diagnosis consisting of conditions not thought to be related to smoking. The exclusion of smoking-related conditions from control diagnoses was intended to reduce potential bias in the assessment of risks due to cigarette smoking. For the purpose of this study, we took lung cancer cases of all cell types and controls from this data pool. Controls had cancers of other organs and

non-neoplastic diseases. The smoking-related cancers excluded from control diagnoses were cancers of the oral cavity, larynx, nasopharynx, kidney, bladder, oesophagus, salivary gland, pancreas and liver; patients with heart disease, stroke, peripheral vascular disease, chronic bronchitis, emphysema, gastrointestinal ulcer, and cirrhosis were also excluded.

All study subjects were interviewed in the hospital by trained interviewers using a structured questionnaire that included sociodemographic variables, lifetime smoking history, cpd, brands of filter and nonfilter cigarettes smoked. For each individual, the average cpd of filter cigarettes was calculated by summing up the cpd for all filter brands and then dividing by the number of filter brands. The average cpd of nonfilter cigarettes was calculated similarly.

As a partial validation procedure, we checked the reliability of the initial smoking data by recontacting 100 cases and 100 controls, selected at random following their discharge from hospital.

In this investigation, only those who were current cigarette smokers and who had switched from nonfilter to filter cigarettes were considered. A current smoker was defined as someone who had smoked at least one cpd for a continuous period of one year or more and was also smoking within the year preceding diagnosis. Those cigarette smokers who smoked cigars or pipes concurrently were excluded. Cases were frequency matched at approximately a 1:2 ratio on sex and age at diagnosis (± 5 years) to controls.⁵

Statistical Techniques

All statistical analyses were performed separately by sex. Paired cpd data before and after switching were used to assess the change in cpd. Mean changes in cpd after switching for cases and controls were adjusted by linear regression for age at switching and duration of nonfilter cigarette smoking utilizing analysis of covariance.⁶ Adjusted means for cases and controls were compared by t-tests using the error mean square from the analysis of covariance with the appropriate degrees of freedom.^{6,7}

Logistic regression analysis⁸ was used to estimate the odds ratio for lung cancer in those who compensated (increased cpd) relative to those who did not compensate. An unmatched analysis was performed with adjustments for nonfilter cpd, duration of nonfilter and filter cigarette smoking, and age at diagnosis or age at switching. Since our study was limited to switchers, all subjects had corresponding sets of time points in their smoking histories (age at start, age at

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switch, and age at diagnosis), thereby facilitating simultaneous adjustment for the same potential confounders in multiple logistic models. In this paper, we restrict the term "compensation" to mean an increase in cpd after switching to filter cigarettes.

Multiple linear regression analysis⁶ was performed among controls to determine if cpd after switching could be predicted by variables such as age at switching, nonfilter cpd, nonfilter duration, and tar yield per day before switching.

Results

A total of 781 male and 461 female lung cancer cases of all cell types and 1,432 male and 868 female controls were studied; all subjects were smokers who had switched to filter cigarettes. Among male switchers, 45 per cent (n = 351) of cases and 41 per cent (n = 580) of controls increased cpd; 42 per cent (n = 327) of cases and 44 per cent (n = 634) of controls smoked the same number of cpd; and 13 per cent (n = 103) of cases and 15 per cent (n = 218) of controls decreased cpd. Among female switchers, 59 per cent of cases (n = 272) and 48 per cent of controls (n = 418) increased cpd; 31 per cent (n = 143) of cases and 41 per cent (n = 356) of controls smoked the same number of cpd; and 10 per cent (n = 46) of cases and 11 per cent (n = 91) of controls decreased cpd.

The maximum reduction after switching among cases and controls was about 50 cpd in males and 60 cpd in females. The maximum increase noted ranged from 50–70 cpd in males and 50–60 cpd in females. In both males and females, the interquartiles (25th to 75th percentiles) ranged from 0–15 cpd in cases and 0–10 in controls.

