Submitted: 29 June, 2023 Accepted: 31 August, 2023 Published: 30 March, 2024 DOI:10.22514/jomh.2024.037

ORIGINAL RESEARCH

JOMH Journal of Men's Health

Influence of major non-communicable chronic disease diagnoses on Chinese adult males' smoking behavior: is there a moderating role for the home environment?

Yue Hu[1], Qihui Chen[2,*], Haochi Zheng[3], Yanjun Liang[4]

[1]College of Economics and Management, China Agricultural University, 100083 Beijing, China
[2]Beijing Food Safety Policy & Strategy Base, China Agricultural University, 100083 Beijing, China
[3]Department of Earth System Science & Policy, University of North Dakota, Grand Forks, ND 58202, USA
[4]Jiangsu Minsheng Vocational Training School, 21000 Nanjing, Jiangsu, China

***Correspondence**
chen1006@umn.edu
(Qihui Chen)

Abstract

Smoking is widely acknowledged as a major contributor to the high prevalence of chronic diseases. It is, therefore, important to explore measures that could help reduce cigarette consumption, especially from a policy perspective. This study investigates the effects of the diagnoses of four major non-communicable chronic diseases (NCDs), namely, diabetes, hypertension, myocardial infarction and stroke, on Chinese adult males' daily cigarette consumption. It also examines how the home environment, including family members' NCD diagnoses and smoking behavior, may moderate these effects and explores whether the impacts of one's own NCD diagnosis and home environment vary with one's smoking intensity. Using longitudinal data from 5388 Chinese males aged 45–85 residing in 9 provinces, our zero-inflated Negative Binomial regression models yielded four findings. First, one's own NCD diagnosis is associated with a 27.3% increase in the odds of smoking cessation compared to continuing smoking among Chinese adult males, but for those who continue to smoke, their own NCD diagnosis does not affect the number of daily cigarettes smoked. Second, the presence of family members who smoke increases the likelihood of Chinese adult males continuing to smoke and their smoking intensity, while family members' NCD diagnosis has a minimal impact on one's cigarette consumption. Third, neither family members' smoking behavior nor their NCD diagnoses moderate the relationship between an individual's own NCD diagnosis and their smoking habits. Finally, the impacts of one's own NCD diagnosis and the home environment vary significantly between heavy and non-heavy smokers. While one's NCD diagnosis significantly reduces cigarette consumption among non-heavy smokers, it has the opposite effect among heavy smokers. The home environment shows a marginally significant impact only among non-heavy smokers.

Keywords

Chronic diseases diagnosis; Smoking; Home environment; Adult male; Zero-inflated negative binomial model; China

1. Introduction

In recent decades, China has experienced rapid changes in dietary patterns and lifestyle, leading to a significant increase in the number of individuals diagnosed with non-communicable chronic diseases (NCDs). The increase in NCD prevalence has placed a heavy health burden on the Chinese population, with NCD-related deaths accounting for a staggering 88.5% of all deaths in the country as of 2019 [1]. Among all NCDs, cardiovascular diseases, in particular strokes and myocardial infarction, are currently the leading cause of death in China, responsible for more than 43% of all deaths in 2018 [2]. Additionally, hypertension and diabetes are the two most prevalent NCDs in China, with official statistics indicating a prevalence of 27.5% for hypertension and 11.9% for diabetes among Chinese adults in 2020 [3].

Numerous studies have established smoking as a significant risk factor contributing to the high prevalence of NCDs [4–10]. In China, where approximately one-third of the world's smokers reside, the impact of smoking is particularly severe, with tobacco-related illnesses claiming the lives of approximately one million individuals annually over the last decade [11]. This alarming statistic underscores the importance of smoking cessation in preventing NCDs and avoiding premature death, especially within the Chinese context.

However, the addictive nature of tobacco makes quitting smoking a challenging task unless strong incentives are provided. This study focuses on the impact of diagnoses of four major NCDs (namely, diabetes, hypertension, myocardial infarction and stroke) as a medically provided incentive in promoting smoking cessation among smokers and explores how the home environment of smokers, including factors such

as household members' NCD diagnoses and smoking habits, may influence the effect of NCD diagnosis. Given the high prevalence of hypertension and diabetes [3] and the role of myocardial infarction and strokes as the leading causes of death in China [2], the four NCDs examined in our study provide a representative snapshot of the overall NCD incidence in China. When smokers receive a diagnosis of a major NCD from medical professionals, they are more perceptive to information regarding the harmful effects of tobacco consumption on their health, which may increase their awareness of the risks associated with smoking, potentially motivating them to quit smoking (or at least reduce their smoking intensity) [12–16]. However, it is important to realize that a newly-diagnosed NCD may also cause stress and anxiety, leading smokers to cope by increasing their smoking intensity [17]. Given these opposing possibilities, the overall impact of an NCD diagnosis on one's smoking behavior remains theoretically ambiguous.

The home environment introduces more complexity to the relationship between NCD diagnosis and smoking behavior, as it can influence health-related actions through various factors such as information exchange, health awareness, and habit formation, to name a few [18]. Besides one's own health shocks, the NCD diagnoses of family members can also trigger changes in one's smoking behavior. For instance, if smokers learn that a family member (*e.g.*, a spouse or parent) has been diagnosed with a severe NCD, they may decide to quit smoking to safeguard their family member's health by reducing second-hand smoke exposure at home. Moreover, a family member's NCD diagnosis can provide health-related information that prompts smokers to reassess their health expectations or the perceived risks and benefits of smoking [13, 19]. On the other hand, similar to an individual's own NCD diagnosis, knowledge of family members' newly-diagnosed NCDs can be stressful and lead to unhealthy behavioral changes, which may result in smoking relapse among those who have already quit smoking or smoking initiation among those who had never smoked before. Furthermore, if some family members are smokers themselves, there could be a peer effect within the household, potentially reducing an individual's perceived risk of smoking [12, 19], thereby weakening the impact of NCD diagnosis on their smoking behavior.

This study explores three main aspects of the NCD diagnosis-smoking nexus. Firstly, we examine how an individual's own NCD diagnosis influences his/her smoking behavior, including both smoking incidence and smoking intensity. Secondly, we investigate how the home environment, encompassing family members' NCD diagnoses and smoking habits, moderates the effect of one's own NCD diagnosis on smoking behavior. Lastly, we analyze how the impacts of an individual's NCD diagnosis and home environment may differ between heavy and non-heavy smokers. To conduct this investigation, we utilize a longitudinal dataset from the China Health and Nutrition Survey (CHNS) that covers nine provinces and 15 years (from 2000 to 2015). The main focus is placed on male respondents aged between 45 and 85, as this group exhibits the most prevalent cases of NCDs and smoking. Given that the key outcome variable, *i.e.*, the daily number of cigarettes smoked, follows a "count" format with many observations having a value of zero, we employ a "zero-inflated" Negative Binomial regression framework as the primary modeling method to better depict and understand the relationship between Chinese adult males' NCD diagnosis and smoking behavior.

Our analysis provides evidence that, holding other factors fixed, a Chinese adult male's own NCD diagnosis is significantly linked to the odds of quitting smoking compared to continuing the habit. However, if a Chinese adult male continues to smoke, an NCD diagnosis does not significantly affect the number of cigarettes he smokes daily. Meanwhile, having a family member who smokes significantly increases the likelihood of a Chinese adult male continuing to smoke and the number of cigarettes he smokes daily. In contrast, family members' NCD diagnoses do not appear to impact his smoking behavior. Finally, neither family members' smoking behavior nor their NCD diagnoses seem to moderate the relationship between an individual's own NCD diagnosis and smoking behavior.

2. Materials and methods

2.1 Data

The data (second-hand, publicly available) used for this study were retrieved from the CHNS, a large-scale longitudinal household survey conducted in more than ten provinces in China that exhibit significant variations in geographical conditions, social and cultural characteristics and levels of economic development. The CHNS was launched in 1989, as the product of an international collaborative effort between the University of North Carolina at Chapel Hill and the Chinese Center for Disease Control and Prevention.

The CHNS originally involved nine provinces, including Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning and Shandong. The first-round survey initiated in 1989 employed a stratified, random sampling strategy to select sample communities and households. Counties in each of the nine provinces were stratified by income levels (low, middle and high), and four counties were randomly selected from each project province. Whenever possible, a lower-income city and the provincial capital city were also chosen. In addition, residential districts within selected cities and villages within selected rural counties were randomly chosen to be the survey sites. Between 1991 and 2015, the CHNS conducted nine rounds of follow-up surveys. In 2011, three municipalities (Beijing, Chongqing and Shanghai) joined the project; in 2015, three more provinces (Shaanxi, Yunnan and Zhejiang) became part of the project.

