

Impact of Tobacco Smoking on Health Care Utilization and Medical Costs in Chronic Obstructive Pulmonary Disease, Coronary Heart Disease and Diabetes*

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[Abstract] Objective: To determine the impact of smoking on disease-specific health care utilization and medical costs in patients with chronic non-communicable diseases (NCDs). **Methods:** Participants were middle-aged and elderly adults with chronic NCDs from a prospective cohort in China. Logistic regressions and linear models were used to assess the relationship between tobacco smoking, health care utilization and medical costs. **Results:** Totally, 1020 patients with chronic obstructive pulmonary disease (COPD), 3144 patients with coronary heart disease (CHD), and 1405 patients with diabetes were included in the analysis. Among patients with COPD, current smokers (β : 0.030, 95% CI: -0.032–0.092) and former smokers (β : 0.072, 95% CI: 0.014–0.131) had 3.0% and 7.2% higher total medical costs than never smokers. Medical costs of patients who had smoked for 21–40 years (β : 0.028, 95% CI: -0.038–0.094) and ≥ 41 years (β : 0.053, 95% CI: -0.004–0.110) were higher than those of never smokers. Patients who smoked ≥ 21 cigarettes (β : 0.145, 95% CI: 0.051–0.239) per day had more inpatient visits than never smokers. The association between smoking and health care utilization and medical costs in people with CHD group was similar to that in people with COPD; however, there were no significant associations in people with diabetes. **Conclusion:** This study reveals that the impact of smoking on health care utilization and medical costs varies among patients with COPD, CHD, and diabetes. Tobacco control might be more effective at reducing the burden of disease for patients with COPD and CHD than for patients with diabetes.

Key words: tobacco smoking; chronic obstructive pulmonary disease; coronary heart disease; diabetes; health care utilization; medical costs

Chronic non-communicable diseases (NCDs) are associated with high rates of morbidity and mortality, and their management involves ongoing medical expenses which entail a heavy burden to individuals and society. Health care systems around the world are facing increasing challenges due to the demands associated with providing health care to greater numbers of patients with chronic NCDs^[1]. As of 2020, more than

300 million people in China had been diagnosed with a chronic NCD^[2]. On average, national health spending in China amounts to 7 230 billion Chinese Yuan (CNY) per year, with up to 70% of this expenditure spent on the diagnosis and treatment of NCDs^[3].

In recent decades, the potential effects of strategies such as reducing tobacco smoking, limiting excessive drinking, increasing levels of physical activity and improving dietary habits to reduce the impact of these health care challenges have received growing interest among policy makers, especially in developing countries^[4, 5]. Studies have provided evidence that these behavioral risk factors increase the morbidity, mortality, health care utilization, and the national and regional economic burden associated with chronic NCDs^[6–9]. Given the important effects of these risk factors, the World Health Organization and other disease control and prevention agencies in many countries have

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advocated for increasing adoption of healthy lifestyles. However, it is difficult for many patients to change multiple unhealthy behaviors at the same time, and few people are able to successfully transition from a lifestyle involving multiple behavioral risk factors to a healthy lifestyle over the long term^[8–11].

Previous studies have reported that 20% of smokers suffer from chronic obstructive pulmonary disease (COPD) and 30% of coronary deaths per year are attributed to smoking^[12, 13]. In addition, studies have shown that smokers have a 30%–40% higher risk of developing type 2 diabetes than non-smokers^[14, 15]. Although many studies have analyzed the effects of tobacco ingredients and doses on the morbidity and mortality associated with chronic NCDs, few studies have focused on the relationship between smoking and the medical burden that patients with chronic NCDs face, which is an issue of urgent concern for policymakers. Evidence concerning the impact of risk behaviors on disease-specific health care utilization and medical costs for individual patients with chronic NCDs is limited. Furthermore, few studies have examined which specific behaviors most urgently need to be addressed in order to reduce the impact of chronic NCDs in different groups of patients. Thus, there is a need to conduct in-depth analyses in order to identify important risk behaviors, and identify effective strategies that could be implemented as priorities to reduce the health care burden associated with specific chronic NCDs.

To assist in identifying strategic priorities for reducing the medical burden associated with chronic NCDs, this study examined the extent of health care utilization and medical costs attributable to measures of smoking history and current smoking behavior. This was done by analyzing health care utilization and medical costs in people in the Dongfeng-Tongji (DFTJ) cohort who had been hospitalized for COPD, coronary heart disease (CHD), or diabetes.

1 SUBJECTS AND METHODS

1.1 Data

We obtained data from the DFTJ cohort study, a dynamic prospective cohort study in Hubei Province, central China. The details of the cohort have been described in a previous report^[16]. Briefly, the purpose of the DFTJ cohort study is to examine determinants of obesity, the metabolic syndrome, diabetes, cardiovascular disease, and other chronic NCDs. The study investigates the role of lifestyle, occupational, environmental, psychosocial and genetic factors in the development of chronic NCDs. As all retired employees were covered by the health-care service system of Dongfeng Motor Corporation (DMC) and each participant had a unique medical insurance card number

and ID, it was easy to track disease prevalence, health care utilization and medical costs. A total of 27 009 retired DMC employees were recruited into the DFTJ cohort study between September 2008 and June 2010, during which they completed baseline questionnaires. The first follow-up investigations, involving 38 295 participants, were conducted from April to October in 2013. At the follow-up investigation, participants repeated the same questionnaire interviews, physical examinations, and had the same blood samples collected as conducted previously in the baseline survey.

In the present study, we included patients who were hospitalized due to COPD, CHD or diabetes in 2013 or 2014. Disease-specific information on hospitalizations was not available in the database of Medical Insurance Center prior to 2013. By means of a unique medical insurance card number and ID for each participant, these health care records could be linked with the information provided in the DFTJ cohort study questionnaires. Patients who had not completed follow-up questionnaires in 2013 were excluded from further analysis, as were individuals where implausible values appeared in the data, such as having spent more than 365 days in hospital in one year. After exclusions, we identified 588, 1666, and 841 participants, who were hospitalized due to COPD, CHD or diabetes in 2013, respectively, and 1020, 3144, and 1405 people hospitalized from 2013 to 2014 for these conditions, respectively. The inclusion and exclusion of study subjects were shown in fig. 1. These three disease diagnoses were made by doctors in the DMC-owned hospitals using well-accepted international diagnostic standards^[16–18].

The study was approved by the Medical Ethics Committee of School of Public Health, Tongji Medical College, Huazhong University of Science and Technology (No. 201210), and was subsequently carried out in accordance with approved guidelines. All participants provided written informed consent prior to participating in the study.

1.2 Measures

We analyzed participants' medical record data from the DMC Medical Insurance Center for four outcomes: the number of inpatient visits, number of days spent as an inpatient, hospital costs, and total medical costs. For each outcome, we extracted data covering 2013 and 2014. For subsequent analyses we used data covering either 2013 alone—the same year that participants completed follow-up assessments to determine their cigarette smoking habits—or data covering 2013 to 2014, since not all patients had hospitalizations in each year.