Distributions of cases and controls by age, education, marital status, religion, and occupation are presented in Table 1. In both males and females, case-control differences were not evident in the sociodemographic variables. Mean ages at diagnoses for males were 57.0 years in cases and 56.1 years in controls. The corresponding ages for females were 56.8 years and 55.8 years.

Mean values of duration of smoking and cpd are shown in Table 2. On the average, both male and female cases had smoked nonfilter cigarettes 1.5–2 years longer than controls. In males, cases and controls smoked approximately the same duration of filter cigarettes while female cases smoked approximately one year longer than the controls. On the average, cases of both sexes smoked about 5 to 6 more cpd than the controls before switching, and about 8 more cpd than the controls after switching. Notably cases showed greater compensation than controls, the mean increase in cpd for cases being about twice that of controls. Adjustments for the differences between cases and controls in duration of nonfilter cigarette smoking, age at switching and age at diagnosis by analysis of covariance did not alter these results.

Mean values of cpd before and after switching by cpd classes before switching (1–10, 11–20, 21–30, 31–40 and 41+) are presented in Table 3. Three points are evident from these data. Most importantly, cases showed greater average compensation than the controls in each cpd class and the differences in compensation between cases and controls within classes were especially great for all the classes in males and for the first four classes in females. Compensation in cpd was evident only when the initial cpd was less than 30. When initial cpd was greater than 30, there was a tendency either not to increase or even to decrease cpd after switching. In both cases and controls, the extent of compensation progressively declined with increasing cpd before switching. The difference in

TABLE 1—Distribution of Demographic Variables among Cases and Controls

Demographic Variables	Males		Females	
	Cases N = 781 %	Controls N = 1432 %	Cases N = 461 %	Controls N = 868 %
Age (years)				
<44	7.8	8.8	10.2	10.6
45–54	29.1	33.2	27.8	31.5
55–64	42.1	41.5	41.2	40.9
65–74	19.6	15.2	18.2	15.7
75+	1.4	1.3	2.6	1.4
Education				
None, Grammar School	21.0	19.9	12.8	13.2
≤High School	24.5	24.0	25.0	21.3
High School Graduate	28.3	26.4	38.0	37.5
Some College	11.3	15.9	15.4	18.0
College	9.6	8.5	5.4	6.7
Postgraduate	5.4	5.3	3.5	3.3
Marital Status				
Single	6.0	7.7	6.7	6.3
Married	74.1	70.0	53.4	55.9
Divorced	9.5	13.0	12.2	12.0
Separated	4.4	4.3	4.3	5.7
Widowed	5.9	5.0	23.4	20.1
Religious Status				
Protestant	42.3	49.7	33.7	29.3
Catholic	43.8	34.5	44.1	36.7
Jewish	9.1	9.5	17.2	13.9
Other	2.2	3.2	3.0	3.4
None	2.6	3.2	2.0	1.2
Race				
Caucasian	85.2	81.8	91.5	85.6
Black	13.4	15.9	7.8	13.0
Hispanic	1.2	1.7	0.7	1.0
Oriental	0.3	0.4	0.0	0.2
Other	—	0.2	—	0.1
Occupation				
Professional	8.6	9.1	4.6	6.4
Business Executive	10.7	9.8	3.9	3.4
Technical	9.3	6.7	26.4	15.2
Clerical/Sales	21.2	20.4	8.3	12.7
Skilled	18.3	17.3	9.4	8.7
Semi-skilled	12.9	11.6	3.1	4.1
Unskilled	6.7	9.0	3.1	4.5
Retired/Unemployed	17.0	16.1	6.5	11.1
Housewife	—	—	34.9	34.0

TABLE 2—Mean Duration of Smoking and Cigarettes per Day (CPD) Smoked Before and After Switching among Cases and Controls

