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Original Article

Prevalence of nicotine dependence among smokers aged 40 years and older in China

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ABSTRACT

Background: Nicotine dependence, also known as tobacco dependence, is a common chronic disease and a major risk factor for chronic respiratory diseases. The present study was designed to determine the prevalence of nicotine dependence and its changes among smokers aged 40 years and older in China, to analyze the characteristics of nicotine dependence among smokers, and to provide a reference for smoking cessation interventions.

Methods: The data were sourced from nationally representative large-sample surveys conducted during 2014–2015 and 2019–2020 in the Chinese population, covering 125 counties (districts) in 31 provinces, autonomous regions and municipalities. Variables related to smoking and nicotine dependence among residents ≥40 years old were collected in face-to-face interviews. A total of 20,062 and 18,975 daily smokers were included in the 2014–2015 and 2019–2020 surveys, respectively. The severity of nicotine dependence was evaluated according to the Fagerström Test for Nicotine Dependence and Heaviness of Smoking Index. The level and change in nicotine dependence among daily smokers aged ≥40 years were estimated using a complex weighted sampling design, and their influencing factors were analyzed.

Results: Levels of nicotine dependence among daily smokers aged ≥40 years in China could be divided into very low, low, medium, high, and very high, accounting for 31.1%, 27.9%, 13.4%, 20.5%, and 7.1% of the total, respectively. The average Fagerström Test for Nicotine Dependence score was 3.9 (95% confidence interval [CI]: 3.8–4.0), with the prevalence of medium–high nicotine dependence being 41.0% (95% CI: 39.0–42.9%) and that of high and very high nicotine dependence being 27.6% (95% CI: 26.0–29.3%), both of which were significantly higher in men than in women (both $P < 0.001$). Among daily smokers, those with a low education level, age at smoking initiation <18 years, and with smoking duration of ≥20 years had a higher degree of nicotine dependence. In terms of geographic region, the level of medium–high nicotine dependence in South China was higher than in other areas, and the decline in the prevalence of high nicotine dependence was the greatest in Northwest China ($P < 0.001$). The prevalence of medium–high and high and very high nicotine dependence was significantly higher in men with chronic respiratory symptoms, chronic obstructive pulmonary disease (COPD), and/or chronic respiratory diseases than in men without these conditions (all $P < 0.05$). The prevalence of high and very high nicotine dependence in women with chronic respiratory symptoms and chronic respiratory diseases was significantly higher than that in women without these conditions (both $P < 0.05$). Compared with that during 2014–2015, the prevalence of high nicotine dependence among daily smokers decreased during 2019–2020 by 4.5 percentage points in the total population ($P < 0.001$) and by 4.8 percentage points in men ($P < 0.001$), with no significant change seen in women ($P > 0.05$). Additionally, the prevalence of high nicotine dependence in men with chronic respiratory symptoms and COPD decreased by 6.7 and 4.7 percentage points, respectively ($P < 0.05$), but showed no significant change in women with these conditions ($P > 0.05$). Multivariate logistic regression analysis showed that the risk of medium-high nicotine dependence was higher among daily smokers who were male; 50–59 years old; unmarried/divorced/widowed/separated; engaged in agriculture, forestry, husbandry,

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fishery and water conservancy; had a low education level; started smoking before the age of 18 years; and smoked for more than 20 years.

Conclusions: The past few years have seen a slight decline in the prevalence of high (severe) nicotine dependence among smokers aged ≥40 years in China. However, 41.0% of daily smokers had medium-high nicotine dependence, and 27.6% had high or very high nicotine dependence, with notable differences in population and geographic distributions. Development of tailored interventions, optimization of smoking cessation service systems, and integration of smoking cessation into the management of chronic diseases will effectively reduce the burden of nicotine dependence in China.

Introduction

Nicotine dependence, also referred to as tobacco dependence, is a complex condition involving a variety of physiological, psychological, and behavioral processes that is considered a mental disorder according to the International Classification of Diseases, Tenth Revision (F17.2). Nicotine dependence is common among smokers and is considered a chronic disease.[1] Similar to many progressive chronic diseases including chronic obstructive pulmonary disease (COPD), diabetes, and hypertension, nicotine dependence is a highly recurrent condition and often requires ongoing assessment and repeated intervention.[2] Individuals with high levels of nicotine dependence should be referred to a smoking cessation clinic for comprehensive and intensive professional smoking cessation intervention and treatment.[2,3]

It is estimated that more than 500 million people worldwide are living with nicotine dependence,[1] with nearly half of daily smokers affected. Nicotine dependence has become a serious public health problem that prevents smokers from quitting and poses long-lasting health hazards to smokers.[4] China is the largest tobacco producer and consumer worldwide, with an estimated 158 million tobacco-dependent individuals and more than 1 million deaths per year owing to smoking-related diseases.[5,6] The economic cost of smoking-attributable chronic diseases is estimated to be approximately 16.7 trillion RMB during the period 2015–2030.[7] For instance, the economic loss owing to COPD in China accounts for approximately 32% of the global estimate (2020–2050),[8] which will place a heavy burden on China's health care system.[7,9,10]

Nicotine dependence varies widely among different populations. A comprehensive understanding of the severity of nicotine dependence among smokers with different characteristics is essential for the development and implementation of effective tobacco control and cessation interventions. Most currently available studies assessing the severity of nicotine dependence in China have focused on only one or a few provinces or cities,[11-13] with suboptimally classified nicotine-dependent populations and poor knowledge of changes in the prevalence of nicotine dependence. According to the results of two nationally representative large-sample surveys, in the current study, we further assessed the severity of nicotine dependence among smokers with different characteristics using two standardized scales, with the aim to understand the prevalence of nicotine dependence and its changes in smokers aged ≥40 years in China and analyze its influencing factors. Our findings can inform the implementation of smoking cessation interventions, the development of smoking cessation service systems, and the evaluation of regional smoking cessation efforts.

Methods

Study population

The data were sourced from a nationally representative survey on COPD conducted among Chinese residents during the periods 2014–2015 and 2019–2020 in 125 surveillance counties (districts) in 31 provinces, autonomous regions and municipalities across China. Using a multi-stage stratified cluster random sampling method, we enrolled Chinese residents who were ≥40 years old and had lived in the surveillance sites for ≥6 of the 12 months prior to the survey. The overall design, sampling method, and quality control of the survey have been described elsewhere.[14,15] A total of 74,559 and 75,107 individuals were surveyed during 2019–2020 and 2014–2015, respectively. After excluding individuals with information missing for key variables such as daily cigarette consumption, time to first cigarette during the day, and age at smoking initiation, a total of 18,975 and 20,062 participants from the 2019–2020 and 2014–2015 surveys, respectively, were included in the current analysis. The study protocol was approved by the Ethical Review Committee of the National Center for Chronic and Non-communicable Disease Control and Prevention, Chinese Center for Diseases Control and Prevention (No. 201901). All respondents signed an informed consent form.