We obtained information about smoking behaviors during the first follow-up investigation of the DFTJ cohort conducted in 2013. We assessed whether people were current, former or never smokers with the question:

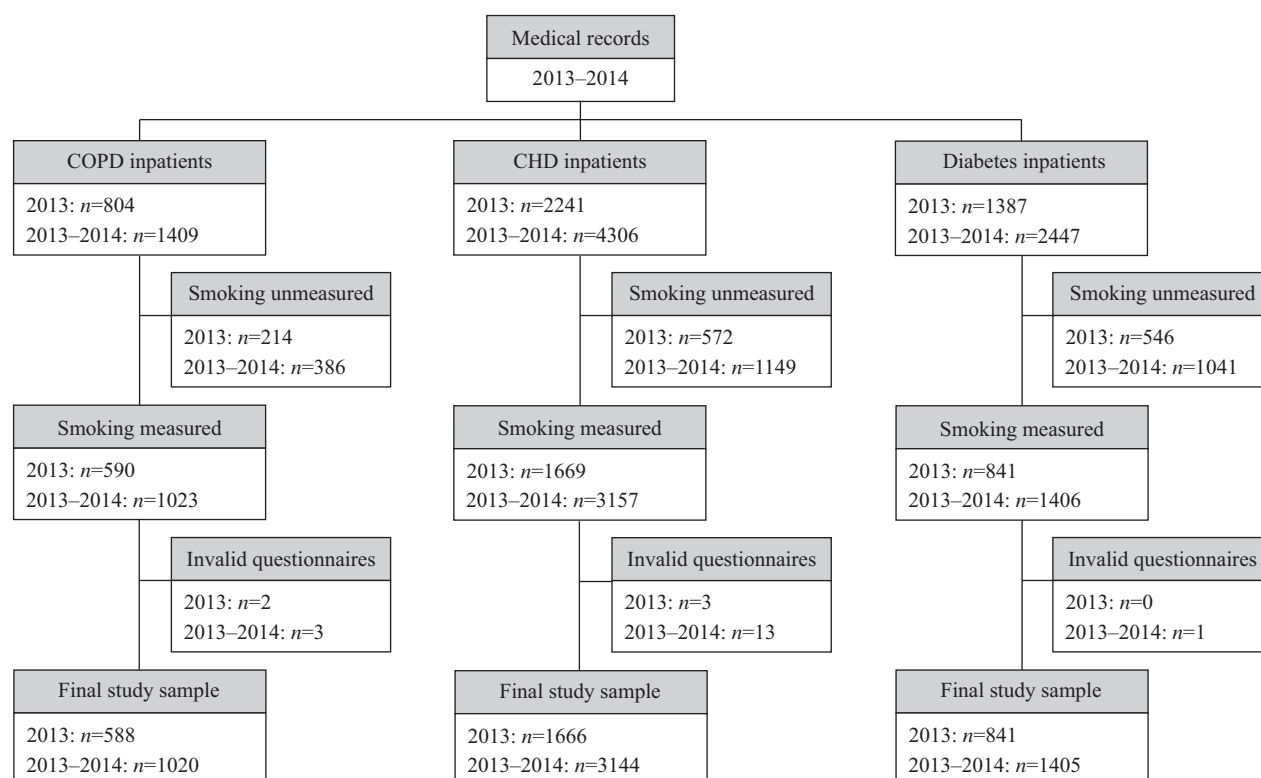


Fig. 1 Inclusion and exclusion flowchart of study subjects

COPD: chronic obstructive pulmonary disease; CHD: coronary heart disease

“Do you smoke tobacco (smoking means smoking at least one cigarette a day and lasting for more than half a year)?” with three response categories: never smokers [never smoke or only occasionally smoke a small number of cigarettes (no more than 1 per day)], current smokers, and former smokers. Current smokers were asked two additional questions: (1) How old were you when you started smoking (years old)? (2) How many cigarettes do you smoke per day? Former smokers were asked: (1) How old were you when you started smoking? (2) How many cigarettes did you smoke per day before quitting? and (3) How old were you when you quit smoking? Smoking behaviors were divided in three dimensions: (1) smoking status (never smokers, former smokers, and current smokers); (2) years of smoking (0, 1–20, 21–40, and ≥ 41); and (3) cigarettes smoked per day (0, 1–10, 11–20, and ≥ 21). The latter two exposure dimensions included both current smokers and former smokers. We also calculated the number of pack-years that participants had smoked, defined as (number of cigarettes smoked per day/20) \times number of years smoked.

We identified covariates to address potential confounding from participant follow-up assessments conducted in 2013, including sociodemographic factors (sex, age, marital status, and education level), lifestyle factors (drinking habits and exercise levels), and comorbidities (hypertension, hyperlipidemia, myocardial infarction, and stroke). Details of comorbidities were self-reported.

1.3 Statistical Analyses

We performed descriptive analyses to compare participants' characteristics and rates of unadjusted outcomes across the three dimensions of tobacco smoking described above. Continuous variables were presented as mean \pm SD, and categorical variables were shown as percentages. Owing to their positively skewed distribution, inpatient days, hospital costs, and total medical costs were also expressed as medians and quartiles. For crude comparisons, we used chi-square tests for categorical variables and analysis of variance and rank-sum tests for continuous variables.

We assessed the relationship between tobacco smoking and the number of inpatient visits (1, ≥ 2) using logistic regression. Participants with missing covariate values were excluded from logistic regression analyses. Two general linear models were used to assess the association between tobacco smoking and log-transformed inpatient days, hospital costs, and total medical costs. Model 1 included tobacco smoking only. Model 2 was adjusted for sex, age, education level, marital status, drinking, exercise, and comorbidity. We conducted all analyses using IBM SPSS Statistics, version 22 (USA). Statistical tests were two-tailed, and P -values < 0.05 were considered significant.

1.4 Patient and Public Involvement

Patients were not directly involved in the development of the research question and the design of this study. All participants were informed about the research questions under investigation, the objectives

of the study, the process of data collection as well as confidentiality of their data, and investigators obtained the written informed consent of each participant before they completed study questionnaires or assessments. All participants had the right to withdraw from the study at any time.

2 RESULTS

A total of 588 patients with COPD, 1666 patients with CHD, and 841 patients with diabetes were included in analyses covering hospitalizations in 2013. For analyses covering hospitalizations in 2013 and 2014, the numbers of patients included were 1020, 3144, and 1405, respectively. In 2013, the proportion of current smokers was 15.7%, 13.7%, and 15.9% for people hospitalized due to COPD, CHD, and diabetes, respectively. For former smokers these rates were 25.7%, 18.7%, and 14.7%, respectively. We observed similar proportions of current smokers in each disease group in data covering hospitalizations in 2013 or 2014. Details of the general characteristics and smoking habits of participants hospitalized with each of these three diseases are shown in Appendix 1. Current smokers tended to be younger and former smokers tended to be older. Current smokers were less likely to suffer from other diseases than former smokers.