Total Number	Males		Females	
	Cases N = 781	Controls N = 1432	Cases N = 461	Controls N = 868
Mean Nonfilter duration in years (SE)	26.3 (0.4)	24.8 (0.3)	22.1 (0.6)	19.8 (0.4)
Mean Filter duration in years (SE)	13.5 (0.3)	13.0 (0.2)	15.6 (0.4)	14.3 (0.3)
Mean Nonfilter cpd (SE)	28.5 (0.5)	22.7 (0.3)	21.8 (0.5)	16.8 (0.3)
Mean Filter cpd (SE)	34.4 (0.6)	26.6 (0.4)	29.7 (0.6)	21.5 (0.4)
Difference in cpd ^a (SE)	5.9 (0.5)	3.9 (0.3)	7.8 (0.6)	4.7 (0.3)

^aDifference in cpd = Filter cpd - Nonfilter cpd.
SE = Standard Error

cpd after adjustments using analysis of covariance for age at switching and duration of nonfilter cigarette smoking did not alter these results appreciably.

Table 4 shows a clearcut dose-response relationship for lung cancer with increasing cpd levels (compensation) in both

TABLE 3—Mean Cigarettes per Day (CPD) Smoked Before and After Switching According to Nonfilter CPD Groups

	Nonfilter cpd in Males									
	1-10		11-20		21-30		31-40		41+	
	Cases n = 42	Controls n = 212	Cases n = 324	Controls n = 786	Cases n = 174	Controls n = 208	Cases n = 158	Controls n = 163	Cases n = 74	Controls n = 57
Mean Nonfilter cpd (SE)	8.4 (0.4)	7.9 (0.2)	19.3 (0.1)	19.1 (0.1)	28.4 (0.2)	28.5 (0.2)	39.2 (0.2)	39.5 (0.1)	57.2 (1.0)	57.5 (1.3)
Mean Filter cpd (SE)	19.1 (1.9)	14.7 (0.7)	27.6 (0.7)	24.2 (0.4)	35.2 (1.0)	33.1 (0.8)	42.6 (1.1)	38.4 (1.2)	53.5 (2.1)	46.7 (2.5)
Difference in cpd ^a (SE)	10.7 (1.9)	6.8 (0.7)	8.2 (0.7)	5.0 (0.4)	6.7 (1.0)	4.6 (0.8)	3.3 (1.1)	-1.1 (1.2)	-3.7 (1.9)	-10.8 (2.3)
	Nonfilter cpd in Females									
	n = 87	n = 308	n = 241	n = 446	n = 72	n = 60	n = 39	n = 35	n = 20	n = 13
Mean Nonfilter cpd (SE)	8.4 (0.3)	7.6 (0.2)	19.0 (0.2)	18.6 (0.1)	28.0 (0.3)	28.3 (0.3)	39.1 (0.3)	39.0 (0.4)	56.9 (2.4)	58.5 (2.1)
Mean Filter cpd (SE)	22.4 (1.2)	14.5 (0.5)	27.1 (0.7)	22.9 (0.4)	35.3 (1.2)	31.7 (1.3)	42.5 (1.6)	36.6 (2.2)	45.7 (3.5)	49.7 (5.6)
Difference in cpd ^a (SE)	14.1 (1.3)	6.9 (0.5)	8.0 (0.7)	4.2 (0.4)	7.3 (1.2)	3.3 (1.3)	3.4 (1.6)	-2.4 (2.2)	-11.2 (4.5)	-8.8 (6.6)

^aDifference in cpd = Filter cpd - Nonfilter cpd.

sexes. The odds ratios increased from 1.19 to 2.37 in males and 1.66 to 3.83 in females corresponding with increases of 1-10 to 21+ cpd after switching.

The odds ratio associated with increasing cpd versus decreasing cpd after switching, relative to those who did not change cpd, was also examined. Compared to those who did not change their cpd, those who increased cpd had an odds ratio of 1.38 (95 per cent confidence intervals = 1.31, 1.69) in males and 2.19 (95 per cent CI = 1.67, 2.89) in females after adjusting for confounders. In contrast, males who decreased cpd had a reduction in the odds ratio to 0.64 (95 per cent CI = 0.47, 0.86); in females, the number of cases who decreased cpd was small (n = 46) and the corresponding odds ratio was 0.97 (95 per cent CI = 0.62, 1.55).