Survey content

An electronic questionnaire was used to conduct face-to-face interviews with participants. All the investigators were adequately trained and qualified to conduct the interviews. We included Chinese citizens (aged 40 years or older) who had been living in their current residence for at least 6 months within the year before the survey, to exclude new immigrants. We excluded people who lived in a communal residence (e.g., a university dormitory, military unit, or nursing home), individuals with cognitive, language, or mental disorders who could not participate in the interview, people with cancer (newly diagnosed or under treatment), individuals with paraplegia, women who were pregnant or breastfeeding, and individuals who did not provide written informed consent.[14] The collected data included: demographic information such as sex, age, occupation, education level, marital status, annual household income, residence (urban and rural), and region; nicotine dependence-related information such as age at smoking initiation, factory-made cigarettes smoked per day, and time to first cigarette during the day; and other information including chronic respiratory symptoms such as cough, sputum production, wheezing, and dyspnea (assessed using the modified Medical Research Council dyspnea scale) as well as diagnoses such as chronic respiratory diseases, cardiovascular and cerebrovascular diseases, diabetes, hypertension, and other chronic diseases made at a medical institution at or above the township level. Spirometry on all eligible participants was performed following a standard protocol with the same brand of spirometer (MasterScreen Pneumo, Jaeger, Germany), as described in the literature.[14]

Definitions

Nicotine dependence was assessed using the Fagerström Test for Nicotine Dependence (FTND) and Heaviness of Smoking Index (HSI). The FTND and HIS are considered the splendid measurement tools in the field of nicotine dependence assessment,[16] and both of these scales are simple and easy to use.[17] The FTND has been used worldwide, with proven reliability and validity.[18,19] The FTND scale comprises six questions[20,21]: How soon after you wake up do you smoke your first cigarette? Do you find it difficult to refrain from smoking in places where it is forbidden? Which cigarette would you hate most to give up? How many cigarettes/day do you smoke? Do you smoke more frequently during the first hours after waking than during the rest of the

day? Do you smoke if you are so ill that you are in bed most of the day? The answers to each question correspond to a score, and the sum of these scores indicates the degrees of nicotine dependence: very low (score of 0–2), low (3–4), medium (5), high (6–7), and very high (8–10). Previous studies have defined high (severe) nicotine dependence as FTND score ≥5 or ≥6.[13,21-26] In this analysis, an FTND score of ≥5 was defined as medium-high nicotine dependence (including medium, high, and very high degrees of nicotine dependence)[11,27] and a score of ≥6 was defined as high and very high nicotine dependence based on our data.[12] Nicotine dependence was also assessed using the HSI,[21] which can reflect the prevalence of nicotine dependence in a dynamic manner. The HIS incorporates FTND items 1 and 4. A sum of the scores of these two questions ≥4 indicates high nicotine dependence.

Chronic respiratory symptoms refer to chronic cough, chronic sputum production, wheezing, and dyspnea reported by survey respondents.[28] COPD was identified according to pulmonary function tests (i.e., post-bronchodilator forced expiratory volume in 1 second/forced vital capacity ratio <70%). Subjects with chronic respiratory diseases (excluding COPD), cardiovascular and cerebrovascular diseases, diabetes and hypertension were defined based on self-reported diagnosis by township or higher level hospitals before the survey. Hypertension also included the following conditions during the survey: average systolic blood pressure (SBP) ≥140 mmHg and/or average diastolic blood pressure (DBP) ≥90 mmHg on the second and third readings (measured three times). Chronic respiratory diseases (excluding COPD) included asthma, chronic bronchitis, emphysema, tuberculosis, bronchiectasis, or pulmonary interstitial fibrosis. Cardiovascular and cerebrovascular diseases included coronary heart disease, cerebrovascular disease, and/or chronic cor pulmonale diagnosed. Chronic diseases included COPD, chronic respiratory diseases (excluding COPD), cardiovascular and cerebrovascular diseases, diabetes, and hypertension defined above.

Quality control

To ensure the quality of the survey data, a rigorous quality control protocol[14] was applied, along with a three-tier quality control system at the national, provincial, and surveillance county (district) levels. Strict quality control measures were implemented before, during, and after the survey, involving the preparatory stage and links including data review, cleansing, and analysis. During the design of the study, the questionnaire was revised and optimized through expert consultations and pilot surveys. Clear question descriptions and a uniform survey method increased the accuracy of responses. Unreasonable values, missing values, and logical errors in the questionnaire were minimized by setting up mandatory items, logical jumps, and reasonable value ranges. The investigators were uniformly trained and carried out surveys using standardized norms and criteria. Simultaneous recordings were conducted for quality control. Self-designed electronic questionnaires and information collection and management systems were used to avoid data entry errors. All these quality control measures ensured the accuracy and reliability of the survey data.

Statistical analysis

The data were processed and analyzed using SAS 9.4 software (SAS Institute Inc., Cary, NC, USA). Based on data of the 2020 national census, post-stratification weights were calculated, and the results were adjusted using complex sampling.[15] The general characteristics of participants are described using frequencies and proportions. The Rao-Scott chi-square test based on a complex sampling design was used to compare differences in the severity of nicotine dependence among daily smokers with different characteristics. According to complex sampling, differences in the mean FTND score of daily smokers with different characteristics among different subgroups were compared using analysis of variance or *t*-tests. Multivariable logistic regression was used to examine factors associated with nicotine dependence. A P value <0.05 was considered to indicate statistical significance.

Results

Sociodemographic characteristics of participants

Among the 74,559 survey respondents during the 2019–2020 period, 18,975 daily smokers were included in the current analysis. Of these, 18,141 (95.6%) were men and 834 (4.4%) were women. The following subgroups had higher proportions: respondents aged ≥60 years (7684/18,975, 40.5%); those living in rural areas (59.4% [11,268/18,975] *vs.* 40.6% [7707/18,975] in urban areas); those living in Eastern China (4782/18,975, 25.2%); respondents engaged in agriculture, forestry, husbandry, and fishery and water conservancy (9370/18,975, 49.4%); individuals with an education level of middle school or higher (10,129/18,975, 53.4%); those who started smoking at age 18 years or later (11,063/18,350, 60.3%); and respondents who had smoked for more than 20 years (17,737/18,350, 96.7%). Smokers with chronic diseases accounted for 64.1% (11,027/17,198) (Table 1).

FTND scores in different subgroups

The average FTND score of daily smokers was 3.9 (95% confidence interval [CI]: 3.8–4.0), and average FTND scores were higher in men (3.9; 95% CI: 3.8–4.0) than in women (3.2; 95% CI: 2.9–3.4) (P<0.001). Participants with an education level of middle school or higher or an annual household income of >56,001 RMB had lower FTND scores, and the results were similar for both men and women. In terms of occupation, administrative officers/clerks/technical staff scored the lowest (3.3), and those who worked in agriculture, forestry, husbandry, and fishery and water conservancy had higher scores (4.1). Scores among respondents who started smoking before the age of 18 years (4.4) were significantly higher than scores among those who started smoking at age 18 years or later (3.6), and participants who had smoked for ≥20 years (3.9) had significantly higher scores than those who had smoked for <20 years (2.8). Patients with chronic respiratory symptoms (4.6), COPD (4.0), or chronic respiratory diseases (4.0) had significantly higher FTND scores than those without these conditions (3.8, 3.9, and 3.9, respectively; all P<0.05) (Table 2).

Degrees of nicotine dependence

According to the FTND scale, the estimated proportions of very low, low, medium, high and very high nicotine dependence among daily smokers aged ≥40 years in China from 2019 to 2020 were 31.1%, 27.9%, 13.4%, 20.5%, and 7.1%, respectively. More specifically, these rates were 30.7%, 27.9%, 13.4%, 20.7%, and 7.3% in men and 42.1%, 27.3%, 11.8%, 16.0%, and 2.8% in women. The prevalence of medium-high nicotine dependence reached 41.0% (95% CI: 39.0–42.9%), which was significantly higher in men (41.4%; 95% CI: 39.5–43.4%) than in women (30.6%; 95% CI: 25.2–36.1%) (P < 0.001). The prevalence of high and very high nicotine dependence was 27.6% (95% CI: 26.0–29.3%), which was also significantly higher in men (28.0%; 95% CI: 26.4–29.7%) than in women (18.8%; 95% CI: 15.2–22.5%) (P < 0.001) (Table 3, Supplementary Tables 1–4).

Among male smokers, the prevalences of both medium–high nicotine dependence and high and very high nicotine dependence were the highest in the age group 50–59 years (45.5% and 31.7%, respectively) (P < 0.001). These rates were also significantly higher in participants with an education level of primary school or lower (46.1% and 32.3%, respectively; *vs.* participants with an education level of middle school or higher) (both P < 0.001) and in respondents with an occupation in agriculture, forestry, husbandry, and fishery and water conservancy (44.4% and 30.8%, respectively) (P < 0.001). The level of nicotine dependence

Table 1
Sociodemographic characteristics of participants (2019–2020).

