Preventive Medicine Reports 46 (2024) 102865

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

The economic cost of direct smoking in South Korea

Kristine Namhee Kwon [a,1,2], Kangyeon Lee [b,1,3], Wankyo Chung [c,*,4]

[a] Department of Health Policy and Management, Milken Institute School of Public Health, George Washington University, Washington, DC, USA
[b] Division of Health Services Management and Policy, College of Public Health, The Ohio State University, Columbus, OH, USA
[c] Department of Public Health Sciences, Graduate School of Public Health, Seoul National University, Seoul, South Korea

ARTICLE INFO

Keywords:
Smoking
Direct smoking
Socioeconomic cost of smoking
Smoking-related diseases
Smoking policy
Cost-of-illness

ABSTRACT

Background: Smoking not only causes negative health outcomes for individuals but also causes an economic burden to society. This study estimated the socioeconomic costs of direct smoking in South Korea in 2020.
Methods: We used the prevalence-based cost-of-illness approach to estimate the sum of the direct (medical, transportation, and caregiving) and indirect (productivity loss due to health service utilization and premature death) costs of 41 smoking-related diseases. We assumed that diseases with death-based hazard ratios greater than 1.0 were related to smoking and used them in cost estimation.
Results: The socioeconomic cost of direct smoking in Korea was USD 10.9 billion in 2020, accounting for 0.67 % of the gross domestic product and 8.0 % of current health expenditures. The direct cost was USD 4,172 million and the indirect cost was USD 6,753 million. The cost of productivity loss due to premature death took up the largest amount of the total cost, accounting for 52.3 %. The amount attributed to males accounted for 90.4 % of the overall cost, totaling to USD 9,877 million. This is attributable to higher smoking rates and higher medical costs in men. Cancer costs accounted for 40.0 % of the total cost, causing the greatest burden of diseases.
Conclusion: Direct smoking imposed a harmful and heavy economic burden on South Korea. Our estimate provides the latest evidence on the financial burden of smoking and strengthens the case for strong tobacco control policies and interventions.

1. Introduction

Smoking has been identified as one of the leading causes of preventable deaths and disability since the early 1960s (Office of Surgeon General, 2004; Murray and Lopez, 1997; Goodchild et al., 2018). South Korea's current adult smoking rate is 19.3 % (male 31.3 %, female 6.9 %) in 2021, based on the Korea National Health and Nutrition Examination Survey (Korea Centers for Disease Control and Prevention, 2021). Even though the smoking rates for men have decreased by half from 66.3 % in 1993, the declining trend has tended to slow down after 2008 (27.8 %), and the smoking rates for women have remained almost unchanged over the past 20 years. Diseases caused by smoking have led not only to direct medical expenses, but also premature death and productivity loss, resulting in significant social and economic burdens. Therefore, periodic monitoring of the social and economic costs of smoking is essential to devise relevant policies and tobacco regulations.

The socioeconomic burden of smoking has been quantified in several countries since the 1990s (WHO, 2011). In 2011, the World Health Organization (WHO) issued clear guidelines for assessing the economic costs of smoking (WHO, 2011). The WHO standard methodology includes direct (healthcare and non-healthcare) and indirect (morbidity and mortality) costs. Some countries have modified their WHO methodologies slightly based on data availability and policy priorities.

Previous studies have used different but limited smoking-related outcome measures, such as disability-adjusted life years (DALYs) (Reitsma et al., 2021), medical costs (Dixon et al., 2022; Xu et al., 2021; Callum et al., 2011; Pichon-Riviere et al., 2020; Castillo-Riquelme et al., 2020), number of deaths (Reitsma et al., 2021; Castillo-Riquelme et al., 2020) and years of life lost (Castillo-Riquelme et al., 2020). Research has been conducted on individual nations such as Thailand

* Corresponding author.
E-mail address: wankyo@snu.ac.kr (W. Chung).
[1] Kristine Namhee Kwon and Kangyeon Lee contributed equally to this work as first authors.
[2] ORCID iD: http://orcid.org/0000-0002-3419-999X.
[3] ORCID iD: http://orcid.org/0009-0000-2278-8407.
[4] ORCID iD: https://orcid.org/0000-0001-8094-2433.

https://doi.org/10.1016/j.pmedr.2024.102865
Received 4 March 2024; Received in revised form 12 August 2024; Accepted 13 August 2024
Available online 23 August 2024