Since greater compensation occurred among those who initially smoked ≤30 cpd (Table 3), we examined the risks associated with increasing cpd according to those who initially smoked ≤30 cpd and >30 cpd. Among those who

initially smoked ≤30 cpd, those who increased cpd had elevated odds ratios of 1.34 (95 per cent CI = 1.08, 1.65) in males, and 1.84 (95 per cent CI = 1.42, 2.38) in females for lung cancer, relative to those who did not increase cpd, after adjustments for age at switch, duration of nonfilter and filter cigarette smoking. Among those who initially smoked >30 cpd, the corresponding odds ratio was also elevated in males: OR = 1.67 (95 per cent CI = 1.08, 2.57); in females, OR = 0.94 (95 per cent CI = 0.37, 2.41); the numbers of cases (n = 59) and controls (n = 48) were relatively small.

The regression of compensation (filter cpd - nonfilter cpd) on nonfilter cpd yielded negative slopes, indicating that nonfilter cpd was a negative predictor of compensation, i.e., the lower the initial cpd, the greater the compensation.

Linear regression analysis among controls was performed to examine the effect of selected variables in predicting cpd after switching. Results were similar for males and females. Cigarettes per day before switching (β = 0.7, S.E. = 0.03) and age at switching (β = 0.2, S.E. = 0.03) predicted cpd after switching in linear regression models. These variables together accounted for 34 per cent and 39 per cent of the variability among males and females, respectively, while duration of nonfilter cigarette smoking, tar yield per day before switching, and age at start of smoking accounted for little or none of the variability.

Discussion

The results of this study indicate that a sizable portion of smokers tend to compensate (increase cpd) after switching from nonfilter to filter cigarettes and that patients with lung cancer compensate more than controls. A greater proportion of females (50-60 per cent) than males (40-45 per cent) showed compensation in cpd. Among switchers who increased cpd, there was a linear dose-response relation between the odds of lung cancer with increasing level of compensation. The linearity of the dose response pattern in both sexes supports the biological plausibility of compensation as an important risk factor for lung cancer. We emphasize that these results are adjusted for past smoking patterns and duration differences.

TABLE 4—Logistic Regression Analysis Results Showing Risks of Lung Cancer for Those Who Increased CPD after Switching

Increase in Filter CPD	Cases	Controls	Odds Ratio ^{ab}	95% Confidence Interval
<i>Males</i>				
Did not increase cpd*	430	852	1.00	—
1-10 vs did not increase cpd	150	326	1.19	0.93-1.51
11-20 vs did not increase cpd	128	180	1.75	1.33-2.29
21+ vs did not increase cpd	73	73	2.37	1.64-3.41
<i>Females</i>				
Did not increase cpd*	189	447	1.00	—
1-10 vs did not increase cpd	126	262	1.66	1.23-2.24
11-20 vs did not increase cpd	101	115	2.97	2.09-4.20
21+ vs did not increase cpd	45	40	3.83	2.31-6.34

^aAdjusted for nonfilter duration, filter duration, nonfilter cpd, and age at switch.

^bTest of linear trend significant at p < 0.05.

*Referent category.

In our study, the lower the initial cpd, the greater the tendency to compensate by increasing cpd. In fact, heavy smokers of nonfilter cigarettes (>30 cpd) on the average tended to decrease rather than increase cpd after switching to filter cigarettes. There may be several explanations for this finding. It is possible that heavy smokers may compensate by altering their smoking topography since there may be a time limitation (less leeway) in smoking additional cigarettes and/or encumbent symptoms might compel them to smoke less upon switching. A similar finding was noted in the 13-year follow-up survey by the American Cancer Society.⁹ Lighter smokers (not separated by switch status) of less than half a pack a day in 1959 showed an average increase in cpd by 1972 which doubled that observed in heavier smokers. Another plausible explanation relates to an upper threshold phenomenon of nicotine dependency. In the already heavy nonfilter cigarette smokers (>30 cpd), the amount of filter cigarettes smoked (even when it is less than the initial cpd) after switching may be sufficient to maintain their required nicotine level.