Tables 1–3 present the data on health care utilization and medical costs by smoking status, years of smoking, and cigarettes smoked per day. Amongst participants hospitalized for COPD in 2013 or 2014, those who were former smokers or who had smoked for over 40 years or over 20 cigarettes a day had higher health care utilization and medical costs. Former smokers had more inpatient visits, hospital costs, and total medical costs than current smokers. The number of inpatient days increased with increasing years of smoking: for 0 (ref), 1–20, 21–40, and ≥ 41 years of smoking, the number of days spent as an inpatient was 15.62 ± 16.12 , 14.16 ± 8.86 , 19.75 ± 20.50 , and 21.07 ± 22.20 , respectively. The number of inpatient days also increased with the number of cigarettes smoked per day: for 0 (ref), 1–10, 11–20, and ≥ 21 cigarettes, the number of days participants spent as an inpatient was 15.82 ± 16.38 , 20.76 ± 23.37 , 17.45 ± 16.50 , and 26.48 ± 25.56 , respectively. We observed similar trends in analyses covering both one year (2013) and two years (2013 or 2014) of hospital data. The same trends in smoking behavior and health care utilization and medical costs were seen in participants hospitalized with CHD group. However, we found no significant associations between smoking habits and health care utilization and medical costs in participants hospitalized for diabetes.

Table 4 presents the association between smoking pack-years and 2013–2014 health care utilization and

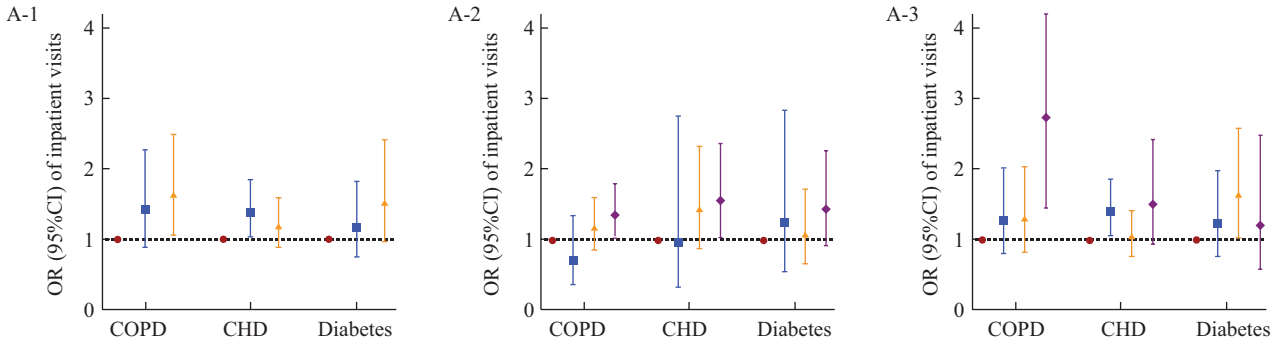
medical costs. Health care utilization and medical costs were significantly higher among the patients who had smoked more than 20 pack-years. The proportion of total medical costs over a two-year period attributable to smoking accounted for 26.48%, 28.30% and 7.59% of total medical costs for patients with COPD, CHD, and diabetes, respectively.

Fig. 2 shows associations between the three dimensions of smoking being assessed and health care utilization and medical costs over two years. For participants hospitalized for COPD in 2013 or 2014, current smokers (OR, 1.430, 95% CI: 0.900–2.270) and former smokers (OR, 1.621, 95% CI, 1.053–2.494) had a higher likelihood of having more than one inpatient visit than never smokers, after adjustment for sex, age, education level, marital status, drinking, exercise, and comorbidities. Patients who had smoked ≥ 41 years had a higher likelihood of having more than one inpatient visit than never smokers (OR, 1.569, 95% CI: 1.037–2.374). Patients who smoked ≥ 21 cigarettes per day had a higher likelihood of more than one inpatient visit than never smokers (OR, 2.737, 95% CI: 1.444–5.190; fig. 2A-1 to 2A-3).

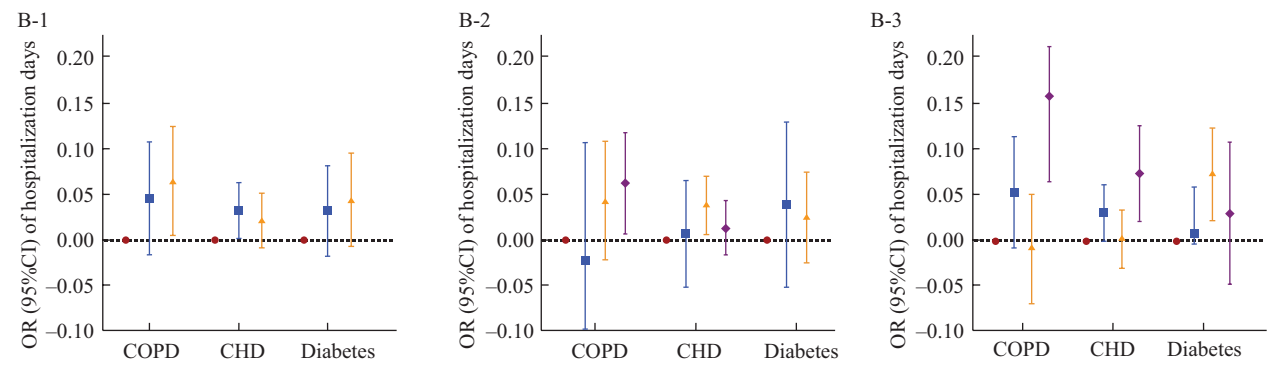
We observed similar associations between smoking habits and inpatient days, hospital costs, and total medical costs for data covering both one year (2013) or two years (2013 or 2014) of hospital data (fig. 2). For participants hospitalized due to COPD in either of the two years, unadjusted analyses showed that current smokers and former smokers had 7.0% and 14.3% higher total medical costs than never smokers, with respective β -coefficient values of $\beta=0.070$ (95% CI, 0.016–0.124) and $\beta=0.143$ (95% CI, 0.096–0.190). The total medical costs of patients who had smoked for 21–40 years and ≥ 41 years were 9.0% and 11.7% higher than those of never smokers, with respective β -coefficient values of $\beta=0.090$ (95% CI, 0.032–0.149) and $\beta=0.117$ (95% CI, 0.070–0.164). Patients who smoked 1–10, 10–20, and ≥ 21 cigarettes per day had 7.9%, 7.1% and 22.2% more inpatient visits than never smokers, with respective β -coefficient values of $\beta=0.079$ (95% CI, 0.023–0.134), $\beta=0.071$ (95% CI, 0.020–0.122), and $\beta=0.222$ (95% CI, 0.134–0.311). Associations were attenuated but the majority remained significant after additional adjustments for sociodemographic and health-related characteristics were made. The association between smoking and health care utilization and medical costs for participants hospitalized due to CHD was similar to that observed in participants hospitalized due to COPD; however, we found no significant associations between smoking and health care utilization and medical costs in participants hospitalized due to diabetes (fig. 2D-1 to 2D-3).