Overall, the CHNS involved approximately 7200 households and 30,000 individuals in its comprehensive data collection efforts. The surveys gathered rich data on their family configuration, demographic and socio-economic characteristics, food and nutrient intake, health status, and the conditions of basic infrastructure and healthcare facilities in their communities. Of particular relevance to the present study, the CHNS began collecting detailed data on sample respondents' cigarette consumption starting from the second-round survey in 1991. Information on hypertension diagnosis was added in the third round in 1993, and data on the diagnoses

of other NCDs were collected in the fourth round in 1997. More detailed information about the CHNS can be found at https://www.cpc.unc.edu/projects/china.

2.2 Sample restrictions

To ensure the suitability of the analytical sample for our intended analysis, several sample restrictions were applied. Firstly, to control for one's "smoking history", we excluded all observations collected before the fifth round (2000) to ensure that each sample observation had information on daily cigarette consumption lagged for one period. Secondly, we focused only on the nine original CHNS provinces, excluding observations from municipalities and provinces that joined the CHNS from 2011 onwards, to maximize the available information in the time dimension for each sample respondent. Thirdly, we excluded female respondents from the sample due to the low prevalence of smoking among them, as only 6.2% had ever smoked. Lastly, we focused on males aged between 45 and 85 years old. The lower bound (age 45) was chosen because very few observations under 45 (—the cut-off between "youth" and "middle age" commonly used in China) in the data had been diagnosed with any NCD. The upper bound (age 85) was chosen because individuals over 85 smoked significantly less than their younger counterparts [20]. To address missing information, especially on NCD diagnosis status, we imputed the data using available information from other rounds as much as possible. For instance, if a male respondent reported a diabetes diagnosis in 2000 but did not provide information on diabetes diagnosis in 2004, we inferred that the missing diabetes diagnosis status in 2004 should be filled in as "already diagnosed with diabetes". After applying these sample restrictions, we obtained a pooled analytical sample comprising 16,188 individual-year observations for 5388 adult males residing in 228 communities across the nine original CHNS provinces. Each adult male appeared in at least two rounds (out of six) of the surveys conducted between 2000 and 2015. Fig. 1 presents a flowchart documenting the sample construction steps mentioned above.

2.3 Variables

2.3.1 Outcome variables

The outcome variable of interest in this study is the number of cigarettes a Chinese adult male smoked daily (*N_smoke*). It should be noted that the values of this variable are "counts". And because many sample respondents never smoked, this variable contains a cluster of "zeros" as its values in the sample. These characteristics naturally suggest the use of a zero-inflated Negative Binomial framework to examine Chinese adult males' smoking behavior and its determinants. Within this framework, whether an observation falls into the "zero-inflated" region (*i.e.*, "not smoking") corresponds to the negation of an indicator variable that represents whether a sample male was smoking during the survey period (*Self_smoke*).

2.3.2 Explanatory variables of primary interest

Two sets of explanatory variables were of primary interest in this study. The first set pertains to the NCD diagnoses for sampled adult males themselves, not including their family members' diagnoses. To capture the overall effect of own NCD diagnoses on smoking behavior, we created a binary variable called "*Self_NCD*", which represents whether a sample male had ever been diagnosed with an NCD at the time of the survey. Due to data limitations, we focus on four specific NCDs: diabetes, hypertension, myocardial infarction and stroke. The binary variable "*Self_NCD*" takes the value of one if a sample male had been diagnosed with any of these four NCDs and zero otherwise. Note that these four NCDs are all cardiovascular diseases. It would be valuable to include diagnoses of other NCDs, such as pulmonary and other chronic respiratory diseases, but no such information was collected by the CHNS (—although information on cancer diagnosis is available, it only started from 2011 and is missing in all previous rounds). On a more positive note, given the high prevalence of hypertension and diabetes [3] and the role of myocardial infarction and strokes as the leading causes of death in China [2], the four NCDs examined in our study provide a representative snapshot of the overall NCD incidence in China.

The second set of explanatory variables in our study focuses on the role of the home environment, specifically examining the influence of family members. Due to data availability, we concentrate on two aspects: family members' NCD diagnoses and their smoking behavior. To study the impact of family members' status on an individual's smoking behavior, we include two binary indicators in the analysis. The first indicator, "*Fam_smoke*", denotes whether a family member (*i.e.*, a parent or a spouse) smokes. The second indicator, "*Fam_NCD*", indicates whether a family member (a parent or a spouse) has received a diagnosis of one of the four NCDs discussed above. Interaction terms between one's own NCD diagnosis and family members' variables are also used in the models to examine the potential mediating role of the home environment.

2.3.3 Control variables

In the empirical models developed in the following section, two sets of control variables are considered, with reference to standard theory and previous empirical findings. The first set comprises demographic and socio-economic characteristics of the sample respondents, such as years of education (*Educ_yrs*), a dummy variable for ethnic minorities (Minority, =1 if a sample male belongs to an ethnic minority group), a dummy for rural residents (Rural, =1 if a sample male holds a rural residential permit, *i.e.*, "*Hukou*"), a dummy for "currently working" (Working, =1 if a sample male reported working in the survey period), and annual per capita household income adjusted for inflation over time (*HH_income*), to control for lifestyle differences associated with differences in these factors. Age in years (*Age_yrs*) and age-squared (*Age_sq*) are also included to capture potential life-cycle smoking patterns [21].

The second set of control variables in our models pertains to Chinese adult males' self-perceived overall health status

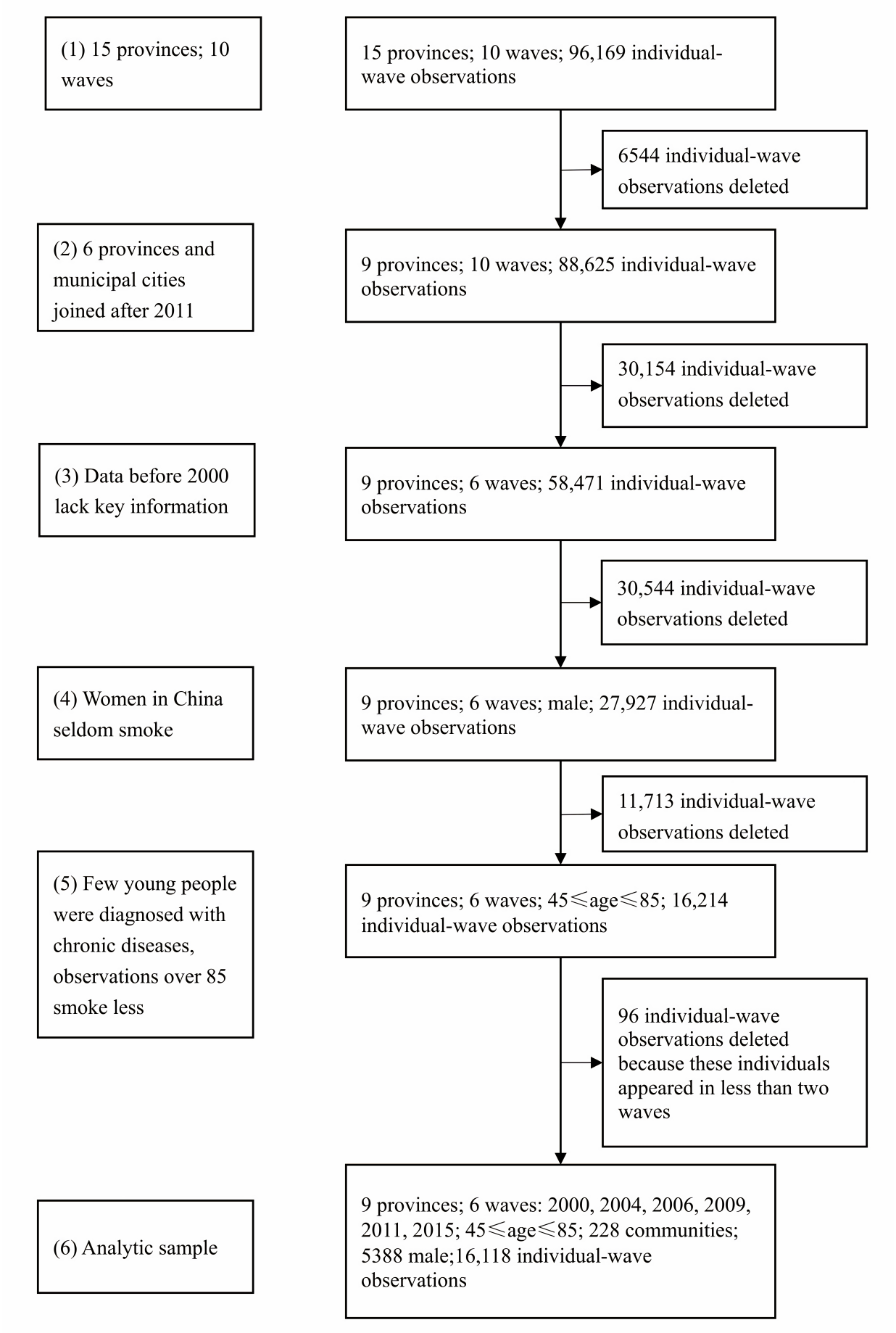

FIGURE 1. Flowchart for sample construction.