Characteristics	Total		Men		Women	
	No.	Proportion (%)	No.	Proportion (%)	No.	Proportion (%)
Total	18,975	100.0	18,141	95.6	834	4.4
Residence						
Urban	7707	40.6	7394	40.8	313	37.5
Rural	11,268	59.4	10,747	59.2	521	62.5
Age						
40–49 years	4457	23.5	4329	23.9	128	15.3
50–59 years	6834	36.0	6568	36.2	266	31.9
≥60 years	7684	40.5	7244	39.9	440	52.8
Marital status						
Married/co-habiting	17,130	90.3	16,459	90.7	671	80.5
Unmarried/divorced/widowed/separated	1845	9.7	1682	9.3	163	19.5
Annual household income*						
<11,000 RMB	5052	26.6	4774	26.3	278	33.3
11,001–30,000 RMB	6002	31.7	5725	31.6	277	33.2
30,001–56,001 RMB	3435	18.1	3302	18.2	133	16.0
>56,001 RMB	4482	23.6	4336	23.9	146	17.5
Occupation						
Agricultural workers†	9370	49.4	8970	49.4	400	47.9
Manufacturing, transportation, and commerce	1589	8.4	1564	8.6	25	3.0
Administrative officers/clerks/technical staff	1234	6.5	1224	6.8	10	1.2
Other employees/unemployed persons	3724	19.6	3631	20.0	93	11.2
Housekeepers	1676	8.8	1483	8.2	193	23.1
Retired individuals	1382	7.3	1269	7.0	113	13.6
Education background						
Primary school or lower	8846	46.6	8238	45.4	608	72.9
Middle school or higher	10,129	53.4	9903	54.6	226	27.1
Age at smoking initiation*						
<18 years	7287	39.7	7076	40.3	211	26.2
≥18 years	11,063	60.3	10,470	59.7	593	73.8
Smoking duration*						
<20 years	613	3.3	492	2.8	121	15.0
≥20 years	17,737	96.7	17,054	97.2	683	85.0
Geographic region						
North China	2684	14.1	2488	13.7	196	23.5
Eastern China	4782	25.2	4598	25.4	184	22.1
Central China	2425	12.8	2380	13.1	45	5.4
South China	2350	12.4	2338	12.9	12	1.4
Southwest	3218	16.9	3144	17.3	74	8.9
Northwest	1891	10.0	1881	10.4	10	1.2
Northeast	1625	8.6	1312	7.2	313	37.5
Chronic respiratory symptoms*						
No	15,090	83.9	14,477	84.1	613	79.7
Yes	2902	16.1	2746	15.9	156	20.3
COPD*						
No	13,169	80.1	12,563	79.8	606	86.4
Yes	3268	19.9	3173	20.2	95	13.6
Chronic respiratory diseases*						
No	16,307	90.2	15,595	90.3	712	88.7
Yes	1762	9.8	1671	9.7	91	11.3
Chronic diseases*						
No	6171	35.9	5919	36.0	252	33.3
Yes	11,027	64.1	10,522	64.0	505	66.7
Diabetes*						
No	17,456	94.2	16,703	94.4	753	91.4
Yes	1072	5.8	1001	5.6	71	8.6
Cardiovascular and cerebrovascular diseases*						
No	17,020	93.4	16,360	93.9	660	81.9
Yes	1204	6.6	1058	6.1	146	18.1
Hypertension*						
No	10,687	57.1	10,215	57.1	472	57.1
Yes	8016	42.9	7661	42.9	355	42.9

* Missing data in different subgroups include: annual household income ($n = 4$), age at smoking initiation ($n = 625$), smoking duration ($n = 625$), chronic respiratory symptoms ($n = 983$), COPD ($n = 2538$), chronic respiratory diseases ($n = 906$), chronic diseases ($n = 1777$), diabetes ($n = 447$), cardiovascular and cerebrovascular diseases ($n = 751$), and hypertension ($n = 272$).

† Agricultural workers: People engaged in agriculture, forestry, husbandry, fishery and water conservancy. No.: Frequency was unweighted; COPD: Chronic obstructive pulmonary disease.

was significantly higher among participants who started smoking before the age of 18 years than in those who started smoking at age 18 years or later ($P < 0.001$) and in respondents with a smoking duration of ≥20 years ($P < 0.001$, *vs.* patients with a smoking duration of <20 years). In terms of annual household income, the subgroup with income >56,001 RMB had the lowest prevalence of medium–high nicotine dependence and high and very high nicotine dependence ($P < 0.001$). The prevalence of medium-high nicotine dependence was the highest among residents of South China (52.4%) and the lowest among those living in Northwest China (36.4%), with statistically significant differ-

Table 2
FTND scores of daily smokers aged ≥40 years with different characteristics in China (2019–2020).

Characteristics	Total				Men				Women			
	No.	Mean (95% CI)	*F*(*t*) value	*P* value	No.	Mean (95% CI)	*F*(*t*) value	*P* value	No.	Mean (95% CI)	*F*(*t*) value	*P* value
Total	18,975	3.9 (3.8–4.0)			18,141	3.9 (3.8–4.0)			834	3.2 (2.9–3.4)		
Residence			–6.05	<0.001			–6.09	<0.001			–1.06	0.288
Urban	7707	3.8 (3.7–3.9)			7394	3.8 (3.7–3.9)			313	3.1 (2.8–3.4)		
Rural	11,268	4.0 (3.9–4.1)			10,747	4.1 (3.9–4.2)			521	3.2 (2.9–3.5)		
Age*			59.75	<0.001			59.20	<0.001			1.01	0.365
40–49 years	4457	3.7 (3.6–3.9)			4329	3.7 (3.6–3.9)			128	2.9 (2.5–3.3)		
50–59 years	6834	4.1 (4.0–4.3)			6568	4.2 (4.1–4.3)			266	3.3 (2.9–3.6)		
≥60 years	7684	3.8 (3.7–3.9)			7244	3.8 (3.7–4.0)			440	3.2 (2.8–3.5)		
Marital status			–2.95	0.003			–3.30	0.001			–1.32	0.187
Married/co-habiting	17,130	3.9 (3.8–4.0)			16,459	3.9 (3.8–4.0)			671	3.1 (2.9–3.4)		
Unmarried/divorced/widowed/separated	1845	4.1 (3.9–4.3)			1682	4.2 (3.9–4.4)			163	3.3 (2.7–3.9)		
Annual household income (RMB) *,†			17.43	<0.001			16.84	<0.001			1.73	0.160
<11,000 RMB	5052	3.9 (3.8–4.1)			4774	4.0 (3.8–4.1)			278	3.2 (2.9–3.6)		
11,001–30,000 RMB	6002	4.0 (3.9–4.2)			5725	4.1 (3.9–4.2)			277	3.3 (2.9–3.7)		
30,001–56,001 RMB	3435	4.0 (3.8–4.1)			3302	4.0 (3.8–4.2)			133	3.3 (2.7–3.9)		
>56,001 RMB	4482	3.7 (3.6–3.9)			4336	3.7 (3.6–3.9)			146	2.8 (2.4–3.3)		
Occupation*			42.66	<0.001			44.19	<0.001			1.74	0.122
Agricultural workers‡	9370	4.1 (3.9–4.2)			8970	4.1 (4.0–4.2)			400	3.3 (2.9–3.7)		
Manufacturing, transportation, and commerce	1589	3.8 (3.6–4.0)			1564	3.8 (3.6–4.0)			25	2.9 (1.8–4.0)		
Administrative officers/clerks/technical staff	1234	3.3 (3.1–3.5)			1224	3.3 (3.1–3.5)			10	3.7 (3.0–4.5)		
Other employees/unemployed persons	3724	4.0 (3.8–4.2)			3631	4.0 (3.9–4.2)			93	2.9 (2.4–3.4)		
Housekeepers	1676	4.1 (3.8–4.3)			1483	4.2 (3.9–4.4)			193	3.3 (2.9–3.7)		
Retired individuals	1382	3.5 (3.2–3.7)			1269	3.5 (3.3–3.7)			113	2.8 (2.2–3.3)		
Education background			9.20	<0.001			9.85	<0.001			2.95	0.003
Primary school or lower	8846	4.1 (4.0–4.3)			8238	4.2 (4.1–4.3)			608	3.4 (3.0–3.7)		
Middle school or higher	10,129	3.7 (3.6–3.8)			9903	3.7 (3.6–3.9)			226	2.7 (2.4–3.1)		
Age at smoking initiation†			22.74	<0.001			21.93	<0.001			4.16	<0.001
<18 years	7287	4.4 (4.2–4.5)			7076	4.4 (4.3–4.5)			211	3.5 (3.1–4.0)		
≥18 years	11,063	3.6 (3.5–3.7)			10,470	3.6 (3.5–3.7)			593	3.0 (2.7–3.4)		
Smoking duration†			–14.95	<0.001			–12.28	<0.001			–4.69	<0.001
<20 years	613	2.8 (2.5–3.1)			492	2.7 (2.4–3.1)			121	3.0 (2.3–3.7)		
≥20 years	17,737	3.9 (3.8–4.0)			17,054	4.0 (3.9–4.1)			683	3.2 (2.9–3.5)		