The association between gender, smoking status, and health care utilization and medical expenses over a two-year period is shown in Appendix 2. We found

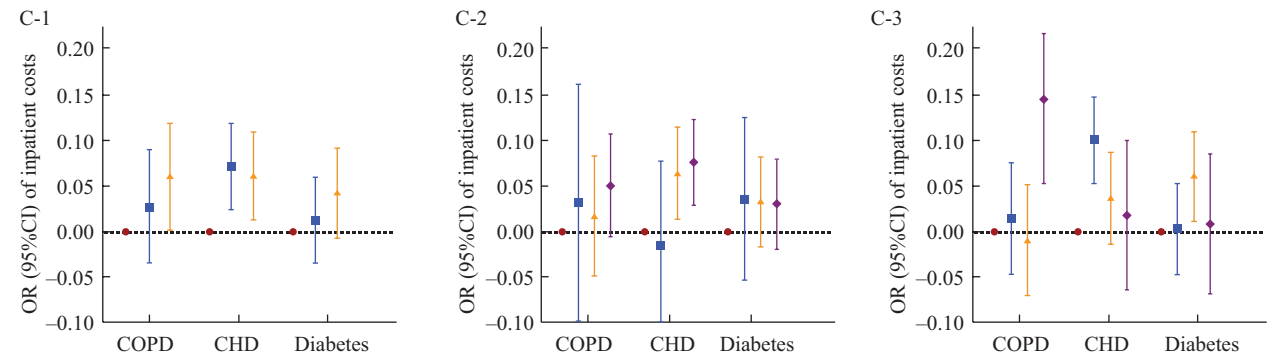
Outcome A: number of inpatient visits



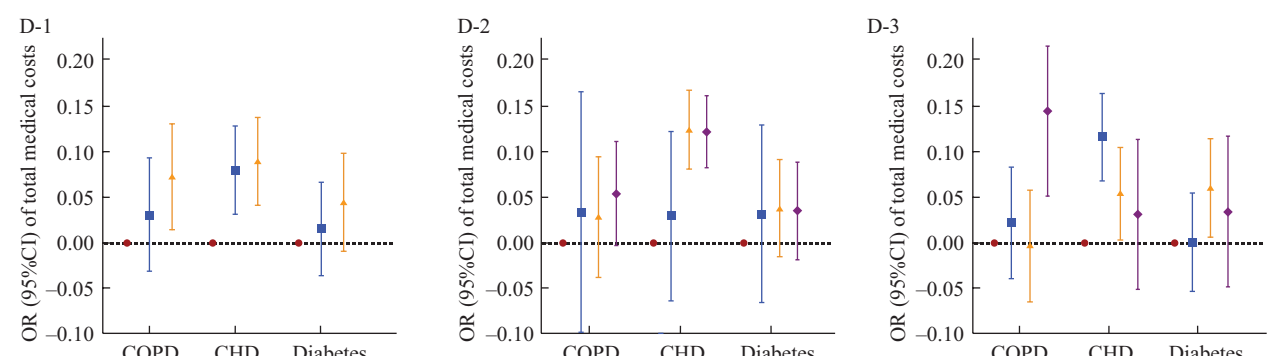
Outcome B: number of hospitalization days



Outcome C: inpatient costs



Outcome D: total medical costs



● Nonsmoker
 ■ Current smoker
 ▲ Ex-smoker

Exposure: smoking status

● 0
 ■ 1-20 years
 ▲ 21-40 years
 ◆ ≥41 years

Exposure: smoking years

● 0
 ■ 1-10 cigarettes
 ▲ 11-20 cigarettes
 ◆ ≥21 cigarettes

Exposure: number of cigarettes/day

Fig. 2 The association between tobacco smoking and health care utilization or medical costs

A-1 to A-3 show the association between smoking and number of inpatient visits; B-1 to B-3 show the association between smoking and number of hospitalization days; C-1 to C-3 show the association between smoking and number of inpatient costs; D-1 to D-3 show the association between smoking and number of total medical costs. COPD: chronic obstructive pulmonary disease; CHD: coronary heart disease.

Table 1 Smoking status and health care utilization and medical costs in participants hospitalized due to COPD, CHD or diabetes