and health behavior. A dummy variable (*Self_health*, =1 if a sample male reported feeling "good" or "very good", and =0 if he reported feeling "very poor", "poor" or "fair") is included to assess the impact of subjective health status [22, 23]. To account for the potential effect of health insurance enrollment on health behavior [24], we include an indicator of health insurance enrollment (*Health_insurance*, =1 if a sample male was enrolled in a health insurance program during the survey period and =0 otherwise) as a control variable. Finally, since one's drinking and smoking behaviors tend to be closely related [24–27], we include a dummy for drinkers (Drinking, =1 if a sample male reported a positive amount of alcohol consumption during the survey period and =0 otherwise) in our models. The 1-period lagged outcome measure (*N_smoke_lag1*) is also included to capture the effect of smoking history and account for the addictive nature of smoking.

Summary statistics of the variables used in the analysis are presented in Table 1.

2.4 Statistical model

As a starting point for our empirical analysis, we consider a statistical model that examines the relationship between a Chinese adult male's daily cigarette consumption (*N_smoke*) and its determinants:

$$N\_smoke_{it} = \beta_0 + \beta_1 S_{it} + \beta_2 F_{it} + \beta_3 (S_{it} \times F_{it}) + \beta_4 Z_{it} + \epsilon_{it} \quad (1)$$

Where the variables may vary across individuals (denoted with subscript *i*) and time periods (denoted with subscript *t*). S_{it}, the main explanatory variable of interest, represents whether an adult male *i* had been diagnosed with an NCD (*i.e.*, one of diabetes, hypertension, myocardial infarction and stroke) by time *t*. F_{it} is a set of variables measuring an adult male *i*'s home environment (whether his parent or spouse smokes at *t* and whether his parent or spouse had been diagnosed with an NCD by *t*). Z_{it} represents the set of control variables discussed in Section 2.3.3. ϵ_{it} is the disturbance term. Before estimating equation (1), a correlation analysis is performed to check if there are multicollinearity issues among the explanatory variables.

It may be tempting to estimate equation (1) using linear regression, but linear models are unsuitable for this study due to the count-data nature of the outcome variable, *N_smoke* (subscripts omitted for ease of exposition), the number of cigarettes smoked per day. As this variable is in the form of counts, a Poisson regression framework could be considered to estimate equation (1). However, a "built-in" property of Poisson distributions, the so-called "equal-dispersion" property, *i.e.*, $Var(N\_smoke\,|X) = E(N\_smoke\,|X)$, for $X = [S, F, Z]$, usually fails to hold in practice [28–31]. To address this concern, we adopt a Negative Binomial regression framework, which accounts for the "over-dispersion" issue [28–31]. Further, taking into account the fact that many sample males did not smoke, which generates a cluster of zeros in *N_smoke*, we adopt a zero-inflated Negative Binomial regression approach to estimating equation (1). More specifically, the "zero-inflation" part is estimated by a Logit model predicting "certain zeros" (*i.e.*, "definitely not smoking"), jointly with a Negative Binomial model predicting the positive number of cigarettes consumed daily, conditional on one being a smoker. More details on the zero-inflated Negative Binomial model are provided in **Supplementary material A**.

Another estimation issue is that, as noted in section 2.3, our analytical sample involves repeated observations over time for a subset of sample males. To address this issue, we adopt the approach suggested by Cameron and Trivedi (2005) [28], originated in Liang and Zeger (1986) [32], and adjust the standard errors of the estimated parameters for intra-community clustering.

It should be noted that different (sub)samples are used in the analysis below for different purposes. For example, the full sample (including both smokers and non-smokers) is used to ensure that our estimation results can be generalized to a larger population, improving the external validity of our study. Admittedly, analysis based on this sample faces a potential reduction in its internal validity, as in that case, some cross-sectional variation must be utilized to identify the parameters in the model. By contrast, excluding never-smokers from the analytical sample improves the transparency of the identification mechanism, which may increase the internal validity of the analysis. But focusing on the smoker subsample could potentially reduce the external validity of our study, as that sample may not be representative of the Chinese adult male population. In any case, comparing results obtained using different subsamples can help inform the driving force of our empirical findings and assess the robustness of these findings.

All procedures and estimations described above were performed using the statistical package Stata (Version SE 17.0, StataCorp LLC, College Station, TX, United States).

3. Results

3.1 Summary statistics

Table 1 presents summary statistics of all variables used in our analysis. Column (1) displays the statistics for the full sample. The average age of all sampled males (across all year-individual observations) was 59 years. Approximately 2/3 of the sample observations resided in rural areas, and 12% belonged to ethnic minority groups. On average, the sampled males had about 8 years of formal schooling and an annual per capita household income of approximately 13,700 yuan in 2015 values (equivalent to about 2200 U.S. Dollars). Regarding health insurance coverage, 78% of the observations reported being enrolled in a health insurance program during the survey period as a result of the rapid expansion of China's health insurance industry since the early 2000s [24, 33–35]. Moreover, 58% of the sampled males reported being actively employed. And 57% reported consuming alcohol during the survey period. Additionally, 52% of the sampled males rated their overall health as "good" or "very good".

TABLE 1. Summary statistics with all individual-wave observations (2000–2015).

		(1)		(2)		(3)		(4)	(5)		(6)		(7)
		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Variable names	Definitions	Full sample		Non-smokers		Smokers		*p*-value (non-smokers *vs.* smokers)	Before NCD diagnosis		After NCD diagnosis		*p*-value (before *vs.* after diagnosis)
Self_smoke	Whether an individual currently smokes (dummy, =1 if yes)	0.53	0.50	0.00	-	1.00	-	-	0.58	0.49	0.47	0.50	<0.001
N_smoke	Number of cigarettes smoked per day (current period)	8.92	10.94	0.00	-	16.91	9.58	<0.001	9.67	10.68	7.64	10.54	<0.001
Self_NCD	Diagnosed with any chronic diseases (dummy, =1 if yes)	0.28	0.45	0.34	0.48	0.23	0.42	<0.001	0.00	-	1.00	-	-
Fam_NCD	Family members diagnosed with chronic diseases (dummy, =1 if yes)	0.26	0.44	0.29	0.46	0.24	0.43	<0.001	0.22	0.42	0.38	0.49	<0.001
Fam_smoke	Other smokers in the household (dummy, =1 if yes)	0.19	0.39	0.16	0.36	0.21	0.41	<0.001	0.21	0.41	0.20	0.40	0.322
Age_yrs	Age (years)	58.95	9.76	60.80	10.24	57.29	9.00	<0.001	57.92	8.62	64.09	8.54	<0.001
Age_sq	$Age^2/100$	35.70	12.07	38.02	12.86	33.63	10.91	<0.001	34.29	10.41	41.81	11.18	<0.001
Minority	Ethnic minority (dummy, =1 if yes)	0.12	0.33	0.10	0.30	0.14	0.35	<0.001	0.12	0.32	0.12	0.32	0.877
Rural	Rural (dummy, =1 if yes)	0.67	0.47	0.63	0.48	0.72	0.45	<0.001	0.71	0.46	0.68	0.47	0.108
Educ_yrs	Years of education	7.70	4.00	7.88	4.17	7.54	3.83	<0.001	7.15	3.91	7.38	3.98	0.057
HH_income	Logarithm values of per capita household income (Yuan, at 2015 prices)	8.98	1.16	9.06	1.15	8.91	1.16	<0.001	8.70	1.14	9.17	1.17	<0.001
Working	Currently working (dummy, =1 if yes)	0.58	0.49	0.50	0.50	0.65	0.48	<0.001	0.65	0.48	0.40	0.49	<0.001
Health_insurance	Has health insurance coverage (dummy, =1 if yes)	0.78	0.41	0.81	0.39	0.76	0.43	<0.001	0.66	0.47	0.92	0.26	<0.001
Drinking	Drinking (dummy, =1 if currently drinking)	0.57	0.50	0.45	0.50	0.69	0.47	<0.001	0.63	0.48	0.51	0.50	<0.001
Self_health	Self-assessed health status (current) (dummy, =1 if "good" or "very good")	0.52	0.50	0.50	0.50	0.54	0.50	<0.001	0.59	0.49	0.42	0.49	<0.001
N_smoke_lag1	Number of cigarettes smoked per day (1-period lagged)	9.54	10.99	2.84	6.95	15.53	10.48	<0.001	10.14	10.63	8.65	10.84	<0.001
N	Number of wave-individual observation	16,188		7651		8537			1888		4659		

Notes: Source: Author's computation using data from the CHNS (2000, 2004, 2006, 2009, 2011, 2015). "Smokers" refer to individuals who reported a positive number of cigarettes smoked per day in the survey period; "heavy smokers" are defined as individuals who smoke more than 20 cigarettes per day [32].
NCD: non-communicable chronic disease; SD: standard deviation.