(Bundhamcharoen et al., 2016; Komonpaisarn, 2022), Indonesia (Meilissa et al., 2022), India (John et al., 2021), and Vietnam (Hoang Anh et al., 2016). Additionally, studies have focused on specific regions, including California in the United States (Max et al., 2016), as well as broader areas like the Gulf Cooperation Council countries (Koronaiou et al., 2021) and South Africa (Boachie et al., 2021). Recent systematic reviews have highlighted considerable heterogeneity across studies, acknowledging different smoking-related diseases, partial utilization of cost measures, and lack of recent evidence (Rezaei et al., 2016; Feirman et al., 2016).

Studies of the costs of smoking in Korea since the late 1980s have had similar limitations (Kim et al., 2001). They used a limited range of smoking-related diseases (Kim et al., 2001; Park et al., 2008), covered only current smokers (Yoo, 2018), and excluded the unemployed population when estimating costs associated with productivity losses (Ra et al., 2024). We address these gaps by including 41 smoking-related diseases based on nationally representative data sources and covering both current and former smoking rates, with current rates of 65.6 % for men and 6.4 % for women, and former rates of 16.5 % for men and 1.6 % for women (Nam et al., 1995). We also included productivity losses for the unemployed, such as older adults, women, children, etc.

Compared to previous literature, our study makes a number of novel contributions. First, we comprehensively estimated the economic burden of smoking by calculating both direct and indirect costs, following the WHO standard guidelines (WHO, 2011). Second, we utilized nationally representative data sources from the national health insurance claims data, which covers the whole population of South Korea. Third, we stratified the cost by sex and disease groups. Lastly, we performed a sensitivity analysis on productivity loss due to premature death using the value of statistical life. This study aims to estimate the total cost of direct smoking in South Korea. Direct smoking in our study refers to firsthand cigarette smoking.

2. Methods

We used prevalence-based cost-of-illness (COI) approach following the WHO toolkit for estimating the socioeconomic cost of smoking (WHO, 2011). Socioeconomic costs are categorized as direct and indirect costs. Direct costs are directly related to health service utilization, including medical, transportation, and caregiving costs. Indirect costs include productivity losses due to premature death and medical utilization caused by smoking-related diseases. Table 1 lists the cost variables, data sources, and data institutions. All variables are presented as 2020 values. This study was approved by the IRB (IRB no. E2202/004-010) of Seoul National University, Republic of Korea.

2.1. Smoking-attributable diseases

We selected 41 smoking-related diseases based on the study by Cheon et al. (2024), who reported the number of deaths caused by smoking in Korea according to the Framework Convention on Tobacco Control. The selected diseases were categorized as cancer, circulatory diseases, other diseases, and external causes.

2.2. Population-attributable fraction (PAF)

The target population was adults aged over 30, considering the starting age of smoking, duration of smoking, and the pathogenesis of smoking-related diseases. We employed the 1995 smoking rates in Korea to reflect the latent period between exposure to smoking and consequent health outcomes (Nam et al., 1995). The smoking rates were as follows: male current smoking rate, 65.6 %; male former smoking rate, 16.5 %; female current smoking rate, 6.4 %; and female former smoking rate, 1.6 %. We used the death-based hazard ratios for each disease according to sex and smoking status employed from Cheon et al. (2024).

We assumed that diseases with hazard ratios greater than 1.0 were related to smoking regardless of their statistical significance. The population attributable fraction (PAF_{ij}) by disease i and sex j is calculated using the following formula (WHO, 2011):

$$PAF_{ij} = \frac{P_{fj}(HR_{fij} - 1) + P_{cj}(HR_{cij} - 1)}{1 + P_{fj}(HR_{fij} - 1) + P_{cj}(HR_{cij} - 1)}$$

where $p_{\bullet j}$ represents current (c) and former (f) smoking rates by sex j. $HR_{\bullet ij}$ denotes the hazard ratio of each smoking-related disease by disease i and sex j.

Table 1
Summary of direct and indirect cost variables and data sources in South Korea.