Health care utilization and medical costs	2013–2014									
	2013					2014				
	Overall n (%)	Never smoked n (%)	Current smoker n (%)	Former smoker n (%)	P	Overall n (%)	Never smoked n (%)	Current smoker n (%)	Former smoker n (%)	P
COPD										
Number of inpatient visits										
1	474 (80.70)	291 (61.40)	68 (14.30)	115 (24.30)	0.017	773 (76.30)	487 (63.00)	122 (15.80)	164 (21.20)	<0.001
≥2	113 (19.30)	53 (46.90)	24 (21.20)	36 (31.90)		242 (23.70)	105 (43.80)	51 (21.30)	84 (35.00)	
Inpatient days										
Mean±SD	16.52±0.76	15.54±0.92	18.63±2.28	17.50±1.55	0.269	17.52±18.46	15.61±16.26	20.55±23.89	19.95±18.56	<0.001
Median (IQR)	12.00 (9.00–17.00)	11.00 (9.00–16.00)	13.00 (9.00–17.75)	13.00 (9.00–19.00)	0.154	12.00 (9.00–19.00)	11.00 (8.00–16.00)	13.00 (9.00–23.50)	14.00 (10.00–23.00)	<0.001
Hospital costs (thousand CNY)										
Mean±SD	9.44±0.49	9.17±0.71	9.76±1.16	9.89±0.77	0.796	10.72±13.18	9.35±11.73	11.67±13.17	13.31±15.8	<0.001
Median (IQR)	6.41 (4.52–9.55)	6.20 (4.48–8.58)	6.33 (4.28–10.70)	7.20 (5.00–10.38)	0.034	6.59 (4.73–11.09)	6.27 (4.56–9.09)	6.88 (4.63–12.90)	7.89 (5.51–15.59)	<0.001
Total medical costs (thousand CNY)										
Mean±SD	9.55±0.50	9.28±0.72	9.77±1.17	10.07±0.78	0.786	10.89±13.42	9.47±12.02	11.74±13.30	13.68±16.01	<0.001
Median (IQR)	6.42 (4.54–9.78)	6.20 (4.49–8.58)	6.33 (4.28–10.70)	7.27 (5.02–11.08)	0.018	6.63 (4.74–11.15)	6.27 (4.56–9.15)	6.88 (4.69–12.90)	8.21 (5.52–15.80)	<0.001
CHD										
Number of inpatient visits										
1	1327 (85.40)	942 (68.70)	183 (13.30)	247 (18.00)	0.140	2407 (77.20)	1683 (69.90)	349 (14.50)	375 (15.60)	0.016
≥2	235 (14.60)	149 (63.40)	31 (13.20)	55 (23.40)		710 (22.80)	457 (64.40)	116 (16.30)	137 (19.30)	
Inpatient days										
Mean±SD	11.17±6.90	10.82±6.60	11.67±6.71	12.05±7.93	0.012	10.90±7.34	10.72±7.22	11.09±7.17	11.50±7.91	0.079
Median (IQR)	9.00 (7.00–14.00)	9.00 (7.00–14.00)	10.00 (7.00–14.00)	10.00 (7.00–15.00)	0.023	9.00 (7.00–13.00)	9.00 (7.00–13.00)	9.00 (7.00–13.00)	9.00 (7.00–14.00)	0.139
Hospital costs (thousand CNY)										
Mean±SD	15.07±20.11	13.60±18.24	15.41±20.31	20.15±25.05	<0.001	17.87±23.41	15.95±20.77	22.01±27.63	22.11±28.18	<0.001
Median (IQR)	8.10 (5.40–12.71)	7.84 (5.25–11.68)	8.03 (5.21–13.46)	9.45 (5.90–18.27)	<0.001	8.93 (5.79–15.51)	8.64 (5.73–13.74)	9.72 (5.98–22.74)	9.74 (5.93–23.82)	<0.001
Total medical costs (thousand CNY)										
Mean±SD	16.19±20.79	14.57±18.90	16.38±20.77	21.90±25.78	<0.001	20.05±24.73	17.84±22.07	24.14±28.63	25.55±29.68	<0.001
Median (IQR)	9.02 (5.76–14.25)	8.62 (5.55–13.08)	8.87 (5.96–14.98)	10.97 (6.63–21.82)	<0.001	10.11 (6.19–20.79)	9.48 (6.02–18.17)	11.72 (6.52–28.60)	13.50 (7.07–28.73)	<0.001
Diabetes										
Number of inpatient visits										
1	709 (85.20)	491 (69.30)	115 (16.20)	103 (14.50)	0.789	1044 (75.00)	737 (70.60)	167 (16.00)	140 (13.40)	0.695
≥2	123 (14.80)	87 (70.70)	17 (13.80)	19 (15.40)		348 (25.00)	240 (69.00)	55 (15.80)	53 (15.20)	

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Health care utilization and medical costs	2013				2013–2014				
	Overall <i>n</i> (%)	Smoking status		<i>P</i>	Overall <i>n</i> (%)	Smoking status		<i>P</i>	
		Never smoked <i>n</i> (%)	Current smoker <i>n</i> (%)			Former smoker <i>n</i> (%)	Never smoked <i>n</i> (%)		Current smoker <i>n</i> (%)
Inpatient days									
Mean±SD	13.14±0.26	13.05±0.32	13.66±0.56	13.47±0.76	0.649	15.91±13.13	16.05±11.23	17.39±20.73	0.212
Median (IQR)	11.00 (8.00–15.00)	11.00 (8.00–15.00)	12.00 (10.00–15.00)	11.00 (8.00–15.00)	0.1117	12.00 (9.00–18.00)	12.00 (9.00–18.00)	12.00 (9.00–17.00)	0.751
Hospital costs (thousand CNY)									
Mean±SD	7.69±0.16	7.66±0.21	7.70±0.35	7.96±0.37	0.808	9.41±7.79	9.48±7.59	10.35±9.30	0.174
Median (IQR)	6.56 (5.00–8.80)	6.52 (4.88–8.63)	6.49 (5.41–8.94)	6.86 (5.24–9.88)	0.408	7.19 (5.44–10.56)	7.29 (5.23–10.97)	7.70 (5.83–10.90)	0.086
Total medical costs (thousand CNY)									
Mean±SD	8.85±0.19	8.92±0.25	8.36±0.38	9.27±0.48	0.431	10.86±9.39	10.89±10.34	12.14±10.76	0.113
Median (IQR)	7.13 (5.45–10.66)	7.26 (5.37–10.70)	6.95 (5.64–9.94)	7.40 (5.57–11.40)	0.569	8.02 (5.71–12.32)	7.79 (5.60–12.30)	8.71 (6.13–14.32)	0.079

COPD: chronic obstructive pulmonary disease; CHD: coronary heart disease; IQR: interquartile range

Table 2 Years of smoking and health care utilization and medical costs in patients hospitalized due to COPD, CHD or diabetes

Health care utilization and medical costs	2013				2013–2014				
	0 <i>n</i> (%)	Years of smoking		<i>P</i>	0 <i>n</i> (%)	Years of smoking		<i>P</i>	
		1–20 <i>n</i> (%)	21–40 <i>n</i> (%)			≥41 <i>n</i> (%)	1–20 <i>n</i> (%)		21–40 <i>n</i> (%)
COPD									
Number of inpatient visits									
1	299 (62.90)	14 (2.90)	58 (12.20)	104 (21.90)	0.004	500 (64.10)	95 (12.20)	166 (21.30)	<0.001
≥2	53 (46.90)	1 (0.90)	21 (18.60)	38 (33.60)		110 (45.80)	43 (17.90)	81 (33.80)	
Inpatient days									
Mean±SD	15.45±0.90	12.93±2.26	16.70±1.30	19.44±2.07	0.148	15.62±16.12	19.75±20.50	21.07±22.20	<0.001
Median (IQR)	11.00 (9.00–16.00)	11.00 (7.00–15.00)	14.00 (9.00–20.00)	13.00 (9.00–18.25)	0.087	11.00 (8.00–16.00)	14.00 (8.75–23.25)	14.00 (9.00–25.00)	<0.001
Hospital costs (thousand CNY)									
Mean±SD	9.12±0.69	8.41±1.48	9.47±0.81	10.31±1.00	0.773	9.43±11.78	12.13±14.18	13.00±15.64	0.002
Median (IQR)	6.19 (4.49–8.68)	6.83 (4.40–10.00)	7.48 (4.69–10.58)	6.56 (4.61–10.73)	0.164	6.26 (4.56–9.22)	7.72 (4.69–13.43)	7.52 (5.48–16.08)	<0.001
Total medical costs (thousand CNY)									
Mean±SD	9.23±0.71	8.45±1.50	9.74±0.82	10.35±1.00	0.801	9.58±12.10	12.45±14.41	13.15±15.78	0.002
Median (IQR)	6.19 (4.50–8.68)	6.83 (4.40–10.00)	7.54 (4.69–11.28)	6.56 (4.67–10.73)	0.113	6.27 (4.56–9.30)	7.87 (4.74–13.64)	7.60 (5.48–16.29)	<0.001