Concerning sampled males' smoking behavior, column (1) of Table 1 reveals that 53% of the observations reported smoking during the survey period. The average number of cigarettes smoked daily in the full sample was 8.9. Among smokers (column 3), approximately 29% were categorized as heavy smokers, who consumed at least 20 cigarettes per day [36]. Regarding health conditions, the prevalence of NCDs was 28% in the full sample: among smokers, 23% reported having received NCD diagnoses (column 3), while among non-smokers, the prevalence was 34% (column 2). It is interesting to note that the incidence of NCDs is lower among smokers (column 3) than non-smokers (column 2). While this finding may seem counterintuitive, it could be explained by the possibility that NCD diagnoses have induced some sample males to cut back on their cigarette consumption. This explanation is, in fact, confirmed by the comparison of one's "before NCD diagnosis" (column 5) and "after NCD diagnosis" status (column 6) for available observations. Before NCD diagnoses, 58% of the sample males smoked, but this proportion dropped to 47% after diagnoses. Echoing this, sample males consumed 9.67 cigarettes daily before NCD diagnoses (column 5) while consuming 6.74 after NCD diagnoses (column 6). Also, as can be seen from Fig. 2, a Chinese adult male's smoking probability (measured on the right vertical axis) and the number of cigarettes smoked daily (measured on the left vertical axis) both decrease with the number of NCD diagnoses.

The home environment of a sampled male is characterized by two binary indicators: *Fam_smoke*, which equals one if there are other smokers in the household and zero otherwise; *Fam_NCD*, which equals one if one or more family members of a sampled male have been diagnosed with NCDs and zero otherwise. As Table 1 shows, 19% of the sampled males have family members who smoke, and 26% had been diagnosed with NCDs by the survey. To better depict the relationship and pin down the direction of causality, we consider a large number of potential confounding variables in our analysis below. Before carrying out the regression analysis, a correlation analysis was performed to check for multicollinearity issues among the explanatory variables. **Supplementary Table 1** in **Supplementary material B** reports the results: all correlations between explanatory variables are small, revealing no concern about multicollinearity issues in our study.

3.2 Main findings

To rigorously evaluate how NCD diagnoses may impact Chinese adult males' smoking behavior while simultaneously addressing the presence of many non-smokers ($N\_smoke = 0$), we employed zero-inflated Negative Binomial regressions to estimate equation (1). Alternative models, including standard Poisson, zero-inflated Poisson, and standard Negative Binomial models, are also estimated. Yet the results of Vuong's (1989) likelihood ratio test [37] suggest that the zero-inflated Negative Binomial model is the most preferred one (—detailed test results are not reported here but are available upon request).

Table 2 presents zero-inflated Negative Binomial estimates of the effects of one's own NCD diagnoses and the home environment, as well as how the latter may moderate the former's effect. Model (1) has the simplest specification, including only the key explanatory variables introduced in section 2.3.2, *i.e.*, *Self_NCD*, *Fam_smoke*, *Fam_NCD*, the interactions between *Self_NCD* and the other two, as well as province and survey-round fixed effects (dummy variables). Model (2) further includes a set of personal and family-level

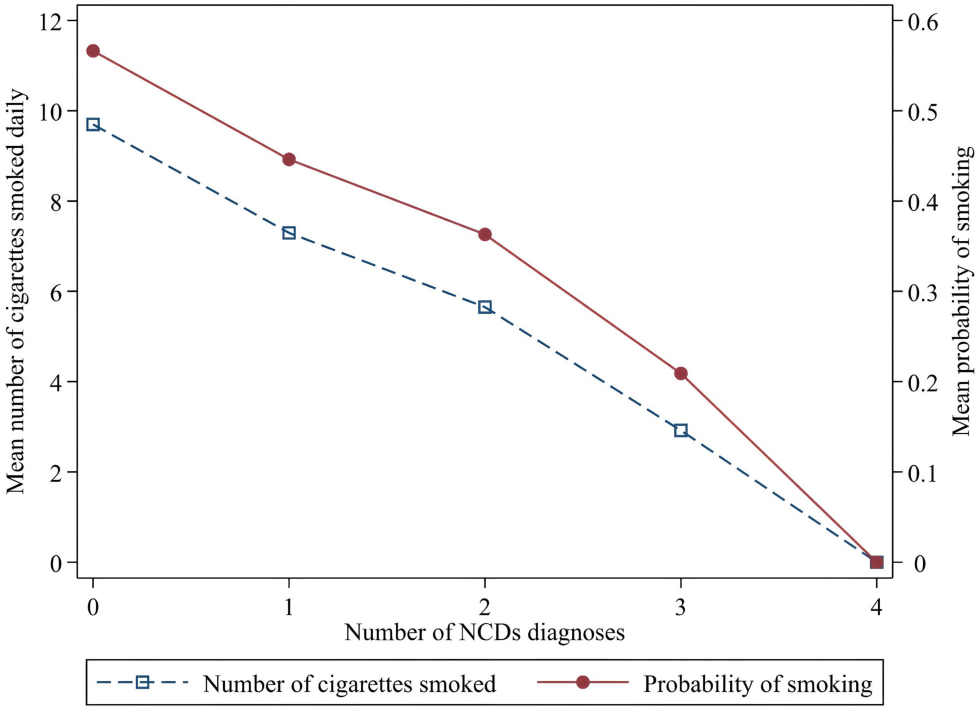

FIGURE 2. Unadjusted associations between the number of major chronic disease diagnosed and smoking probability and average daily cigarette consumption. NCDs: non-communicable chronic diseases.

control variables, as discussed in section 2.3.3, to reduce confounding issues. Model (3) excludes the observations of never-smokers to ensure the identification of model parameters comes entirely from subjects with smoking experiences. Model (4) used only the observations whose first and last appearances form a balanced panel dataset to better control for one's smoking history. Lastly, to avoid sample truncation due to the death of some sample males (possibly due to smoking-related issues), Model (5) excluded sample respondents above the age of 60.

The analysis of the impact of NCD diagnoses received by oneself reported in Table 2 suggests that being diagnosed with an additional NCD is negatively associated with the probability of smoking (δ_{Self_NCD}= −0.591–−0.230). (It should be noted that all models in Table 2 include interaction terms; thus, the interpretation of the main effects of the variables discussed thus far should also consider the interaction terms involving these variables. But as discussed below, the interaction terms are, in general, statistically insignificant). To put the estimates into perspective, consider the estimate from Model (2): δ_{Self_NCD}= −0.241, which means that being diagnosed with an additional NCD reduces the odds of smoking relative to not smoking by 27.3% (=$e^{0.241}$ − 1), a sizable effect. In contrast, one's own NCD diagnosis has virtually no effect on the number of cigarettes smoked daily, conditional on the individual continuing smoking.

Regarding the roles of family members' smoking status and NCD diagnoses, our analysis reveals that the presence of other smokers in the family (*Fam_smoke*) has a positive impact (albeit only marginally significant at the 10% level) on both a Chinese adult male's smoking incidence (δ_{fam_smoke}= 0.023–0.033). The impact of having a smoking member in the family on one's daily number of cigarettes smoked (η_{fam_smoke}= 0.304–0.402) is statistically more significant (at the 1% level). In contrast, the effects of family members' NCD diagnoses (*Fam_NCD*) are less robust. The effect of *Fam_NCD* is significant at the 1% level in Model (1) (δ_{fam_NCD}= −0.228) but became statistically insignificant when a large set of control variables were added to Model (2) (δ_{fam_NCD}= −0.083), suggesting the possibility of confounding that the significant effect of *Fam_NCD* in Model (1) captures the impact of some control variables, such as family income (*HH_income*) and the number of cigarettes smoked per day in the previous period (*N_smoke_lag1*). Models (3)–(5) all include *Fam_NCD* as a predictor, but its effect remains statistically insignificant in these models.