Cost Variables	Data Sources (Institution)
Direct Cost	
Medical Cost	
Covered cost for inpatient, outpatient, or pharmaceutical (by sex and disease)	National Health Insurance Claims Data (NHIS, 2022)
Uncovered cost (by sex and disease)	Health Insurance Patients' Medical Expenditure Survey (NHIS, 2020)
Transportation Cost	
Number of inpatient or outpatient visits (by sex and disease)	National Health Insurance Claims Data (NHIS, 2022)
Transportation expense	Korea Health Panel Survey (KIHASA, 2019)
Consumer Price Index	(Statistics Korea, 2020)
Caregiving Cost	
Days of hospitalization (by disease)	National Health Insurance Claims Data (NHIS, 2022)
Average caregiving cost per day	Medical Service Experience Survey (KIHASA, 2019)
Rate of caregiving utilization	Korea Health Panel Survey (KIHASA, 2019)
Consumer Price Index	(Statistics Korea)
Indirect Cost	
Productivity Loss due to Premature Deaths	
Number of deaths (by sex, age, and disease)	Causes of Death Statistics (Statistics Korea, 2020)
Survival rate (by age)	Life table (Statistics Korea, 2020)
Average wage (by age)	Local Area Labour Force Survey (Statistics Korea, 2020)
Value of life (by sex, and age)	Life table (Statistics Korea, 2020)
Productivity Loss due to Medical Utilization	
Days of hospitalization (by sex, age, and disease)	National Health Insurance Claims Data (NHIS, 2022)
Number of outpatient visits (by sex, age, and disease)	National Health Insurance Claims Data (NHIS, 2022)
Average wage (by sex, and age)	Local Area Labour Force Survey (Statistics Korea, 2020)

Abbreviations: NHIS, National Health Insurance Service; KIHASA, Korea Institute for Health and Social Affairs.

2.3. Direct cost

The direct cost (DC), the sum of medical, transportation, and caregiving costs, was calculated as follows:

$$DC = \sum_i \sum_j PAF_{ij} \times (MC_{ij} + TC_{ij} + CC_{ij})$$

The medical cost (MC_{ij}) was estimated using the total inpatient cost I_{ij}, outpatient cost O_{ij}, and pharmaceutical cost P_{ij} for each disease i and sex j, using the following formula:

$$MC_{ij} = \frac{I_{ij}}{1-\alpha} + \frac{O_{ij}}{1-\beta} + \frac{P_{ij}}{1-\gamma}$$

Because there are additional medical costs not covered by National

Health Insurance but needs to be added up to make total medical cost, we inflated the medical costs I_{ij}, O_{ij}, and P_{ij} covered by National Health Insurance with non-reimbursement rates of α, β, and γ in 2020 as reported by 14.3 %, 22.5 %, and 2.4 % respectively (Health Insurance Patients' Medical Expenditure Survey in Table 1).

Transportation cost (TC_{ij}) was calculated using the number of inpatient visits IV_{ij} and outpatient visits OV_{ij}. T represents the average transportation cost of a round trip to a hospital. The formula used is as follows:

$$TC_{ij} = (IV_{ij} \times T) + (OV_{ij} \times T)$$

We used the 2019 average transportation cost and converted it to 2020 value using the Consumer Price Index. The transportation for inpatient services costs USD 31.9, while that of outpatient service costed USD 3.7 (Korea Health Panel Survey in Table 1).

The caregiving cost (CC_{ij}) is estimated with the length-of-stay in the hospital LOS_{ij}, the average caregiving cost per day ACD, and rate of caregiving utilization δ. The formula used is as follows:

$$CC_{ij} = LOS_{ij} \times ACD \times \delta$$

The average caregiving cost per day is reported annually and is approximately USD 72.5 in 2020 (Medical Service Experience Survey in Table 1). The rate of caregiving utilization is 72.06 % in 2020 (Korea Health Panel Survey in Table 1).

2.4. Indirect cost

Indirect cost (IC) is the opportunity cost of productivity loss due to health-service utilization ($PL1_{ijk}$) and premature death ($PL2_{ijk}$) caused by smoking-related diseases. It was calculated as:

$$IC = \sum_i \sum_j \sum_k PAF_{ij} \times (PL1_{ijk} + PL2_{ijk})$$

The cost of productivity loss due to health-service utilization for smoking-related diseases ($PL1_{ijk}$) was calculated using the value of time AE_k, length-of-stay in the hospital ID_{ijk}, and number of outpatient visits OD_{ijk} by disease i, sex j, and age k. This study assumed a one-day loss for inpatient services and a one-third-day loss for outpatient services. The formula used is as follows:

$$PL1_{ijk} = AE_k \times \{ID_{ijk} + \frac{1}{3} OD_{ijk}\}$$

The value of time is estimated based on potential wage loss, regardless of employment status (Health Insurance Review and Assessment Service, 2021). The logged hourly wages by age (Local Area Labour Force Survey in Table 1) were regressed on a quadratic function of age. We then exponentiated the predicted values from the regression to produce the time values for all ages.