One possible source of bias in this study is recall bias. If cases overestimated their exposure, while controls underestimated it, then the risk will appear larger than real. As a partial validation procedure, we reinterviewed 100 cases and 100 controls following their discharge from hospital. The results from the second interview showed good agreement with first reported cpd in both groups (average correlation 0.90) and revealed no differential reporting between cases and controls. The average difference between first and second interviews for both cases and controls was only one cpd.

The major reason for limiting our analysis to switchers only was to facilitate adjustment for the corresponding sets of confounders (duration of nonfilter smoking, age at switch, and duration of filter smoking) within the comparison groups, i.e., switchers who did not compensate, using multiple logistic analysis. Since there is also intense interest in comparing switchers with exclusive nonfilter cigarette smokers, we attempted to assess their patterns of odds ratio. Wynder and Kabat¹⁰, observed minimum odds ratios for lung cancer of 0.66 and 0.74 in males and females, respectively, among switchers who had smoked filter cigarettes for more than 10 years, relative to exclusive nonfilter smokers. Assuming that 0.66 and 0.74 represent the odds ratios among male and female switchers who increased by 1–10 cpd after switching (this was the median class of cpd change in our study), we computed odds ratios due to various levels of compensation relative to nonfilter cigarette smokers (Figure 1). Further reductions in odds ratios are evident with no compensation (0.55 and 0.45 in males and females, respectively), whereas for switchers who compensate, the odds ratios increase in a linear fashion, and even become greater than that of nonfilter only smokers when the compensation level exceeds 20 cpd.

Compensation as a risk factor has not been stressed in epidemiologic studies comparing the health risk of nonfilter to filter cigarette switchers relative to exclusive nonfilter cigarette smokers. Compensation is undoubtedly a complex phenomenon. It includes changes in puff frequency, duration, rate and interval.² Nevertheless, the relatively simple measure of compensation used in this study (increase in cpd after switching) has proved to be an important risk factor for lung cancer in itself. Based on our results, the lung cancer risk among smokers who switch to filter cigarettes would be reduced further if they strive not to increase cpd after switching. Proponents of the idea that switching cigarettes is of some benefit should also advocate that individuals who continue smoking should avoid compensating after switching.

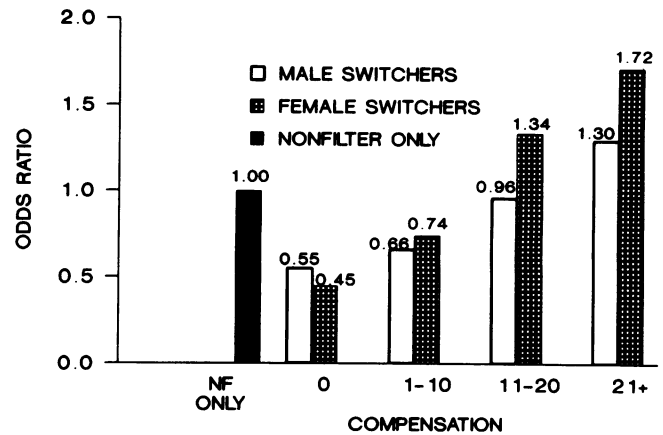


FIGURE 1—Risks among Switchers Relative to Nonfilter Only Smokers According to Different Levels of Compensation.*

*Compensation is the increase in cigarettes per day after switching to filter cigarettes.

SOURCE: Computed from the results of this study and the results of the study by Wynder and Kabat¹⁰.

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