To investigate whether the effect of one's own NCD diagnosis (*Self_NCD*) may be moderated by family members' smoking behavior and health shocks (NCD diagnoses), we follow the standard practice in the literature [38] and include relevant interaction terms—*i.e.*, those between the presence of other smokers in the family and one's own NCD diagnosis (*Fam_smoke* × *Self_NCD*) and between family members' NCD diagnoses and one's own NCD diagnosis (*Fam_NCD* × *Self_NCD*)—in the models. The results indicate that neither family members' smoking behavior nor their NCD diagnoses had a moderating effect on the relationship between one's own NCD diagnosis and smoking behavior, even though family members' smoking behavior has a significant direct impact on one's smoking behavior. As robustness checks, excluding sampled males who never smoked (Model 3), keeping the observations whose first and last appearances form a balanced panel data (Model 4), and dropping males aged above age 60 (Model 5) resulted in estimates of the impacts of one's own NCD diagnosis and those of the home environment that are similar to those in Model (2), the largest model with the largest sample size.

To help visualize the effects of NCD diagnoses, Fig. 3 presents line plots linking the predicted probability of smoking (measured on the right vertical axis) and the predicted number of cigarettes smoked daily (measured on the left vertical axis) with the number of NCD diagnoses (the horizontal axis), based on estimates from a version of Model (2) in Table 2 that uses four dummy variables of the number of NCD diagnoses (instead of a single dummy variable *Self_NCD*) as the key predictors. The figure indicates that as the number of NCD diagnoses increases, both the probability of smoking and the number of cigarettes smoked daily reduce significantly, but the decline in smoking probability (from 0.56 to essentially zero) is much more significant than that in smoking intensity (from 15 to 9 cigarettes per day).

To further see if the effect size of NCD diagnosis varies across different NCDs, we estimated zero-inflated Negative Binomial models separately for the diagnoses of diabetes, hypertension, myocardial infarction and stroke. The results, reported in **Supplementary Table 2**, indicate that the diagnosis of each of these four NCDs on smoking incidence is at least marginally significant (at the 10% level); the effect of myocardial infarction diagnosis has the largest and most statistically significant effect (at the 1% level), followed by the diagnosis of stroke, diabetes and hypertension. Although the effect sizes differ somewhat across NCDs, they all point in the same direction: NCD diagnoses exert deterring effects on smoking. Again, the effects of NCDs on smoking intensity are mostly statistically insignificant if a smoker decides not to quit smoking, and the moderating effect of the home environment is essentially non-existent.

The estimated effects of the control variables also provide valuable insights. Among the basic demographic characteristics examined in Table 2, age exhibits a significant and nonlinear (inverted U-shaped) effect on Chinese adult males' cigarette consumption, indicating that Chinese adult male smokers tend to reduce their cigarette consumption after reaching a certain age. Per capita household income and years of education also have deterring effects on smoking, but they operate through different mechanisms. Education does not influence one's smoking incidence but significantly reduces the daily number of cigarettes consumed among smokers. On the other hand, higher income reduces the likelihood of smoking, but conditional on an individual being a smoker, income has little impact on the number of cigarettes smoked daily. Moreover, factors such as employment status, residing in rural areas, self-assessed health status, and alcohol consumption are all statistically significant contributors to Chinese adult males' cigarette consumption, but their roles differ to some extent. For instance, working increases both the likelihood and the intensity of smoking, while alcohol drinking affects only the likelihood of smoking but not the intensity of smoking.

TABLE 2. Zero-inflated negative binomial estimates of associations between one's chronic diseases, home environment, and smoking behavior among Chinese adult males (aged 45–85).

	Model (1)		Model (2)		Model (3)		Model (4)		Model (5)	
Outcome variables	Number of cigarettes smoked per day		Number of cigarettes smoked per day		Number of cigarettes smoked per day		Number of cigarettes smoked per day		Number of cigarettes smoked per day	
	If smoking	Number smoked	If smoking	Number smoked	If smoking	Number smoked	If smoking	Number smoked	If smoking	Number smoked
Sample	Full sample		Full sample		Never smokers dropped		Balanced panel		age ≥60 dropped	
Self_NCD	−0.591***	−0.048*	−0.241***	0.013	−0.230***	0.013	−0.238**	−0.010	−0.333***	0.030
	(0.069)	(0.026)	(0.077)	(0.020)	(0.083)	(0.020)	(0.105)	(0.027)	(0.120)	(0.023)
Fam_NCD	−0.228***	−0.027	−0.083	0.014	−0.112	0.014	−0.011	−0.005	−0.100	0.018
	(0.058)	(0.023)	(0.062)	(0.016)	(0.073)	(0.016)	(0.085)	(0.024)	(0.102)	(0.020)
Fam_smoke	0.402***	0.023	0.346***	0.029*	0.333***	0.029*	0.304***	0.033	0.324***	0.034*
	(0.061)	(0.019)	(0.065)	(0.016)	(0.081)	(0.016)	(0.084)	(0.023)	(0.105)	(0.017)
Self_NCD × *Fam_NCD*	0.173*	−0.035	0.099	−0.018	0.109	−0.018	0.132	0.021	0.253	−0.022
	(0.098)	(0.043)	(0.112)	(0.033)	(0.119)	(0.033)	(0.154)	(0.046)	(0.193)	(0.050)
Self_NCD × *Fam_smoke*	−0.011	−0.002	−0.108	−0.007	−0.132	−0.007	−0.056	0.017	−0.169	−0.018
	(0.117)	(0.043)	(0.116)	(0.034)	(0.127)	(0.034)	(0.154)	(0.049)	(0.234)	(0.052)
Age_yrs			−0.008	0.025***	−0.168***	0.025***	0.000	0.014	−0.585**	0.026
			(0.026)	(0.008)	(0.035)	(0.008)	(0.035)	(0.012)	(0.228)	(0.041)
Age_sq			0.000	−0.027***	0.125***	−0.027***	−0.010	−0.018*	0.511**	−0.026
			(0.021)	(0.007)	(0.028)	(0.007)	(0.028)	(0.010)	(0.218)	(0.040)
Minority			0.045	−0.013	0.003	−0.013	0.057	−0.025	−0.162	−0.029
			(0.102)	(0.028)	(0.104)	(0.028)	(0.120)	(0.031)	(0.118)	(0.029)
Rural			−0.023	0.058***	−0.270***	0.058***	−0.039	0.054***	−0.284***	0.042**
			(0.065)	(0.019)	(0.080)	(0.019)	(0.075)	(0.021)	(0.106)	(0.019)
Educ_yrs			−0.012	−0.006***	0.002	−0.006***	−0.017	−0.010***	0.007	−0.010***
			(0.008)	(0.002)	(0.010)	(0.002)	(0.010)	(0.003)	(0.013)	(0.002)
HH_income			−0.097***	0.008	−0.032	0.008	−0.081**	0.014	−0.013	0.003
			(0.026)	(0.006)	(0.029)	(0.006)	(0.035)	(0.009)	(0.040)	(0.007)
Working			0.192***	0.052***	0.197***	0.052***	0.196**	0.041**	0.112	0.068***
			(0.062)	(0.016)	(0.070)	(0.016)	(0.077)	(0.020)	(0.098)	(0.019)

TABLE 2. Continued.

	Model (1)		Model (2)		Model (3)		Model (4)		Model (5)	
Outcome variables	Number of cigarettes smoked per day		Number of cigarettes smoked per day		Number of cigarettes smoked per day		Number of cigarettes smoked per day		Number of cigarettes smoked per day	
	If smoking	Number smoked	If smoking	Number smoked	If smoking	Number smoked	If smoking	Number smoked	If smoking	Number smoked
Sample	Full sample		Full sample		Never smokers dropped		Balanced panel		age ≥60 dropped	
Health_insurance			−0.058	0.042**	0.045	0.042**	−0.074	0.059**	0.065	0.024
			(0.067)	(0.018)	(0.082)	(0.018)	(0.090)	(0.025)	(0.102)	(0.019)
Drinking			0.844***	0.010	0.853***	0.010	0.838***	0.017	0.912***	0.025
			(0.057)	(0.013)	(0.064)	(0.013)	(0.072)	(0.017)	(0.084)	(0.016)
Self_health			0.034	0.002	0.053	0.002	0.069	0.007	−0.014	−0.000
			(0.045)	(0.011)	(0.054)	(0.011)	(0.062)	(0.016)	(0.068)	(0.012)
N_smoke_lag1			0.163***	0.025***	0.091***	0.025***	0.166***	0.026***	0.094***	0.025***
			(0.005)	(0.001)	(0.004)	(0.001)	(0.006)	(0.001)	(0.005)	(0.001)
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey-wave dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.207**	2.760***	−0.425	1.645***	5.898***	1.645***	−0.661	1.979***	16.786***	1.685
	(0.094)	(0.032)	(0.792)	(0.249)	(1.076)	(0.249)	(1.115)	(0.353)	(5.952)	(1.073)
N	15,950		15,542		10,785		7362		6472	
Log pseudolikelihood	−40,826.26		−35,124.54		−32,994.43		−16,490.50		−20,761.86	