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Health care utilization and medical costs	2013						2013–2014						P
	Years of smoking			Years of smoking			Years of smoking			Years of smoking			
	0 n (%)	1–20 n (%)	21–40 n (%)	≥41 n (%)	P	0 n (%)	1–20 n (%)	21–40 n (%)	≥41 n (%)	P			
CHD													
Number of inpatient visits													
1	954 (69.70)	34 (2.50)	176 (12.90)	205 (15.00)	0.005	1725 (71.00)	63 (2.60)	297 (12.20)	343 (14.10)	0.004			
≥2	152 (64.70)	2 (0.90)	32 (13.60)	49 (20.90)		471 (65.90)	12 (1.70)	96 (13.40)	136 (19.00)				
Inpatient days													
Mean±SD	10.86±6.68	10.92±6.05	11.95±7.50	11.95±7.40	0.024	10.77±7.37	10.72±6.92	11.48±7.79	11.21±7.44	0.272			
Median (IQR)	9.00 (7.00–14.00)	9.00 (7.00–14.00)	10.00 (7.00–15.00)	10.00 (7.00–14.00)	0.039	9.00 (7.00–13.00)	9.00 (7.00–13.00)	9.00 (7.00–14.00)	9.00 (7.00–14.00)	0.279			
Hospital costs (thousand CNY)													
Mean±SD	13.72±18.45	14.36±17.42	19.14±23.76	17.69±23.39	<0.001	16.13±21.09	18.43±23.94	22.38±28.99	22.50±27.61	<0.001			
Median (IQR)	7.87 (5.26–11.72)	6.31 (4.45–16.91)	8.95 (5.66–15.64)	8.60 (5.83–15.00)	0.002	8.66 (5.74–13.91)	8.26 (4.79–17.35)	9.51 (5.87–22.41)	10.28 (6.26–26.53)	<0.001			
Total medical costs (thousand CNY)													
Mean±SD	14.69±19.12	15.29±17.61	20.94±24.52	18.88±23.97	<0.001	18.01±22.36	20.77±24.29	25.75±30.45	24.97±28.81	<0.001			
Median (IQR)	8.63 (5.56–13.10)	8.81 (4.79–16.91)	10.55 (6.68–18.82)	10.05 (6.30–16.77)	<0.001	9.55 (6.03–18.25)	11.34 (5.18–24.61)	12.45 (6.93–28.73)	12.49 (6.93–30.07)	<0.001			
Diabetes													
Number of inpatient visits													
1	504 (70.20)	14 (1.90)	94 (13.10)	106 (14.80)	0.542	758 (71.70)	26 (2.50)	139 (13.20)	134 (12.70)	0.558			
≥2	90 (73.20)	4 (3.30)	12 (9.80)	17 (13.80)		244 (70.10)	9 (2.60)	41 (11.80)	54 (15.50)				
Inpatient days													
Mean±SD	13.01±0.32	12.78±1.49	13.42±0.81	13.57±0.58	0.862	15.47±11.43	15.37±9.36	16.71±19.42	16.97±14.46	0.389			
Median (IQR)	11.00 (8.00–15.00)	11.50 (8.00–15.25)	11.00 (9.00–14.00)	12.00 (9.00–15.00)	0.267	12.00 (9.00–18.00)	13.00 (10.00–17.00)	12.00 (9.00–17.00)	12.00 (9.00–20.00)	0.586			
Hospital costs (thousand CNY)													
Mean±SD	7.62±0.20	7.62±0.97	7.81±0.42	7.91±0.35	0.928	9.15±7.44	8.98±4.52	10.13±9.71	9.95±7.87	0.302			
Median (IQR)	6.52 (4.86–8.63)	6.24 (5.19–9.33)	6.43 (5.05–9.02)	6.93 (5.63–9.25)	0.451	7.01 (5.38–10.39)	7.70 (5.44–10.37)	7.41 (5.43–10.76)	7.52 (5.85–11.15)	0.198			
Total medical costs (thousand CNY)													
Mean±SD	8.86±0.24	8.09±1.01	9.09±0.53	8.71±0.40	0.898	10.52±8.77	10.01±5.32	11.78±10.88	11.65±11.19	0.197			
Median (IQR)	7.17 (5.34–10.70)	7.08 (5.24–9.51)	6.88 (5.42–11.12)	7.33 (5.84–10.41)	0.847	7.74 (5.59–12.21)	8.40 (6.30–12.59)	8.47 (5.83–12.65)	8.61 (6.19–12.77)	0.207			

COPD: chronic obstructive pulmonary disease; CHD: coronary heart disease; IQR: interquartile range

Table 3 Cigarettes smoked per day and health care utilization and medical costs in patients hospitalized due to COPD, CHD or diabetes