(*continued on next page*)

Table 2 (*continued*)

Characteristics	Total				Men				Women			
	No.	Mean (95% CI)	*F*(*t*) value	*P* value	No.	Mean (95% CI)	*F*(*t*) value	*P* value	No.	Mean (95% CI)	*F*(*t*) value	*P* value
Geographic region*			23.01	<0.001			22.28	<0.001			2.77	0.011
North China	2684	3.8 (3.6–4.0)			2488	3.8 (3.6–4.0)			196	3.1 (2.8–3.4)		
Eastern China	4782	3.8 (3.6–4.0)			4598	3.8 (3.6–4.0)			184	3.2 (2.6–3.9)		
Central China	2425	4.0 (3.7–4.3)			2380	4.0 (3.8–4.3)			45	2.4 (1.6–3.3)		
South China	2350	4.5 (4.2–4.9)			2338	4.5 (4.2–4.9)			12	1.9 (0–4.1)		
Southwest	3218	3.9 (3.7–4.2)			3144	3.9 (3.7–4.2)			74	2.8 (2.1–3.5)		
Northwest	1891	3.5 (3.3–3.8)			1881	3.6 (3.3–3.9)			10	1.6 (0.7–2.4)		
Northeast	1625	3.8 (3.7–4.0)			1312	3.9 (3.8–4.1)			313	3.5 (3.2–3.7)		
Chronic respiratory symptoms†			–18.08	<0.001			–18.00	<0.001			–3.38	0.001
No	15,090	3.8 (3.7–3.9)			14,477	3.8 (3.7–3.9)			613	3.0 (2.7–3.3)		
Yes	2902	4.6 (4.4–4.8)			2746	4.6 (4.5–4.8)			156	3.9 (3.2–4.7)		
COPD†			–3.25	0.001			–2.94	0.003			–0.65	0.519
No	13,169	3.9 (3.8–4.0)			12,563	3.9 (3.8–4.0)			606	3.1 (2.8–3.4)		
Yes	3268	4.0 (3.8–4.2)			3173	4.0 (3.8–4.2)			95	3.4 (2.8–4.0)		
Chronic respiratory diseases†			–3.58	<0.001			–3.55	<0.001			–1.00	0.318
No	16,307	3.9 (3.8–4.0)			15,595	3.9 (3.8–4.0)			712	3.1 (2.8–3.4)		
Yes	1762	4.0 (3.9–4.2)			1671	4.1 (3.9–4.3)			91	3.5 (2.8–4.2)		
Chronic diseases†			–1.21	0.225			–0.96	0.335			–1.79	0.074
No	6171	3.9 (3.7–4.0)			5919	3.9 (3.8–4.0)			252	2.9 (2.3–3.4)		
Yes	11,027	3.9 (3.8–4.0)			10,522	3.9 (3.8–4.0)			505	3.3 (3.0–3.6)		
Diabetes†			0.56	0.573			0.17	0.861			0.83	0.408
No	17,456	3.9 (3.8–4.0)			16,703	3.9 (3.8–4.0)			753	3.2 (2.9–3.4)		
Yes	1072	3.6 (3.4–3.9)			1001	3.7 (3.4–4.0)			71	3.0 (2.5–3.5)		
Cardiovascular and cerebrovascular diseases†			–1.32	0.187			–1.47	0.141			–2.22	0.027
No	17,020	3.9 (3.8–4.0)			16,360	3.9 (3.8–4.0)			660	3.1 (2.8–3.3)		
Yes	1204	3.9 (3.7–4.1)			1058	4.0 (3.7–4.2)			146	3.7 (3.1–4.3)		
Hypertension†			1.36	0.174			1.21	0.227			0.87	0.386
No	10,687	3.9 (3.8–4.0)			10,215	4.0 (3.9–4.1)			472	3.2 (2.7–3.6)		
Yes	8016	3.8 (3.7–4.0)			7661	3.9 (3.7–4.0)			355	3.2 (2.7–3.6)		

* Differences in FTND scores by age, income, occupation, and geographic region were compared using analysis of variance based on complex sampling.

† Missing data in different subgroups include: annual household income ($n = 4$), age at smoking initiation ($n = 625$), smoking duration ($n = 625$), chronic respiratory symptoms ($n = 983$), COPD ($n = 2538$), chronic respiratory diseases ($n = 906$), chronic diseases ($n = 1777$), diabetes ($n = 447$), cardiovascular and cerebrovascular diseases ($n = 751$), and hypertension ($n = 272$).

‡ Agricultural workers: People engaged in agriculture, forestry, husbandry, fishery and water conservancy. No.: Frequency was unweighted; CI: Confidence interval; COPD: Chronic obstructive pulmonary disease; FTND: Fagerström Test for Nicotine Dependence.

Table 3
Nicotine dependence in daily smokers aged ≥40 years with different characteristics in China (2019–2020).