Notes: Source: Author's computation using data from the CHNS (2000, 2004, 2006, 2009, 2011, 2015).
Estimated coefficients are reported in the table. Standard errors are reported in parentheses, adjusted for clustering at the community level.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

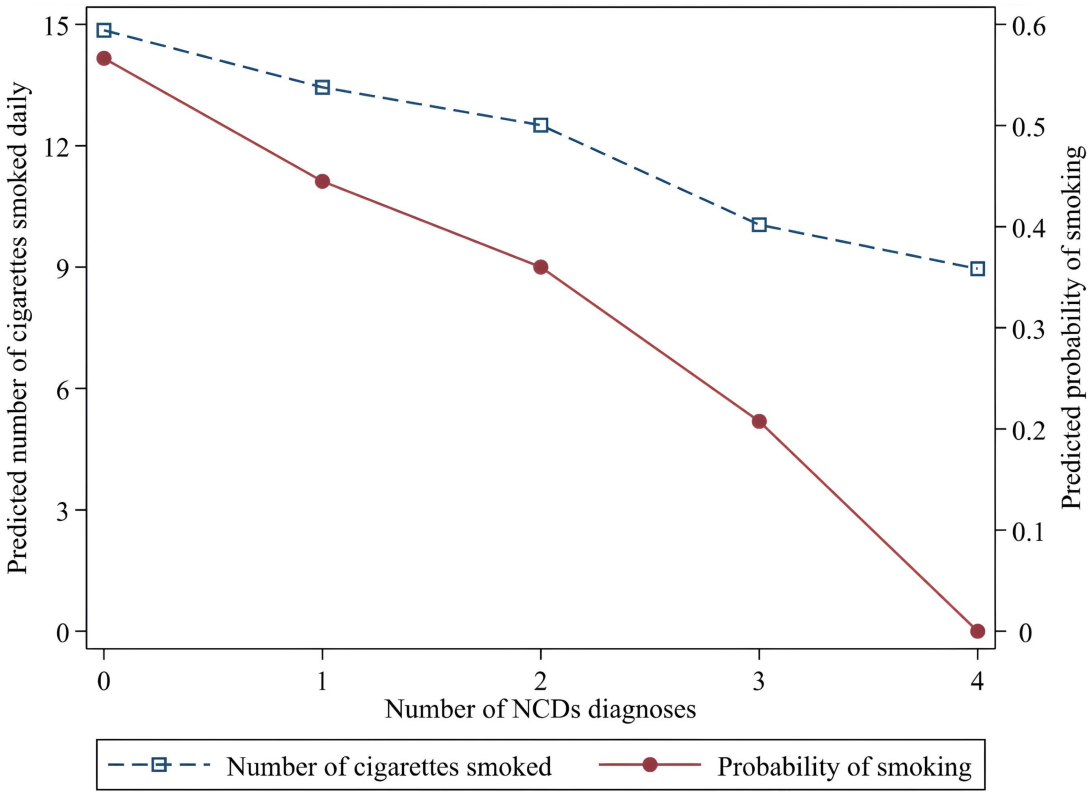

FIGURE 3. Estimated Effects of the number of major chronic disease diagnoses on smoking probability and average daily cigarette consumption. NCDs: non-communicable chronic diseases.

3.3 Role of smoking intensity

Given the addictive nature of smoking, smoking intensity may moderate the effects of one's own NCD diagnosis and home environment on smoking behavior. To examine how smoking intensity might influence the impact of one's own NCD diagnoses and home environment on smoking behavior, we excluded never-smokers in the analysis reported in Table 3. We used Negative Binomial models to separately estimate the effects of one's own NCD diagnoses on smoking for non-heavy smokers (Models 1 and 2) and heavy smokers (Models 3 and 4). Models (1) and (3) were estimated without personal and family-level control variables, similar to Model (1) in Table 2. In contrast, Models (2) and (4) include the full set of controls, similar to Model (2) in Table 2.

Comparing the results between heavy smokers and non-heavy smokers reveals three notable findings. First, one's own NCD diagnosis (*Self_NCD*) significantly reduces cigarette consumption among non-heavy smokers but is associated with increased cigarette consumption among heavy smokers (though this effect is not statistically significant). This difference may be attributed to heavy smokers' higher levels of nicotine addiction and dependence, which makes them more likely to use smoking as a coping mechanism when facing stress from an NCD diagnosis [39, 40]. Second, family members' smoking behavior (*Fam_smoke*) significantly increases daily cigarette consumption among non-heavy smokers, while family members' NCD diagnoses (*Fam_NCD*) significantly decrease it. However, neither family members' smoking behavior nor their NCD diagnoses significantly impact heavy smokers' smoking behavior, likely due to their long-established smoking habits, and few other things may change their smoking behavior. Finally, for both heavy and non-heavy smokers, family members' smoking behavior and NCD diagnoses do not moderate the relationship between one's own NCD diagnosis and smoking behavior.

4. Discussion

This study utilized (zero-inflated) Negative Binomial models to examine the effects of NCD diagnoses (more precisely, major cardiovascular diseases) on daily cigarette consumption among Chinese adult males and how family members' smoking behavior and NCD diagnoses may moderate these effects. From our analysis of the CHNS data, four important findings emerged. Firstly, in line with previous research [12–16, 41–43], we found a strong association between one's own health shocks (NCD diagnoses) and smoking behavior, highlighting the importance of regular health check-ups to keep individuals informed about their health status, and suggesting that including annual physical check-ups in basic medical insurance packages could be beneficial. However, if a male adult does not quit smoking after receiving an NCD diagnosis, the diagnosis is unlikely to significantly impact his smoking intensity. This finding reflects the role of nicotine addiction in preventing smokers from stopping smoking, even after being diagnosed with an NCD. Thus, a national tobacco policy with strong legislation and comprehensive health promotion may be needed to promote the reduction of smoking.

Second, the home environment also plays a role. The presence of (other) smokers in the family has a significantly

TABLE 3. Negative Binomial estimates of associations between chronic disease diagnoses, home environment, and smoking behavior of baseline non-heavy smokers *vs.* heavy smokers (aged 45–85).

Outcome variables	Model (1)	Model (2)	Model (3)	Model (4)
	Number of cigarettes smoked daily		Number of cigarettes smoked daily	
Sample	Baseline (2000) non-smokers & non-heavy smokers; never-smokers dropped		Baseline (2000) heavy smokers	
Self_NCD	−0.228*** (0.050)	−0.150*** (0.050)	0.008 (0.016)	0.024* (0.013)
Fam_NCD	−0.080* (0.041)	−0.072* (0.042)	0.000 (0.017)	0.012 (0.014)
Fam_smoke	0.071** (0.036)	0.067* (0.037)	−0.004 (0.014)	0.003 (0.012)
Self_NCD × *Fam_NCD*	0.080 (0.075)	0.055 (0.074)	−0.039 (0.026)	−0.033 (0.022)
Self_NCD × *Fam_smoke*	0.036 (0.078)	0.000 (0.079)	−0.001 (0.033)	−0.007 (0.029)
Age_yrs		−0.060*** (0.019)		0.004 (0.007)
Age_sq		0.047*** (0.016)		−0.004 (0.006)
Minority		0.015 (0.064)		−0.004 (0.018)
Rural		−0.096** (0.041)		0.030*** (0.011)
Educ_yrs		0.010* (0.006)		−0.005*** (0.001)
HH_income		−0.020 (0.015)		0.001 (0.005)
Working		0.043 (0.038)		0.011 (0.010)
Health_insurance		0.010 (0.044)		0.023** (0.011)
Drinking		0.352*** (0.037)		0.019** (0.009)
Self_health		0.001 (0.028)		0.005 (0.008)
N_smoke_lag1		0.042*** (0.003)		0.010*** (0.001)
Province dummies	Yes	Yes		Yes
Survey-wave dummies	Yes	Yes		Yes
Constant	1.957*** (0.072)	3.223*** (0.587)	3.117*** (0.021)	2.798*** (0.220)
N	6496	6322	4581	4463
Log pseudolikelihood	−17,113.29	−16,459.12	−15,020.36	−14,242.93

Notes: Source: Author's computation using data from the CHNS (2000, 2004, 2006, 2009, 2011, 2015). Estimated coefficients are reported in the table. Standard errors are reported in parentheses.
** $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.*

positive effect on both the likelihood of smoking and the daily number of cigarettes smoked (providing that one is still smoking) for Chinese adult males. It is thus necessary to urge Chinese individuals to avoid smoking in front of family members, as this can protect their family from second-hand smoke and reduce the probability of the latter's smoking initiation due to peer pressure or curious imitation. In contrast, the NCD diagnoses of family members do not appear to impact Chinese adult males' smoking behavior, which aligns with previous research findings [20, 42]. The finding that Chinese adult males alter their smoking behavior only in response to their own NCD diagnosis suggests that they are more responsive to direct health shocks than indirect ones.