Finally, the cost of productivity loss due to premature death ($PL2_{ijk}$) is estimated using the number of deaths from smoking-related diseases (D_{ijk}) and the value of life (V_{jk}). The formula used is as follows:

$$PL2_{ijk} = D_{ijk} \times V_{jk}$$

The following formula based on human capital approach was used to estimate the value of life V(k) by sex j and age k using the 2020 values:

$$\mathrm{V}(k) = \int_k^{\infty} e^{-r(t-k)} W(t) \frac{S(t)}{S(k)} dt \approx \sum_{t=k}^{100} \frac{W(\alpha) \frac{S(t)}{S(k)}}{(1+r)^{t-k}}$$

Conditional on survival to each age, prospective annual wage by age was discounted into values of life at each age k. To allow a nonlinear continuous function for annual wage across ages, it was assumed that wages of 65 years of age and above decline by 5 % per year (Chung, 2014). A social discount rate r of 4.5 % was applied (Ministry of Economy and Finance, 2019; Health Insurance Review and Assessment Service, 2021). Based on our estimates, the value of life for men is lowest at age 100 (USD 3,200) and highest at age 31 (USD 579,900). For women, the value of life is also lowest at age 100 (USD 3,200) and highest at age 31 (USD 581,200).

2.5. Sensitivity analysis

We conducted two sensitivity analyses. First, given the challenge of selecting diseases with a causal relation to smoking, we used only diseases with statistically significant hazard ratios in our cost estimation. Second, we used the value of statistical life (VSL), which is based on an individual's willingness-to-pay (WTP) for risk reduction, to estimate the productivity loss due to premature death (Viscusi, 2008). Our primary method, the human capital approach, utilizes discounted expected lifetime earnings as the main determinant of the value of life, which may potentially underestimate it. According to Viscusi (2021), the estimated VSL as of January 1, 2021, was USD 11.0 million for the United States and USD 6.7 million for Korea, taking into account the differences in GDP per capita between the two countries. Therefore, we used USD 6.7 million as the value of life in 2020 for the sensitivity analysis.

3. Results

The socioeconomic cost of diseases caused by direct smoking in Korea was USD 10.9 billion in 2020 (Table 2). Direct cost was USD 4,172 million, whereas indirect cost was USD 6,753 million, taking up 61.8 % of the total cost. Among the five cost categories, cost of productivity loss due to premature death amounted to USD 5,710 million, 52.3 % of the total cost, followed by medical costs, 33.7 % of the total cost. The cost attributable to males was USD 9,877 million (90.4 %), while the cost attributed to females was USD 1,048 million. The higher costs for males appear to be attributable to the high rates of smoking and medical costs.

The cost of cancer was USD 4,365 million, accounting for the largest proportion of the total cost at 40.0 %, followed by circulatory diseases (30.3 %), other diseases (22.6 %), and external causes (7.1 %). While the cost of cancer was the highest for males, covering 41.5 % of the male total cost, the cost of circulatory diseases was the highest for females, accounting for 37.3 % of the female total cost.

It was lung cancer (C34) that showed the highest socioeconomic cost, accounting for 19.1 %, followed by stroke (I60-I69) (10.3 %), ischemic heart diseases (I20-I25) (10.0 %), diabetes mellitus (E10-E14) (8.2 %), and hypertensive diseases (I10-I13) (6.6 %). As for male costs, lung cancer still had the highest cost at 19.8 %, followed by ischemic heart disease, stroke, and diabetes mellitus. Unlike male costs, stroke accounted for the largest share at 13.1 % for the female costs, which was followed by lung cancer, hypertensive diseases, and organic, including symptomatic mental disorders (F00-F09).

Direct costs of medical cost, transportation cost, and caregiving cost was USD 4,172 million, covering 38.2 % of the total cost. Indirect cost of productivity losses due to health service utilization and premature death due to smoking-related diseases was USD 6,753 million (61.8 %) (Table 3).