Characteristics	Very low		Low		Medium		High		Very high		χ^2 value	*P* value
	No.	Weighted proportion (%, 95% CI)	No.	Weighted proportion (%, 95% CI)	No.	Weighted proportion (%, 95% CI)	No.	Weighted proportion (%, 95% CI)	No.	Weighted proportion (%, 95% CI)		
Total	5608	31.1 (29.3–33.0)	5049	27.9 (26.2–29.5)	2630	13.4 (12.4–14.3)	4105	20.5 (19.2–21.9)	1583	7.1 (6.3–7.9)		
Sex											26.79	<0.001
Men	5274	30.7 (28.9–32.5)	4852	27.9 (26.3–29.5)	2526	13.4 (12.4–14.5)	3932	20.7 (19.4–22.1)	1557	7.3 (6.5–8.1)		
Women	334	42.1 (36.5–47.6)	197	27.3 (21.3–33.2)	104	11.8 (7.8–15.8)	173	16.0 (12.7–19.3)	26	2.8 (1.3–4.4)		
Residence											16.76	0.002
Urban	2398	32.3 (30.1–34.5)	2123	28.7 (26.6–30.8)	1066	13.2 (11.9–14.4)	1543	19.5 (18.0–21.1)	577	6.3 (5.2–7.4)		
Rural	3210	29.7 (27.4–32.0)	2926	26.8 (25.0–28.6)	1564	13.6 (12.4–14.7)	2562	21.8 (20.2–23.5)	1006	8.1 (7.2–9.1)		
Age											32.28	<0.001
40–49 years	1421	33.2 (29.9–36.5)	1248	29.4 (26.6–32.3)	594	12.7 (11.1–14.2)	854	18.6 (16.6–20.7)	340	6.1 (5.1–7.1)		
50–59 years	1869	27.9 (26.3–29.6)	1769	27.1 (25.0–29.1)	939	13.8 (12.3–15.3)	1606	23.0 (21.1–25.0)	651	8.2 (6.9–9.4)		
≥60 years	2318	32.8 (30.0–35.6)	2032	27.3 (24.9–29.7)	1097	13.5 (11.9–15.1)	1645	19.6 (17.9–21.3)	592	6.8 (5.7–7.9)		
Marital status											6.83	0.145
Married/co-habiting	5102	31.3 (29.5–33.1)	4567	28.0 (26.4–29.7)	2377	13.5 (12.5–14.5)	3680	20.2 (18.8–21.6)	1404	7.0 (6.1–7.8)		
Unmarried/divorced/widowed/separated	506	29.5 (24.8–34.1)	482	26.3 (22.8–29.9)	253	11.7 (9.5–14.0)	425	23.9 (19.7–28.2)	179	8.6 (5.7–11.6)		
Annual household income*											28.20	0.005
<11,000 RMB	1445	31.2 (28.5–33.9)	1300	27.1 (24.7–29.5)	699	12.7 (11.2–14.2)	1185	22.2 (20.1–24.3)	423	6.8 (5.5–8.1)		
11,001–30,000 RMB	1729	29.6 (26.9–32.2)	1556	26.4 (23.9–29.1)	860	14.4 (12.8–15.9)	1305	21.4 (19.4–23.5)	552	8.2 (7.1–9.4)		
30,001–56,001 RMB	996	29.8 (27.2–32.3)	968	28.4 (25.7–31.2)	457	12.9 (11.1–14.7)	749	21.6 (19.0–24.2)	265	7.3 (5.6–9.0)		
>56,001 RMB	1437	33.4 (30.4–36.4)	1224	29.3 (27.0–31.6)	613	13.2 (11.7–14.8)	865	18.0 (16.2–19.7)	343	6.1 (4.9–7.4)		
Occupation											81.00	<0.001
Agricultural workers†	2643	29.7 (27.5–31.9)	2439	26.3 (24.3–28.2)	1312	13.4 (12.4–14.5)	2127	22.0 (20.4–23.5)	849	8.6 (7.5–9.7)		
Manufacturing, transportation and commerce	486	32.0 (27.5–36.5)	467	27.8 (24.9–30.7)	221	14.6 (11.7–17.6)	298	19.8 (15.0–24.7)	117	5.8 (4.0–7.5)		
Administrative officers/clerks/technical staff	448	40.4 (36.1–44.7)	341	29.7 (26.1–33.4)	156	10.6 (8.3–12.9)	204	13.9 (11.0–16.8)	85	5.4 (3.8–7.1)		
Other employees/unemployed persons	1084	29.1 (26.2–32.0)	992	27.8 (25.5–30.1)	540	14.5 (12.6–16.4)	802	21.7 (18.9–24.5)	306	6.9 (5.4–8.3)		
Housekeepers	449	28.1 (23.7–32.6)	415	28.5 (24.5–32.5)	235	11.7 (9.4–14.1)	436	24.8 (21.2–28.3)	141	6.9 (5.3–8.6)		
Retired individuals	498	35.1 (30.7–39.3)	395	32.3 (28.1–36.6)	166	12.4 (8.5–16.4)	238	15.1 (12.6–17.7)	85	5.1 (3.7–6.5)		
Education level											58.36	<0.001
Primary school or lower	2384	27.7 (25.2–30.2)	2271	26.9 (24.7–29.1)	1264	13.7 (12.2–15.3)	2115	23.3 (21.4–25.2)	812	8.4 (7.4–9.3)		
Middle school or higher	3224	33.7 (31.9–35.5)	2778	28.6 (26.9–30.3)	1366	13.0 (12.1–14.0)	1990	18.5 (17.1–19.8)	771	6.2 (5.3–7.0)		
Age at smoking initiation*											183.29	<0.001
<18 years	1623	24.2 (22.1–26.4)	1853	26.2 (24.0–28.4)	1093	15.1 (13.7–16.5)	1857	23.9 (22.1–25.7)	861	10.6 (9.2–11.9)		
≥18 years	3779	35.5 (33.1–37.8)	3036	29.1 (27.3–30.9)	1465	12.4 (11.4–13.4)	2109	18.1 (16.6–19.6)	674	4.9 (4.2–5.6)		

(*continued on next page*)

Table 3 (*continued*)

Characteristics	Very low		Low		Medium		High		Very high		χ^2 value	*P* value
	No.	Weighted proportion (%, 95% CI)	No.	Weighted proportion (%, 95% CI)	No.	Weighted proportion (%, 95% CI)	No.	Weighted proportion (%, 95% CI)	No.	Weighted proportion (%, 95% CI)		
Smoking duration*											54.69	<0.001
<20 years	323	50.1 (43.8–56.4)	153	26.4 (20.9–31.9)	53	8.1 (4.7–11.4)	67	13.5 (8.5–18.5)	17	1.9 (0.4–3.5)		
≥20 years	5079	30.2 (28.5–32.0)	4736	28.0 (26.3–29.6)	2505	13.7 (12.7–14.7)	3899	20.7 (19.4–22.1)	1518	7.4 (6.6–8.2)		
Geographic region											74.89	<0.001
North China	856	32.4 (29.6–35.3)	665	28.8 (25.3–32.3)	360	13.6 (12.1–15.0)	543	18.8 (17.3–20.3)	260	6.4 (3.8–8.9)		
Eastern China	1476	33.8 (30.4–37.2)	1272	27.9 (25.3–30.4)	621	11.2 (9.9–12.6)	975	19.2 (17.1–21.2)	438	7.9 (6.5–9.3)		
Central China	755	32.0 (27.3–36.6)	612	25.1 (22.3–28.0)	317	14.6 (11.7–17.4)	512	19.7 (16.7–22.7)	229	8.6 (6.5–10.7)		
South China	401	18.0 (13.1–22.8)	702	29.8 (26.1–33.5)	391	17.2 (15.1–19.3)	636	27.5 (21.9–33.1)	220	7.5 (4.5–10.6)		
Southwest	953	28.7 (24.8–32.6)	927	29.0 (23.7–34.2)	459	13.9 (11.2–16.6)	688	22.8 (19.0–26.6)	191	5.6 (4.4–6.7)		
Northwest	678	39.3 (34.3–44.3)	460	24.4 (22.4–26.4)	247	13.1 (11.1–15.1)	372	17.4 (13.4–21.3)	134	5.8 (4.2–7.5)		
Northeast	489	30.5 (26.9–33.9)	411	29.0 (23.7–34.3)	235	13.5 (11.4–15.7)	379	20.3 (18.5–22.2)	111	6.7 (5.5–7.9)		
Chronic respiratory symptoms*											113.56	<0.001
No	4709	32.9 (31.0–34.8)	4190	28.6 (27.1–30.2)	2073	13.2 (12.1–14.2)	3056	19.3 (18.0–20.6)	1062	6.0 (5.2–6.8)		
Yes	593	21.6 (18.1–25.1)	642	25.0 (21.6–28.4)	435	14.7 (12.4–17.0)	813	26.1 (23.5–28.7)	419	12.6 (10.9–14.4)		
COPD*											5.93	0.205
No	3957	31.4 (29.6–33.3)	3514	27.6 (25.8–29.5)	1804	13.3 (12.3–14.3)	2827	20.4 (19.1–21.7)	1067	7.3 (6.3–8.2)		
Yes	912	29.7 (26.3–33.0)	842	26.6 (24.1–29.1)	484	13.6 (11.5–15.8)	745	23.2 (20.5–25.9)	285	6.9 (5.6–8.1)		
Chronic respiratory diseases*											9.55	0.049
No	4887	31.5 (29.6–33.4)	4384	28.2 (26.7–29.7)	2246	13.5 (12.5–14.5)	3473	20.0 (18.6–21.3)	1317	6.8 (6.0–7.7)		
Yes	494	30.3 (27.0–33.6)	431	25.5 (21.3–29.7)	250	12.2 (9.8–14.7)	410	23.8 (20.9–26.6)	177	8.2 (6.2–10.1)		
Chronic diseases*											1.01	0.908
No	1841	31.4 (29.0–33.8)	1713	28.2 (26.0–30.5)	823	12.8 (11.5–14.0)	1297	20.7 (18.9–22.4)	497	6.9 (5.8–7.9)		
Yes	3275	31.2 (29.1–33.4)	2865	27.6 (25.7–29.5)	1538	13.4 (12.1–14.6)	2428	20.6 (19.1–22.1)	921	7.2 (6.3–8.1)		
Diabetes*											12.98	0.011
No	5151	30.9 (29.0–32.8)	4678	28.1 (26.4–29.7)	2419	13.3 (12.3–14.3)	3787	20.8 (19.4–22.2)	1421	6.9 (6.1–7.7)		
Yes	354	37.9 (33.5–42.4)	255	24.4 (19.6–29.2)	140	13.1 (9.5–16.7)	212	16.5 (13.4–19.6)	111	8.1 (6.0–10.3)		
Cardiovascular and cerebrovascular diseases*											2.66	0.616
No	5063	31.4 (29.4–33.3)	4583	28.1 (26.5–29.7)	2345	13.3 (12.3–14.3)	3636	20.3 (18.9–21.8)	1393	6.9 (6.1–7.8)		
Yes	353	30.9 (26.8–35.0)	273	25.2 (19.9–30.5)	192	14.7 (11.4–18.0)	279	21.6 (18.3–24.8)	107	7.6 (5.6–9.6)		
Hypertension*											2.04	0.729
No	3124	30.7 (28.7–32.6)	2920	28.1 (26.2–30.1)	1468	13.2 (12.0–14.3)	2254	20.7 (19.2–22.3)	921	7.3 (6.4–8.1)		
Yes	2421	32.0 (29.7–34.3)	2074	27.6 (25.4–29.8)	1119	13.5 (12.0–15.1)	1771	20.1 (18.2–21.9)	631	6.8 (5.7–7.9)		