Thirdly, it was found that neither family members' smoking behavior nor their NCD diagnoses had a moderating effect on the relationship between one's own NCD diagnosis and smoking behavior, indicating that the influence of the family environment on smoking behavior is more of an additive nature rather than an interactive one. This, again, suggests the role of nicotine addiction, which overshadows the influence of the home environment.

Finally, consistent with existing findings [44], the effects of one's own NCD diagnosis were observed mainly among non-heavy smokers, indicating that the responsiveness of smoking behavior to health shocks varies with smoking intensity. This, in turn, suggests that different smoking cessation interventions may be necessary to target different types of smokers. For heavy smokers, more intensive guidance and assistance, such as promoting professional smoking cessation clinics, could be beneficial to support their efforts to quit smoking and improve their overall health outcomes.

These analyses and findings help contribute to the rapidly developing field of the impact of disease awareness on health behavior [13–16, 41–48], by providing new evidence on NCD diagnosis-smoking relationship among Chinese adult males. Among existing studies in the field, the study of Hu *et al.* (2021) [46] is the closest to ours. Hu *et al.* [46] also examined the impact of chronic disease diagnosis on Chinese adult males' smoking behavior using the CHNS data. But our study extends the Hu *et al.* [46] study in three important aspects. Firstly, our study devoted substantial efforts to investigating the role of the home environment, including family members'

smoking behavior and NCD diagnoses, which were largely ignored in the Hu *et al.* [46] study. We explored not only how home-environment factors influence Chinese adult males' smoking behavior directly but also how they moderate the influence of NCD diagnoses on smoking behavior indirectly. Our findings show that family members' behavior matters for one's own smoking behavior, but to a limited extent, and has virtually no moderating effect on the NCD diagnosis-smoking relationship. These findings reveal more clearly the significant role nicotine addiction plays in deterring smoking reduction, which was not adequately stressed in the Hu *et al.* [46] study. With these explorations, our study helps strengthen the validity of the Hu *et al.* [46] study, serving as a complement to it. Secondly, we performed a series of robustness checks, estimating our models using different subsamples, which strengthened the validity of our main findings (and that of the Hu *et al.* [46] study). Finally, we explored the role of smoking intensity, which was not examined in the Hu *et al.* [46] study.

Despite the important findings reported above, we acknowledge several limitations of this study. Firstly, the data available to us only contain information on family members who resided with the respondents at the time of the survey and participated in the survey. This limitation could have led to an underestimation of family members' NCD diagnoses, as those not living in the households were not accounted for, potentially reducing the impact of family health shocks. Secondly, the four NCDs examined in this study are all cardiovascular diseases. It would certainly be worthy of investigating the impact of NCDs other than cardiovascular diseases. Unfortunately, the CHNS collected limited information on other NCDs. Future studies exploring the role of other NCDs are expected to be fruitful. Thirdly, the relatively small size of our analytical sample prevented the differentiation of influences from different family members, such as parents, spouses, and children. Future studies with larger datasets comprising more comprehensive family information could extend our analysis. Furthermore, we recognize the possibility of reverse causality, as smoking behavior can also influence the development of NCDs. Although we have controlled for the number of cigarettes smoked in the previous period in our models, this approach may not fully address the endogeneity issue. To address this concern, employing alternative identification strategies such as instrumental variables or control functions could be desirable in future inquiries [29]. Finally, given the low incidence of smoking among children and females and the low prevalence of NCDs among young adults in China, our study focused on middle-aged and older males in China. Future studies on smoking behavior among younger individuals and females would be important. Despite these limitations, we believe our analyses have provided valuable new insights into the potential association between NCD diagnoses and tobacco control, which could be used as a reference to improve China's healthcare policy.

5. Conclusions

Our study examined the impacts of non-communicable disease (NCD) diagnoses on Chinese adult males' daily cigarette consumption, how their home environment may moderate these effects, and whether these impacts vary between heavy and non-heavy smokers. Using (zero-inflated) Negative Binomial regression models applied to six rounds of CHNS data from 2000 to 2015, several key findings were observed. Firstly, Chinese adult males tend to reduce their cigarette consumption in response to their own NCD diagnoses. However, we did not find significant effects of family members' NCD diagnoses on their smoking behavior. On the other hand, the presence of (other) smokers in the family was associated with an increase in daily cigarette consumption for Chinese adult males. Furthermore, we discovered that neither family members' smoking behavior nor their NCD diagnoses had a moderating effect on the relationship between an individual's own NCD diagnosis and smoking behavior. In contrast, the impacts of one's own NCD diagnosis and home environment differed significantly between heavy and non-heavy smokers, with the latter exhibiting a significant reduction in cigarette consumption in response to their own NCD diagnosis, while the former showing an increase in smoking intensity after being diagnosed with an NCD. Moreover, the home environment significantly impacts smoking behavior among non-heavy smokers but not among heavy smokers.

Our findings complement the existing literature on the effects of health shocks and home environment on individuals' smoking behavior and may have important implications for health policy in China and other developing countries alike. For instance, the inclusion of annual physical check-ups in basic medical insurance programs could help individuals stay informed about their health status and potentially reduce smoking among those diagnosed with NCDs. Additionally, providing more intensive guidance and support to heavy smokers may be necessary to assist them in reducing or quitting their smoking habits. A national tobacco policy with strong legislation and comprehensive health promotion may also be considered. Finally, educating the public about the importance of avoiding smoking in front of family members can protect these members from second-hand smoke and discourage smoking initiation due to peer effects or imitation.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

YH, QHC and HCZ—designed the study; revised the manuscript. YH and QHC—performed the research; performed data analysis. HCZ and YJL—provided advice on data analysis and interpretation of findings. YH, QHC and YJL—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Since our study was conducted based on the de-identified, publicly available (second-hand) data

from the China Health and Nutrition Survey (CHNS: https://www.cpc.unc.edu/projects/china), it does not constitute human subject research. Institutional review board (IRB) review was waived by the Ethical Committee of China Agricultural University in our case because there was no interaction with any individual, and no identifiable private information was used during our study.

ACKNOWLEDGMENT

The authors thank Junfei Bai, Sean T. Hammond, Soizik Laguette, Jianjun Lv, Xu Tian, Yubin Wang, Laping Wu, Jeffrey VanLooy, Bo Zhang, Chen Zhu and participants of the 2023 AAEA annual meetings in Washington D.C., for their helpful comments on earlier versions of this paper. Constructive comments provided by two anonymous reviewers, especially those on robustness checks and interpretations of our findings, are also gratefully acknowledged. This research was conducted based upon data from the China Health and Nutrition Survey (CHNS). We thank the National Institute of Nutrition and Food Safety, China Center for Disease Control and Prevention; the Carolina Population Center, the University of North Carolina at Chapel Hill; the National Institutes of Health (NIH; R01-HD30880, DK056350, and R01-HD38700); and the Fogarty International Center, NIH, for financial support for the CHNS data collection and analysis files since 1989.

FUNDING

This work was financially supported by the National Natural Science Foundation of China (grant number: 71973134) and the 2115 Talent Development Program of China Agricultural University.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jomh.org/files/article/1773594051089448960/attachment/Supplementary%20material.docx.

REFERENCES

[1] National Center for Cardiovascular Disease, China. Report on Cardiovascular Disease in China (2018). Encyclopedia of China Publishing House: Beijing, China. 2019.

[2] Ma LY, Chen WW, Gao RL, Liu LS, Zhu ML, Wang YJ, *et al*. China cardiovascular diseases report 2018: an updated summary. Journal of Geriatric Cardiology. 2020; 17: 1–8.

[3] Chinese Center for Disease Control and Prevention. Report on the Nutrition and Chronic Diseases Status of Chinese Residents (2020). People's Medical Publishing House: Beijing, China. 2021.