Among costs for males, the cost of productivity loss due to premature death was the largest at USD 5,289 million (53.6 %), followed by medical cost at USD 3,270 million (33.1 %), cost of productivity loss due to health service utilization (9.3 %), caregiving costs (3.5 %), and transportation costs (0.6 %). Among female costs, the cost of productivity loss due to premature death was also the largest at USD 421 million (40.1 %), followed by medical cost at USD 413 million (39.4 %), cost of productivity loss due to health service utilization (12.1 %), caregiving costs (7.5 %), and transportation costs (0.9 %).

Notably, the cost of productivity loss due to premature death includes external causes such as accidents, suicide, and homicide. While the data from Statistics Korea included external causes, data from the

Table 2
Socioeconomic cost of smoking by sex and diseases in South Korea, 2020.

Unit:	ICD-10	Male Cost			Female Cost			Total Cost
USD Million*		Direct	Indirect	Total	Direct	Indirect	Total	
All Causes		**3670.8**	**6205.8**	**9876.6**	**500.8**	**547.3**	**1048.1**	**10924.7**
Cancer		**1236.5**	**2859.1**	**4095.7**	**101.7**	**167.5**	**269.2**	**4364.9**
Oropharynx	C00-C14	43.5	79.3	122.9	1.1	1.7	2.9	125.7
Esophagus	C15	62.5	139.0	201.5	1.4	3.9	5.3	206.8
Stomach	C16	132.5	275.9	408.4	4.5	10.1	14.6	423.0
Small Intestine	C17	5.5	10.5	16.0	0.1	0.1	0.2	16.2
Colon	C18	28.4	46.7	75.1	4.5	7.2	11.7	86.8
Rectum	C19, C20	48.1	73.9	122.0	2.9	4.3	7.2	129.2
Liver	C22	169.2	477.2	646.4	6.0	13.5	19.5	665.9
Gallbladder	C23, C24	22.7	57.7	80.3	2.6	6.3	8.9	89.3
Pancreas	C25	38.9	141.4	180.3	2.7	8.7	11.4	191.7
Larynx	C32	27.2	31.9	59.1	0.8	0.8	1.6	60.7
Lung	C34	552.6	1398.6	1951.2	48.5	82.2	130.7	2081.9
Breast	C50	1.0	0.7	1.7	15.5	13.1	28.6	30.3
Cervix	C53	–	–	–	6.0	10.0	15.9	15.9
Ovary	C56	–	–	–	1.3	2.4	3.8	3.8
Bladder	C67	55.5	60.3	115.8	1.9	2.1	4.1	119.9
Kidney	C64	13.3	20.7	33.9	0.3	0.4	0.6	34.5
Prostate	C61	7.3	4.6	11.8	–	–	–	11.8
Brain	C71	6.3	18.7	25.0	–	–	–	25.0
Thyroid	C73	1.0	0.6	1.6	1.7	0.7	2.4	4.0
Leukemia	C91-C95	21.1	21.5	42.6	–	–	–	42.6
Circulatory		**1461.4**	**1460.6**	**2922.0**	**225.6**	**165.8**	**391.3**	**3313.3**
Hypertensive D[1].	I10-I13	383.7	212.0	595.7	84.8	40.2	125.0	720.8
Ischemic heart D[1].	I20-I25	453.1	563.6	1016.7	35.1	35.9	71.0	1087.7
Arrhythmia	I47-I49	35.1	19.1	54.2	7.9	4.2	12.1	66.3
Heart Failure	I50	24.4	48.0	72.5	8.1	14.3	22.3	94.8
Stroke	I60-I69	447.5	543.4	990.9	74.9	61.9	136.8	1127.7
Atherosclerosis	I70-I74	117.6	74.4	192.0	14.9	9.2	24.1	216.0
Other Diseases		**972.8**	**1181.6**	**2154.4**	**173.5**	**138.8**	**312.3**	**2466.7**
Diabetes Mellitus	E10-E14	465.5	341.2	806.7	55.5	31.3	86.8	893.5
Organic[2]	F00-F09	144.7	88.8	233.5	70.5	23.7	94.2	327.7
Sudden Death	R96	0.0	22.6	22.6	0.0	1.4	1.4	24.1
Aging	R54	0.1	60.1	60.2	0.1	19.6	19.6	79.8
COPD[3]	J44	101.8	180.1	281.9	8.6	13.8	22.4	304.3
Tuberculosis	A15-A19	25.5	33.9	59.4	2.1	1.7	3.8	63.2
Pneumonia	J09-J18	143.0	323.0	466.0	18.6	33.4	52.1	518.1
Ulcer	K25-K27	63.0	38.5	101.5	14.8	8.2	23.0	124.4
Liver Cirrhosis	K74	29.2	93.4	122.6	3.2	5.8	9.0	131.6
External Causes		–	**704.6**	**704.6**	–	**75.2**	**75.2**	**779.8**
Accident	V01-V99	–	60.8	60.8	–	5.7	5.7	66.5
Poisoning	X40-X49	–	13.6	13.6	–	1.3	1.3	14.9
Unspecified Causes	X58-X59	–	10.8	10.8	–	1.8	1.8	12.6
Suicide	X60-X84	–	570.6	570.6	–	61.0	61.0	631.6
Homicide	X85-Y09	–	8.9	8.9	–	3.8	3.8	12.7
Injury Undetermined	Y10-Y34	–	39.9	39.9	–	1.6	1.6	41.5