* Missing data in different subgroups include: annual household income ($n = 4$), age at smoking initiation ($n = 625$), smoking duration ($n = 625$), chronic respiratory symptoms ($n = 983$), COPD ($n = 2538$), chronic respiratory diseases ($n = 906$), chronic diseases ($n = 1777$), diabetes ($n = 447$), cardiovascular and cerebrovascular diseases ($n = 751$), and hypertension ($n = 272$).

† Agricultural workers: People engaged in agriculture, forestry, husbandry, fishery and water conservancy. No.: Frequency was unweighted; CI: Confidence interval; COPD: Chronic obstructive pulmonary disease.

ences ($P < 0.05$). The prevalence of medium–high nicotine dependence among patients with chronic respiratory symptoms, COPD, and chronic respiratory diseases was 53.6%, 43.9%, and 44.3%, respectively, which were significantly higher than those among participants without these conditions (39.0%, 41.5%, and 40.8%, respectively; all $P < 0.05$). Furthermore, the prevalence of high and very high nicotine dependence was 39.0%, 30.3%, and 32.0%, respectively, in patients with chronic respiratory symptoms, COPD, and chronic respiratory diseases, which were also significantly higher than those in participants without these conditions (25.7%, 28.1%, and 27.2%, respectively; all $P < 0.05$) (Supplementary Tables 1 and 2).

Among female smokers, there were statistically significant differences in the prevalences of medium–high as well as high and very high nicotine dependence among participants with different education levels and occupations ($P < 0.05$). These prevalences were the highest for women working in agriculture, forestry, husbandry, and fishery and water conservancy (35.9% and 25.5%) and for those with an education level of primary school or lower (35.7% and 23.0%). There were no significant differences in the level of nicotine dependence in terms of age group, age at smoking initiation, and smoking duration (all $P > 0.05$). The prevalences of high and very high nicotine dependence were 32.7% and 30.1%, respectively, in respondents with chronic respiratory symptoms and chronic respiratory diseases, which were higher than those in participants without these conditions (16.0% and 16.8%, respectively; $P < 0.05$) (Table 3, Supplementary Tables 1–2).

Multivariate analysis of factors associated with medium–high nicotine dependence

Multivariate logistic regression analysis was performed with medium–high nicotine dependence of current daily smokers as the dependent variable and sex, residence, age, marital status, annual household income, occupation, education level, age at smoking initiation, smoking duration, and region as independent variables. We found that sex, age, marital status, occupation, education level, age at smoking initiation, and smoking duration were influencing factors of nicotine dependence among current daily smokers. Daily smokers who were male (odds ratio [OR]=1.64, 95% CI: 1.19–2.25); 50-59 years old; unmarried/divorced/widowed/separated; engaged in agriculture, forestry, animal husbandry, fishery and water conservancy (*vs*. retired individuals, administrative officers/clerks/technical staff); and those with a low education level (OR=1.19, 95% CI: 1.05–1.34), an age at smoking initiation of <18 years (OR=1.68, 95% CI: 1.48–1.91), and/or a smoking duration of ≥20 years (OR=1.66, 95% CI: 1.12–2.46) were at high risk of developing medium–high nicotine dependence (Table 4).

Change in the prevalence of high nicotine dependence

The prevalence of high nicotine dependence among smokers aged ≥40 years in China decreased from 35.0% (95% CI: 33.0–36.9%) in 2014–2015 to 30.5% (95% CI: 28.5–32.5%) in 2019–2020 ($P < 0.001$). Similarly, a significant decrease was observed in men (35.8% to 31.0%, $P < 0.001$), residents of urban areas (33.1% to 29.1%, $P < 0.05$), and rural residents (36.5% to 32.2%, $P < 0.05$), but not in women (22.0% to 18.2%, $P > 0.05$). Furthermore, the prevalences of high nicotine dependence in North China, Eastern China, Southwest China, and Northwest China decreased by 6.7, 8.5, 4.3, and 9.9 percentage points, respectively (all $P < 0.05$). There was no significant change in the prevalences of high nicotine dependence in Central, South, and Northeast China (all $P > 0.05$) (Supplementary Table 5).

Among male smokers, the prevalence of high nicotine dependence decreased most significantly in the age groups 40–49 years and 50–59 years (both $P < 0.05$), down by 6.5 and 4.2 percentage points, respectively. Similarly, significant declines were observed in urban and rural residents (decreased by 4.1 and 4.6 percentage points, respectively; both $P < 0.05$); married/co-habiting respondents (decreased by 5.1 percentage points; $P < 0.001$); individuals engaged in manufacturing, transportation, and commerce; agriculture, forestry, husbandry, fishery and water conservancy, and administrative officers/clerks/technical staff or other employees/unemployed persons (all $P < 0.05$); in people with an educational level of primary school or below or middle school or above (decreased by 4.7 and 4.8 percentage points, respectively; $P < 0.001$ and $P = 0.001$); and in respondents with smoking duration ≥20 years (decreased by 5.2 percentage points; $P < 0.001$). The decline in smokers with a smoking duration of <20 years was not statistically significant (P=0.899). The decrease in high nicotine dependence among patients with chronic respiratory symptoms was significantly larger than that in asymptomatic participants (6.7 *vs*. 4.0 percentage points; $P = 0.001$ and $P < 0.001$). Additionally, the prevalence of high nicotine dependence declined significantly in patients with COPD (by 4.7 percentage points), patients with hypertension (by 5.1 percentage points), smokers without COPD (by 4.4 percentage points), and individuals without hypertension (by 3.9 percentage points) (all $P < 0.05$). However, there was no significant decrease in patients with chronic respiratory diseases, diabetes, or cardiovascular and cerebrovascular diseases (all $P > 0.05$) (Supplementary Table 6).

Among female smokers, the prevalence of high nicotine dependence among urban residents, individuals with an education level of middle school or above, and women with a smoking duration of ≥20 years decreased significantly by 6.9, 9.1, and 5.5 percentage points, respectively (all $P < 0.05$). The prevalence of high nicotine dependence also increased among smokers with chronic respiratory symptoms, COPD, chronic respiratory diseases, diabetes, and cardiovascular and cerebrovascular diseases, but the differences were not statistically significant (all $P > 0.05$) (Supplementary Table 7).