Health care utilization and medical costs	2013-2014										P
	2013					2014					
	0 n (%)	1-10 n (%)	11-20 n (%)	≥21 n (%)	P	0 n (%)	1-10 n (%)	11-20 n (%)	≥21 n (%)	P	
COPD											
Number of inpatient visits											
1	296 (62.30)	67 (14.10)	92 (19.40)	20 (4.20)	0.004	499 (64.00)	114 (14.60)	139 (17.80)	28 (3.60)	<0.001	
≥2	56 (49.60)	23 (20.40)	21 (18.60)	13 (11.50)		111 (46.30)	44 (18.30)	59 (24.60)	26 (10.80)		
Inpatient days											
Mean±SD	15.55±0.90	17.61±1.59	17.99±2.36	18.79±2.58	0.472	15.82±16.38	20.76±23.37	17.45±16.50	26.48±25.56	<0.001	
Median (IQR)	11.00 (9.00-16.00)	12.50 (9.00-20.50)	13.00 (9.00-17.00)	14.00 (9.00-22.50)	0.211	11.00 (8.00-16.00)	13.00 (9.00-22.50)	14.00 (9.00-21.00)	17.00 (11.75-30.25)	<0.001	
Hospital costs (thousand CNY)											
Mean±SD	9.18±0.69	9.68±0.82	9.72±1.16	10.58±1.36	0.905	9.77±13.18	11.56±12.23	10.83±10.57	17.73±20.06	<0.001	
Median (IQR)	6.24 (4.49-8.74)	6.62 (4.64-12.20)	6.52 (4.53-9.50)	7.54 (4.89-13.10)	0.104	6.27 (4.56-9.30)	7.04 (4.81-12.54)	7.58 (5.22-13.23)	10.94 (5.60-21.75)	<0.001	
Total medical costs (thousand CNY)											
Mean±SD	9.29±0.71	9.73±0.82	9.89±1.17	10.63±1.37	0.912	9.92±13.48	11.79±12.33	11.05±10.82	17.82±20.30	<0.001	
Median (IQR)	6.24 (4.50-8.74)	6.62 (4.64-12.20)	6.67 (4.58-9.78)	7.54 (5.12-13.10)	0.091	6.27 (4.56-9.31)	7.14 (4.89-12.66)	7.66 (5.22-13.50)	10.94 (5.63-21.75)	<0.001	
CHD											
Number of inpatient visits											
1	957 (69.80)	200 (14.60)	171 (12.50)	43 (3.10)	0.005	1735 (71.40)	286 (11.80)	331 (13.60)	77 (3.20)	0.001	
≥2	155 (66.00)	35 (14.90)	37 (15.70)	8 (3.40)		472 (66.00)	116 (16.20)	92 (12.90)	35 (4.90)		
Inpatient days											
Mean±SD	10.86±6.65	12.11±7.54	11.47±7.42	12.45±6.64	0.033	10.79±7.38	11.61±8.09	10.56±6.91	12.64±7.42	0.011	
Median (IQR)	9.00 (7.00-14.00)	10.00 (7.00-15.00)	9.00 (7.00-14.00)	11.00 (8.00-15.00)	0.018	9.00 (7.00-13.00)	9.00 (7.00-14.00)	9.00 (6.00-13.00)	11.00 (7.25-16.00)	0.001	
Hospital costs (thousand CNY)											
Mean±SD	13.68±18.37	19.19±23.46	17.84±23.00	15.36±23.96	<0.001	16.10±21.01	23.74±28.47	21.12±27.73	21.13±28.02	<0.001	
Median (IQR)	7.87 (5.26-11.71)	9.14 (5.70-18.33)	8.62 (5.58-15.21)	8.31 (5.58-11.95)	0.003	8.65 (5.72-13.91)	10.92 (6.26-28.65)	9.16 (5.81-20.77)	10.18 (6.16-20.41)	0.003	
Total medical costs (thousand CNY)											
Mean±SD	14.68±19.03	20.63±24.10	19.20±23.75	16.71±24.37	<0.001	18.00±22.28	26.61±29.47	23.86±29.28	23.94±29.23	<0.001	
Median (IQR)	8.64 (5.55-13.15)	10.23 (6.43-20.85)	9.80 (6.10-16.27)	10.13 (6.24-15.00)	<0.001	9.56 (6.02-18.26)	14.15 (7.39-31.42)	11.26 (6.31-25.79)	11.70 (6.55-28.12)	<0.001	
Diabetes											
Number of inpatient visits											
1	504 (70.20)	81 (11.30)	99 (13.80)	34 (4.70)	0.397	763 (72.20)	121 (11.40)	132 (12.50)	41 (3.90)	0.661	
≥2	90 (73.20)	16 (13.00)	15 (12.20)	2 (1.60)		243 (69.80)	38 (10.90)	52 (14.90)	15 (4.30)		

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Health care utilization and medical costs	2013				2013-2014				P
	Cigarettes smoked per day				Cigarettes smoked per day				
	0 n (%)	1-10 n (%)	11-20 n (%)	≥21 n (%)	0 n (%)	1-10 n (%)	11-20 n (%)	≥21 n (%)	
Inpatient days									
Mean±SD	12.99±0.32	13.20±0.72	14.34±0.77	11.61±0.80	15.45±11.40	14.60±9.65	18.86±21.62	16.14±11.83	0.007
Median (IQR)	11.00 (8.00-15.00)	12.00 (9.00-15.00)	12.00 (10.00-15.25)	12.00 (7.25-14.00)	12.00 (9.00-18.00)	11.00 (8.00-17.00)	13.00 (10.00-20.75)	13.00 (9.00-17.00)	0.142
Hospital costs (thousand RMB)									
Mean±SD	7.66±0.20	7.93±0.41	7.93±0.39	6.82±0.52	9.17±7.45	9.14±7.50	10.84±9.95	9.06±5.32	0.058
Median (IQR)	6.52 (4.88-8.63)	6.89 (5.53-9.30)	6.68 (5.14-9.26)	6.28 (4.72-7.76)	7.01 (5.38-10.41)	7.19 (5.45-10.70)	7.82 (5.84-11.86)	7.35 (5.69-10.42)	0.108
Total medical costs (thousand RMB)									
Mean±SD	8.90±0.24	8.84±0.50	8.82±0.46	8.22±0.71	10.55±8.78	10.28±8.26	12.69±13.08	11.15±7.06	0.031
Median (IQR)	7.17 (5.37-10.70)	7.33 (5.77-10.73)	7.06 (5.62-10.50)	6.50 (4.87-10.09)	7.75 (5.59-12.29)	8.15 (5.97-11.69)	8.49 (6.15-13.49)	9.95 (6.07-13.77)	0.107

COPD: chronic obstructive pulmonary disease; CHD: coronary heart disease; IQR: interquartile range

a significant association between smoking status and health care utilization and medical expenses in males for three patient groups, but no association in female patients hospitalized due to COPD or diabetes. A significant association between smoking status and total medical costs was found in patients with CHD who were ≤70 years old and who had quit smoking, and in participants who were >70 years old and kept smoking.

Appendix 2 shows crude OR and β-coefficients, with their respective 95% CI, for hospitalization data covering 2013 only. Less than 1.1% of the observations in 2013 contained missing data pertaining to smoking-related variables, which were excluded from regression estimates. The number of participants with missing values and percentages is shown in Appendix 3-1.

3 DISCUSSION

To our knowledge, this study provides the first empirical evidence of the impact of tobacco smoking on health care utilization and medical costs for middle-aged and elderly patients with three major chronic NCDs. Overall, our findings show that tobacco smoking is associated with more inpatient visits, more days spent as an inpatient, greater hospital costs, and higher total medical costs among people hospitalized with COPD or CHD. However, we rarely observed such associations among people hospitalized with diabetes. We also found that relationships between smoking habits and health care utilization and medical costs were stronger when analyses covered two years of medical record data rather than one year of data.

Differences in the impact of tobacco smoking on health care utilization and medical costs for participants with these three diseases appear to be related to the differing effects of tobacco smoking on the occurrence and development of each of these diseases. Tobacco smoking leads directly to abnormal lung inflammation and decreased lung function, which are important contributors to the pathogenesis of COPD^[19]. Increased blood pressure, heart rate, and coronary vasoconstriction induced by smoking are generally accepted as mechanisms that contribute to the development of CHD in people who smoke^[20]. However, studies on the relationship between smoking and diabetes have produced inconsistent results^[21-25]. Some studies have demonstrated that smoking accelerates the development of diabetes; however, other studies have shown that smoking increases energy expenditure, decreases weight, and thus delays the progress of diabetes. It is possible that other risk factors, such as unhealthy dietary patterns and a lack of exercise, are more important contributors to the development of diabetes than smoking.