[4] Marti-Aguado D, Clemente-Sanchez A, Bataller R. Cigarette smoking and liver diseases. Journal of Hepatology. 2022; 77: 191–205.

[5] Ogunlayi F, Coleman PC, Fat LN, Mindell JS, Oyebode O. Trends in socioeconomic inequalities in behavioural non-communicable disease risk factors: analysis of repeated cross-sectional health surveys in England between 2003 and 2019. BMC Public Health. 2023; 23: 1442.

[6] Titova OE, Baron JA, Michaëlsson K, Larsson SC. Swedish snuff (snus) and risk of cardiovascular disease and mortality: prospective cohort study of middle-aged and older individuals. BMC Medicine. 2021; 19: 111.

[7] Ramamoorthy T, Leburu S, Kulothungan V, Mathur P. Regional estimates of noncommunicable diseases associated risk factors among adults in India: results from national noncommunicable disease monitoring survey. BMC Public Health. 2022; 22: 1069.

[8] Dahal S, Sah RB, Niraula SR, Karkee R, Chakravartty A. Prevalence and determinants of non-communicable disease risk factors among adult population of Kathmandu. PLOS ONE. 2021; 16: e0257037.

[9] Jeong SM., Yoo JE, Park J, Jung W, Lee KN, Han K, *et al*. Smoking behavior change and risk of cardiovascular disease incidence and mortality in patients with type 2 diabetes mellitus. Cardiovascular Diabetology. 2023; 22: 1–11.

[10] Ahmed S, Moniruzzaman M, Ahmed MM. Noncommunicable disease risk factors among working adults in Dhaka city: a cross-sectional survey. Epidemiology and Health System Journal 2023; 10: 45–51.

[11] GBD 2015 Tobacco Collaborators. Smoking prevalence and attributable disease burden in 195 countries and territories, 1990–2015: a systematic analysis from the Global Burden of Disease Study 2015. The Lancet. 2017; 389: 1885–1906.

[12] Clark AE, Etilé F. Don't give up on me baby: spousal correlation in smoking behaviour. Journal of Health Economics. 2006; 25: 958–978.

[13] Khwaja A, Sloan F, Chung S. The effects of spousal health on the decision to smoke: evidence on consumption externalities, altruism and learning within the household. Journal of Risk and Uncertainty. 2006; 32: 17–35.

[14] Dai T, Jiang S, Liu X, Sun A. The effects of a hypertension diagnosis on health behaviors: a two-dimensional regression discontinuity analysis. Health Economics. 2022; 31: 574–596.

[15] Bünnings C. Does new health information affect health behaviour? The effect of health events on smoking cessation. Applied Economics. 2017; 49: 987–1000.

[16] Marti J, Richards MR. Smoking response to health and medical spending changes and the role of insurance. Health Economics. 2017; 26: 305–320.

[17] Friedman AS. Smoking to cope: addictive behavior as a response to mental distress. Journal of Health Economics. 2020; 72: 102323.

[18] Fadlon I, Nielsen TH. Family health behaviors. American Economic Review. 2019; 109: 3162–3191.

[19] Smith VK, Taylor DH, Sloan FA, Johnson FR, Desvousges WH. Do smokers respond to health shocks? Review of Economics and Statistics. 2001; 83: 675–687.

[20] Margolis R. Health shocks in the family. Journal of Aging and Health. 2013; 25: 882–903.

[21] Kenkel D, Lillard DR, Liu F. An analysis of life-course smoking behavior in China. Health Economics. 2009; 18: S147–S156.

[22] Lanari D, Pasqualini M, Pieroni L. Is it time to quit? Smoking persistence and self-rated health. Journal of Population Ageing. 2022; 15: 363–380.

[23] Marsaudon A, Rochaix L. Impact of acute health shocks on cigarette consumption: a combined DiD-matching strategy to address endogeneity issues in the French Gazel panel data. 2017. Available at: https://shs.hal.science/halshs-01626187/document (Accessed: 15 September 2023).

[24] Cheng L, Liu H, Zhang Y, Shen K, Zeng Y. The impact of health insurance on health outcomes and spending of the elderly: evidence from China's new cooperative medical scheme. Health Economics. 2015; 24: 672–691.

[25] Arcidiacono P, Sieg H, Sloan F. Living rationally under the volcano? An empirical analysis of heavy drinking and smoking. International Economic Review. 2007; 48: 37–65.

[26] Hu Y, Chen Q, Zhang B. Effects of chronic disease diagnoses on alcohol consumption among elderly individuals: longitudinal evidence from China. BMJ Open. 2022; 12: e062920.

[27] Shankar A, Klein R, Klein BEK. The association among smoking, heavy drinking, and chronic kidney disease. American Journal of Epidemiology. 2006; 164: 263–271.

[28] Cameron AC, Trivedi PK. Microeconometrics: methods and applications. Cambridge university press: Cambridge, UK. 2005.

[29] Cameron AC, Trivedi PK. Microeconometrics: methods and applications. 2nd edn. Cambridge university press: Cambridge, UK. 2022.
[30] Hansen B. Econometrics. Princeton University Press: Princeton, US. 2022.
[31] Asteriou D, Hall SG. Applied econometrics. Bloomsbury Publishing: London, UK. 2021.
[32] Liang K, Zeger SL. Longitudinal data analysis using generalized linear models. Biometrika. 1986; 73: 13–22.
[33] Chen Q, Pei C, Huang J, Tian G. Public health insurance and enrollees' diet structure in rural China. Heliyon. 2022; 8: e09382.
[34] Chen Q, Chu X, Wang S, Zhang B. A triple-difference approach to re-evaluating the impact of China's new cooperative medical scheme on incidences of chronic diseases among older adults in rural communities. Risk Management and Healthcare Policy. 2020; 13: 643–659.
[35] Yip W, Hsiao W. China's health care reform: a tentative assessment. China Economic Review. 2009; 20: 613–619.
[36] Neumann T, Rasmussen M, Heitmann BL, Tonnesen H. Gold standard program for heavy smokers in a real-life setting. International Journal of Environmental Research and Public Health. 2013; 10: 4186–4199.
[37] Vuong QH. Likelihood ratio tests for model selection and non-nested hypotheses. Econometrica. 1989; 57: 307.
[38] Hayes AF. Introduction to mediation, moderation, and conditional process analysis. 3rd edn. Guilford Press: New York, USA. 2022.
[39] Garey L, Olofsson H, Garza T, Shepherd JM, Smit T, Zvolensky MJ. The role of anxiety in smoking onset, severity, and cessation-related outcomes: a review of recent literature. Current Psychiatry Reports. 2020; 22: 38.
[40] Watson NL, Heffner JL, McClure JB, Mull KE, Bricker JB. Differential prevalence of established risk factors for poor cessation outcomes among smokers by level of social anxiety. The American Journal on Addictions. 2017; 26: 176–182.
[41] Kim D, Sambou MO. Changes in smoking and drinking behaviors after the incidence of chronic diseases. Addiction Research & Theory. 2019; 27: 405–411.
[42] Wang Q, Rizzo JA, Fang H. Changes in smoking behaviors following exposure to health shocks in China. International Journal of Environmental Research and Public Health. 2018; 15: 2905.
[43] Zeng S, Shimokawa S. The effect of health information on smoking intensity: does addiction matter? Applied Economics. 2020; 52: 2408–2426.
[44] Darden M. Smoking, expectations, and health: a dynamic stochastic model of lifetime smoking behavior. Journal of Political Economy. 2017; 125: 1465–1522.
[45] Chen Q, Huang J, Dang Y, Hu Y. Effects of hypertension diagnoses on alcohol consumption among Chinese adults—evidence from a two-dimensional regression discontinuity design. Agricultural and Applied Economics Association: Washington D.C. 2023 Annual Meeting, 23–25 July. 2023.
[46] Hu Y, Chen Q, Zhang B. Can chronic disease diagnosis urge the patients to quit smoking?—Evidence from the China health and nutrition survey. Risk Management and Healthcare Policy. 2021; 14: 3059–3077.
[47] Qin W. A diagnosis of diabetes and health behavior maintenance in middle-aged and older adults in the United States: the role of self-efficacy and social support. Preventive Medicine. 2022; 155: 106958.
[48] Wang Y, Jin Z, Yuan Y. The consequences of health shocks on households: evidence from China. China Economic Review. 2023; 79: 101969.

How to cite this article: Yue Hu, Qihui Chen, Haochi Zheng, Yanjun Liang. Influence of major non-communicable chronic disease diagnoses on Chinese adult males' smoking behavior: is there a moderating role for the home environment? Journal of Men's Health. 2024; 20(3): 45-59. doi: 10.22514/jomh.2024.037.