Discussion

In the present study, we used data from two nationally representative sample-based surveys in 2014–2015 and 2019–2020 to analyze the severity and changes in nicotine dependence among smokers aged ≥40 years in China. The results showed that the prevalence of medium–high nicotine dependence among daily smokers aged 40 years or older in China was 41.0% and the prevalence of high and very high nicotine dependence was 27.6% during the period 2019–2020. Based on the current smoking rate (27.2%)[29] in adults aged ≥40 years and 2020 national census data, there are approximately 69.41 million adults aged ≥40 years with medium–high nicotine dependence in China and 46.81 million with high and very high nicotine dependence. Compared with other countries, China has a higher prevalence of nicotine dependence among smokers aged ≥40 years. In the United States, the 2011 National Health and Wellness Survey data showed that the prevalence of high nicotine dependence among smokers aged 45–64 and ≥65 years was 30.2% and 22.1%, respectively.[21] In a study of adults in four Eastern European countries during 2009–2011, 25% of daily smokers were highly tobacco dependent.[30] In a study conducted in 18 European countries in 2010, 21.2% of smokers had high nicotine dependence.[31] The prevalence of nicotine dependence among smokers aged 35–49, 50–64, and ≥65 years in Singapore was 6.1%, 6.1% and 3.6%, respectively, according to the Singapore Mental Health Study 2016.[32] As a major tobacco consumer, China faces serious challenges in tobacco exposure control and smoking cessation interventions and treatments[12,33] owing to the high prevalence of tobacco use in the population[29] and high nicotine dependence among smokers.

Nicotine dependence is a major barrier to quitting smoking, and assessing smokers' FTND scores can help in developing individualized cessation plans and triage treatments to increase the chances of successful smoking cessation.[34] In the present study, the average FTND score among daily smokers was 3.9, which is close to the level in Russia (3.9), but lower than that in Azerbaijan (4.1), Georgia (4.6),[26,35] Viet Nam (5.1),[36] and Nepal (5.2).[37] The level of nicotine dependence was higher

Table 4
Logistic regression analysis of factors influencing nicotine dependence (FTND score ≥5).

Influencing factor	Total		Men		Women	
	OR value (95% CI)	*P* value	OR value (95% CI)	*P* value	OR value (95% CI)	*P* value
Sex						
Men	1.64 (1.19–2.25)	0.003	–	–	–	–
Women	1.00 (ref)		–		–	
Residence						
Urban	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Rural	1.09 (0.97–1.22)	0.131	1.09 (0.97–1.23)	0.138	1.08 (0.69–1.70)	0.729
Age						
40–49 years	0.86 (0.75–0.98)	0.025	0.86 (0.75–0.99)	0.035	0.63 (0.21–1.87)	0.399
50–59 years	1.15 (1.04–1.27)	0.008	1.15 (1.04–1.28)	0.008	1.08 (0.68–1.71)	0.739
≥60 years	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Marital status						
Married/co-habiting	0.78 (0.62–0.99)	0.038	0.75 (0.58–0.96)	0.025	1.38 (0.66–2.89)	0.384
Unmarried/divorced/widowed/separated	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Annual household income						
<11,000 RMB	0.85 (0.71–1.01)	0.069	0.83 (0.69–1.00)	0.052	1.55 (0.72–3.38)	0.262
11,001–30,000 RMB	0.99 (0.86–1.14)	0.851	0.96 (0.83–1.11)	0.595	2.05 (1.01–4.16)	0.047
30,001–56,001 RMB	0.98 (0.83–1.16)	0.823	0.96 (0.81–1.14)	0.639	2.39 (1.01–5.66)	0.047
56,001 RMB	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Occupation						
Agricultural workers*	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Manufacturing, transportation, and commerce	0.90 (0.69–1.17)	0.424	0.89 (0.68–1.15)	0.354	1.98 (0.31–12.84)	0.469
Administrative officers/clerks/technical staff	0.56 (0.45–0.70)	<0.001	0.55 (0.44–0.69)	<0.001	1.69 (0.35–8.31)	0.512
Other employees/unemployed persons	0.99 (0.87–1.12)	0.833	0.99 (0.87–1.13)	0.881	0.60 (0.24–1.48)	0.261
Housekeepers	1.07 (0.88–1.29)	0.521	1.02 (0.85–1.23)	0.808	1.32 (0.72–2.41)	0.360
Retired individuals	0.61 (0.47–0.79)	<0.001	0.61 (0.47–0.79)	0.000	0.78 (0.32–1.91)	0.584
Education level						
Primary school or lower	1.19 (1.05–1.34)	0.006	1.18 (1.05–1.34)	0.008	1.52 (0.77–3.02)	0.225
Middle school or higher	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Age at smoking initiation						
<18 years	1.68 (1.48–1.91)	<0.001	1.69 (1.47–1.93)	<0.001	1.06 (0.63–1.81)	0.815
≥18 years	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Smoking duration						
<20 years	1.00 (ref)		1.00 (ref)		1.00 (ref)	
≥20 years	1.66 (1.12–2.46)	0.012	1.83 (1.19–2.82)	0.007	1.21 (0.55–2.63)	0.637
Geographic region						
North China	0.92 (0.75–1.12)	0.391	0.95 (0.76–1.18)	0.629	0.62 (0.30–1.30)	0.205
Eastern China	0.96 (0.79–1.17)	0.661	0.98 (0.79–1.21)	0.818	0.92 (0.53–1.58)	0.750
Central China	0.99 (0.80–1.22)	0.927	1.02 (0.82–1.27)	0.859	0.69 (0.25–1.90)	0.465
South China	1.21 (0.91–1.62)	0.193	1.24 (0.91–1.70)	0.168	1.20 (0.30–4.92)	0.794
Southwest	0.87 (0.66–1.16)	0.352	0.90 (0.67–1.22)	0.487	0.64 (0.21–1.90)	0.413
Northwest	0.79 (0.61–1.02)	0.067	0.82 (0.63–1.06)	0.132	0.10 (0.01–1.27)	0.075
Northeast	1.00 (ref)		1.00 (ref)		1.00 (ref)	

* Agricultural workers: People engaged in agriculture, forestry, husbandry, fishery and water conservancy. CI: Confidence interval; FTND: Fagerström Test for Nicotine Dependence; OR: Odds ratio. –: Not applicable.

in men, who had higher FTND scores than women (3.9 *vs*. 3.2) and higher prevalences of medium–high as well as high and very high nicotine dependence. These findings are consistent with those of Cai et al,[11] Ma et al,[12] and Cong et al[33] in China and Shahwan et al[32] in Singapore. During 2019–2020, the prevalence of high nicotine dependence among smokers decreased by 4.5 percentage points compared with that during 2014–2015. This decline was not obvious and was slightly greater in men than in women (4.8 *vs*. 3.8 percentage points). As shown in our study, although the smoking rate among women in China was low, 30.6% of female smokers were moderately (or higher) tobacco dependent; therefore, smoking cessation interventions for women should not be overlooked. Furthermore, women are more likely to become addicted to nicotine and have more difficulty quitting smoking.[38] Nicotine dependence among women may continue to increase as more young women become accepting of smoking,[39] society becomes more tolerant of female smoking, and women's spending power grows.[40] Because women have greater responsibilities in caring for children, a change in women's smoking behavior and awareness will also greatly benefit their families.[41] Thus, health education on smoking cessation should be promoted among women, and woman-focused smoking cessation services should be offered.

Our study showed that men aged 50–59 years had the highest prevalences of medium–high as well as high and very high nicotine dependence, which was similar to the findings of Manimunda et al,[27] Liu et al,[41] and Han et al.[42] A possible explanation is that this subgroup has been smoking for an extended period and is still under considerable work pressure, which increases their likelihood of addiction. Among smokers with different occupations, manual laborers engaged in agriculture, forestry, husbandry, and fishery and water conservancy as well as unemployed people had higher levels of nicotine dependence, consistent with the findings of Cong et al.[33] Because individuals employed in low-wage or blue-collar positions experience greater job and economic insecurity and have higher rates of unemployment and workplace injuries, they are more likely to smoke and have an increased risk of developing high nicotine dependence.[43,44] Most of our participants aged 40–59 years were employed. Compared with the data during 2014–2015, the largest decrease in the prevalence of high nicotine dependence was in the age groups 40–49 and 50–59 years during 2019–2020, suggesting that tobacco control interventions may be more effective in working populations. Thus, workplaces and institutions should be mobilized to participate in smoking cessation intervention programs by incorporating smoking cessation into health management programs for employees and creating a smoke-free working environment.