As noted in the introduction, previous studies

Table 4 The association of pack-years of smoking with 2013–2014 health care utilization and medical costs in linear regression analyses

Health care utilization and medical costs	Pack-years of smoking		
	0 (ref)	≤20, OR/β (95% CI)	>20, OR/β (95% CI)
COPD			
Number of inpatient visits			
Model 1	1.000	1.537 (0.974, 2.426)	2.230 (1.620, 3.070)***
Model 2	1.000	1.327 (0.821, 2.147)	1.947 (1.363, 2.781)***
Number of hospitalization days ¹			
Model 1	0.000	0.045 (−0.017, 0.107)	0.077 (0.032, 0.121)***
Model 2	0.000	0.025 (−0.042, 0.091)	0.042 (−0.014, 0.097)
Inpatient costs ¹			
Model 1	0.000	0.045 (−0.018, 0.107)	0.100 (0.055, 0.145)***
Model 2	0.000	−0.008 (−0.073, 0.058)	0.023 (−0.032, 0.078)
Total medical costs ¹			
Model 1	0.000	0.050 (−0.013, 0.113)	0.101 (0.056, 0.147)***
Model 2	0.000	−0.002 (−0.068, 0.065)	0.024 (−0.031, 0.079)
CHD			
Number of inpatient visits			
Model 1	1.000	1.420 (1.091, 1.848)**	1.198 (0.971, 1.480)
Model 2	1.000	1.334 (1.001, 1.777)*	1.139 (0.893, 1.454)
Number of hospitalization days ¹			
Model 1	0.000	0.034 (0.005, 0.064)*	0.008 (−0.015, 0.031)
Model 2	0.000	0.039 (0.006, 0.072)*	0.016 (−0.013, 0.045)
Inpatient costs ¹			
Model 1	0.000	0.107 (0.061, 0.153)***	0.090 (0.054, 0.126)***
Model 2	0.000	0.084 (0.034, 0.135)**	0.053 (0.008, 0.097)*
Total medical costs ¹			
Model 1	0.000	0.131 (0.083, 0.178)***	0.108 (0.072, 0.145)***
Model 2	0.000	0.102 (0.050, 0.153)***	0.066 (0.020, 0.111)**
Diabetes			
Number of inpatient visits			
Model 1	1.000	1.018 (0.674, 1.538)	1.132 (0.828, 1.548)
Model 2	1.000	1.111 (0.712, 1.732)	1.183 (0.831, 1.683)
Number of hospitalization days ¹			
Model 1	0.000	−0.008 (−0.055, 0.040)	0.036 (−0.001, 0.073)
Model 2	0.000	0.009 (−0.045, 0.063)	0.053 (0.006, 0.100)*
Inpatient costs ¹			
Model 1	0.000	0.004 (−0.042, 0.049)	0.046 (0.011, 0.082)*
Model 2	0.000	0.006 (−0.046, 0.058)	0.046 (0.001, 0.091)*
Total medical costs ¹			
Model 1	0.000	−0.004 (−0.053, 0.046)	0.053 (0.014, 0.092)**
Model 2	0.000	−0.002 (−0.058, 0.055)	0.055 (0.006, 0.104)*

COPD: chronic obstructive pulmonary disease; CHD: coronary heart disease; ref: reference; OR: odds ratio; β: beta coefficient. Model 1: smoking status, years of smoking and cigarettes smoked per day; Model 2: adjusted for gender, age, education, marital status, drinking, exercise and comorbidity. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. ¹: Inpatient days, hospital costs and total medical costs were log-transformed in the analysis. Linear regressions were performed using log-transformed inpatient days, hospital costs and total medical costs as dependent variables.

examining the relationship between smoking and the economic burden of chronic NCDs have mainly used overall estimates of the prevalence of smoking behaviors and costs at the national or regional level^[8–10]. However, if studies aim to assess the impact of smoking behavior at the individual level, then they must assess the economic burden of specific chronic NCDs at the individual level and link these costs to specific individual behaviors. A number of studies have reported on rates of health care utilization and medical costs associated with

specific types of chronic NCDs; however, most such studies suffer from methodological limitations, such as using self-reported diagnoses and outcomes^[26, 27]. The present study extends and deepens the approach of previous studies by using hospital-confirmed cases and accurate data on health care utilization and medical costs. Our results suggest that tobacco cessation would decrease health care utilization and medical costs more effectively for people with COPD and CHD than for people with diabetes.

This study also demonstrated that health care utilization and medical costs among former smokers were higher than for current smokers. One possible explanation for this finding may relate to the circumstances of the participants in our study, who were retired employees; some of them may have quit smoking due to increased age and the onset of disease. Similarly, another possible explanation may be related to the “sick-quitter bias” and the “healthy smoker effect” documented in previous studies, whereby the main reason for quitting smoking is illness; thus, current smokers have better health than former smokers^[28–30]. Although we could not verify the impact of smoking cessation on health care utilization and medical costs in this study, we found that participants who smoked for a longer duration of time and consumed more cigarettes per day had higher health care utilization and medical costs than people with shorter or less intense smoking histories. Prior studies have found that a greater number of years since quitting is associated with reduced risk of death, health care utilization, and costs from smoking-related diseases^[29, 31–33]. Therefore, our findings suggest that earlier smoking cessation and consuming fewer cigarettes when smoking would contribute to better health and fewer health expenses, consistent with previous results^[19, 34, 35]. We did not observe a clear dose-response relationship between cigarettes consumed per day and health care utilization and medical costs, but such a dose-response relationship could be difficult to observe if participants have different degrees of smoke inhalation and thereby differences in the extent of exposure to noxious substances, when smoking.

The present study has several strengths. First, it provides new evidence that smoking contributes to greater health care utilization and higher medical costs for individual patients with specific chronic NCD. Second, we assessed disease diagnosis and health care utilization and medical costs based on electronic medical records, which would greatly reduce the risk of bias associated with other methods of collection, such as self-report, used in previous investigations^[26, 27]. Third, participants in this study were retired DMC employees with full medical insurance coverage, which would reduce selection bias caused by differential access to financial and health services. However, this may also mean that these findings could have less external validity for populations with inequitable access to healthcare. Fourth, owing to the long-term nature of chronic NCDs, we assessed health care utilization and medical costs over a two-year period, which provided evidence of stronger associations with smoking behavior than assessments based on one year of data only.

There are a few limitations of this study that must be noted. First, the study is focused on patients with chronic NCDs. There are hundreds of millions

of people in China who are suffering from chronic NCDs, and China has the largest number of smokers in the world. Therefore, although prevention is the key to reducing rates of chronic NCDs, it is equally important to study the effects of behavioral risk factors on the medical burden of patients with existing chronic NCDs, and there are few studies in this area. Second, exercise, alcohol intake and dietary composition are also important risk factors for the development of chronic NCDs. However, this study only considered exercise and alcohol intake as covariates, and did not include dietary factors due to the complexity of accurately assessing dietary intake. Third, we did not take into account the impact of passive smoking.

In summary, this study reveals that the impact of smoking tobacco on health care utilization and medical costs varies among patients with COPD, CHD, and diabetes. In particular, tobacco control might be more effective at reducing the medical burden and costs of treatment associated with COPD and CHD than diabetes. This study provides in-depth evidence for placing tobacco control as a priority in strategies for reducing the impact of chronic NCDs.

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Conflict of Interest Statement

The authors have no conflict of interest.

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