Among people with lower levels of education, both men and women had higher levels of nicotine dependence and a higher risk of nicotine dependence, similar to the results of nationally representative surveys

conducted by Liu et al,[41] Cong et al,[33] and Grant et al.[45] These subgroups typically have low awareness about the hazards of smoking and their own health conditions, they are more susceptible to social context-based misinformation, and they have less access to smoking cessation services.[46] Additionally, men living alone have higher levels of nicotine dependence than those who have a spouse, and those who live alone are less likely to quit smoking, as observed by Pennanen et al.[47]

As shown in this study, people who started smoking at a younger age (i.e., smoking initiation before the age of 18 years) were more likely to develop higher levels of nicotine dependence, which was consistent with the findings of Roberts et al,[26] Cong et al,[33] and Yang et al.[48] Many factors may explain this phenomena. According to Yang et al,[49] the prevalence of nicotine dependence among adolescent smokers is approximately 40.0% worldwide, and factors such as secondhand smoke exposure, tobacco advertisement exposure, and smoking among parents and close friends are all associated with nicotine dependence among adolescents. According to the China National Youth Tobacco Survey in 2019, only 35.0%, 25.6%, and 26.2% of Chinese junior high school, senior high school, and vocational school students believed that it was hard to quit after starting to smoke,[50] highlighting the poor awareness about nicotine dependence among adolescents. Adolescence is a crucial stage for the development of smoking habits in many individuals,[51] and quitting smoking becomes more difficult as with older age.[34] A possible explanation is that the duration of smoking increases, nicotine is involved in strengthening brain circuits with the help of high-affinity isoforms of $\alpha 4$ and $\beta 2$ subunits ($\alpha 4\beta 2$ neuronal nicotinic acetylcholine receptors), promoting psychological and physiological dependence on tobacco.[52,53] Therefore, tobacco control interventions for adolescents are particularly important. Targeted measures for tobacco control should be developed, including raising adolescents' awareness about the hazards of smoking and nicotine dependence, addressing the challenges introduced by new tobacco products, and engaging adolescents in tobacco control efforts, thereby enabling young people to actively refuse tobacco and prevent initiation of smoking.[33] In addition, tobacco use is heritable behaviours.[54] It has been suggested that genetic influences may play an important role in vulnerability to nicotine addiction,[55] and familial aggregation was observed,[16] which also provides new guidance for the smoking cessation interventions.[56] Accumulating evidence supports a role for epigenetics in the development and maintenance of many substance addictions, however, the interaction between nicotine and specific epigenetic changes is likely complex, dynamic and context-specific, and the involvement of epigenetics in nicotine dependence is less clear. By continuous exploration of next-generation sequencing technologies, epigenetics provides a promising avenue for future interventions to treat nicotine dependence.[57]

In our study, the level of nicotine dependence differed among different geographic regions. The rate of nicotine dependence was relatively high in South China, with the prevalence of medium–high nicotine dependence reaching 52.4%, and more than one-third of smokers had high or very high nicotine dependence. Notably, the prevalence of medium–high nicotine dependence was as high as 39.5% among women in Northeast China. Compared with data in 2014–2015, the prevalence of high nicotine dependence in Northwest China decreased the most during 2019–2020 ($P < 0.001$), possibly because some provinces and cities in Northwest China (e.g., Yinchuan in Ningxia Hui Autonomous Region, Lanzhou in Gansu Province, and Xi'an in Shaanxi Province) successively strengthened their tobacco control regulations or policies between 2016 and 2018, along with an increase in tobacco taxes and cigarette prices.[58] The impact of regional culture, economic level, environment, and other factors on the prevalence of nicotine dependence should be further explored.[59] Region-specific tobacco control policies should be established and implemented, and the performance of tobacco control efforts should be evaluated regularly. Standardized smoking cessation clinics and smoking cessation services with local characteristics will help to lower the prevalence of nicotine dependence in different regions.[29]

Smoking is a main behavioral risk factor for chronic diseases such as respiratory diseases, cardiovascular and cerebrovascular diseases, and diabetes. Our study showed that the level of nicotine dependence was higher in patients with chronic respiratory symptoms, COPD, and chronic respiratory diseases, especially in men. Compared with the data in 2014–2015, the decline in the rate of high nicotine dependence was higher in male smokers with chronic respiratory symptoms than in asymptomatic patients and higher in patients with COPD than that in non-COPD patients. Additionally, the prevalence of high nicotine dependence was increased among female smokers with chronic respiratory symptoms, COPD, chronic respiratory diseases, diabetes, and cardiovascular and cerebrovascular diseases, although the differences were not statistically significant. Therefore, smoking cessation interventions for patients with chronic diseases in China have yielded some positive outcomes, but require further strengthening. Smoking cessation is the most important intervention to slow the progression of chronic respiratory disease.[60,61] Melzer et al[60] found that smoking cessation interventions were more effective in smokers with chronic respiratory diseases than in those without chronic respiratory diseases because the former had greater motivation to overcome nicotine dependence. Thus, interventions for smoking cessation in patients with chronic respiratory diseases are highly cost-effective and of great public health importance. Barriers and facilitators for smoking cessation in patients with chronic diseases should be adequately assessed, and smoking cessation treatments should be adjusted according to the needs of patients and the severity of nicotine dependence.[62]

Current smoking cessation services in China include brief cessation interventions and quit-smoking hotlines at the population level as well as smoking cessation clinics at the individual level,[63] all of which are effective in helping smokers to quit smoking.[64] Although the construction of comprehensive smoking cessation service systems in China has received extensive policy support,[65-67] these systems still face many difficulties and challenges such as a low utilization rate of brief cessation interventions, low accessibility to quit-smoking hotlines, a shortage of smoking cessation clinics, and insufficient capacity among medical staff to provide effective smoking cessation services. Thus, the awareness, accessibility, and utilization rates of smoking cessation services must be further improved.[68]

Integrating multiple models of smoking cessation services and incorporating smoking cessation into routine health care services can make full use of smoking cessation services, thereby raising the performance of smoking cessation interventions.[69,70] In line with recommendations of the World Health Organization's *Framework Convention on Tobacco Control*, smoking cessation interventions can be gradually integrated into the management of patients with chronic diseases.[63] Regular assessment of the severity of nicotine dependence and capacity-building for professional services, such as smoking cessation consultation, interventions, and treatments in grassroots medical institutions, will enable the provision of effective smoking cessation services to patients with nicotine dependence. New smoking cessation intervention technologies and service models can be actively explored, including the development of smoking cessation applications and online smoking cessation mini-programs. Diversified smoking cessation service resources can provide strong technical support for the improvement of China's smoking cessation service system and help meet the demand for professional smoking cessation services in China.[68]

The present study was based on two large-sample surveys covering 31 provinces (autonomous regions and municipalities) in China, with nationally representative samples, strict survey quality control measures, and high data quality. However, the surveys were based on face-to-face interviews, during which there might be recall bias present in the collected information such as age at smoking initiation, daily cigarette consumption, and time to first cigarette. Additionally, only nicotine dependence among smokers of factory-made cigarettes was analyzed in our study; other types of tobacco such as hand-rolled cigarettes and

hookahs were not included, which might have a certain impact on the results of our study and should be explored in future research.

In summary, this study revealed the level of nicotine dependence among smokers aged ≥40 years in China remains high, with more than 40% of patients having medium or higher nicotine dependence and only a small decline in the prevalence of high nicotine dependence. There are approximately 69.41 million individuals aged ≥40 years with medium or higher nicotine dependence. The findings highlight that the large tobacco-dependent population has led to a substantial demand for smoking cessation intervention services, and tobacco control as well as prevention and control of smoking-related diseases still face many challenges. Construction of smoking cessation service systems, especially regarding capacity-building for professional smoking cessation interventions in grassroots medical institutions, will help to integrate smoking cessation services into the management of chronic diseases and thus effectively reduce the tobacco use and the burden of nicotine dependence. The results of this study can inform scientific, feasible, and effective region- and population-tailored tobacco control measures that can help improve public health outcomes in China and beyond.

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Declaration of competing interest

Authors have declared that no conflict of interest exists.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.pccm.2024.05.003.

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