Abbreviations: [1]D, diseases; [2]Organic, including symptomatic and mental disorders; [3]COPD, chronic obstructive pulmonary disease.
* USD 1 equal to KRW 1180 as of 2020 (Bank of Korea, 2023).

National Health Insurance did not cover medical costs if the cause was intentional, extremely negligent, or criminal. Therefore, neither the direct costs nor the cost of productivity loss due to health service utilization can be measured for external causes.

4. Sensitivity analyses

Although we used more representative hazard ratios, estimated from four large Korean cohorts and a *meta*-analysis (Cheon et al., 2024), the cost of smoking was estimated based on the assumption that diseases with hazard ratios greater than 1.0 were related to smoking regardless of their statistical significance. When we used only statistically significant hazard ratios for a sensitivity analysis (10 diseases for male former smokers and 35 diseases for male current smokers; 18 diseases for female former smokers and 31 diseases for female current smokers), the total cost of smoking was estimated at USD 10.8 billion, which is a 1.5 % reduction from our estimate.

We estimated the productivity loss due to premature death using the human capital approach. Primarily, the number of Koreans who experienced premature death due to smoking was estimated to be 39,927, of which 35,680 (89.4 %) were male and 4,247 (10.6 %) were female in 2020. Divided into individual disease groups, 18,860 (47.2 %) were due to cancer, followed by external causes (9,801 persons, 24.5 %) and circulatory diseases (8,575 persons, 21.5 %).

When we applied the VSL of Viscusi (2021) to calculate the productivity loss due to premature death for further sensitivity analysis, the total socioeconomic cost of smoking was estimated to be USD 270.9 billion (Table 4), accounting for 16.5 % of the total GDP of Korea (World

Table 3
Socioeconomic cost of smoking by sex, disease group, and cost variables in South Korea, 2020.

Unit: USD Million*	Direct Cost				Indirect Cost			Total Cost
	Medical	Transportation	Caregiving	Total Direct Cost	Productivity Loss due to Medical Utilization	Productivity Loss due to Premature Deaths	Total Indirect Cost	
Total								
All Causes	**3681.8**	**70.5**	**419.3**	**4171.6**	**1043.2**	**5709.9**	**6753.1**	**10924.7**
Cancer	1226.4	11.0	100.9	1338.3	204.4	2822.2	3026.6	4364.9
Circulatory	1510.4	34.1	142.4	1687.0	466.6	1159.7	1626.3	3313.3
Other	944.9	25.5	176.0	1146.4	372.2	948.2	1320.4	2466.7
External Causes	–	–	–	–	–	779.8	779.8	779.8
Male								
All Causes	**3269.1**	**60.9**	**340.7**	**3670.8**	**916.6**	**5289.2**	**6205.8**	**9876.6**
Cancer	1133.4	10.2	93.0	1236.5	187.8	2671.4	2859.1	4095.7
Circulatory	1314.4	28.6	118.3	1461.4	406.7	1053.9	1460.6	2922.0
Other	821.3	22.1	129.4	972.8	322.2	859.4	1181.6	2154.4
External Causes	–	–	–	–	–	704.6	704.6	704.6
Female								
All Causes	**412.7**	**9.6**	**78.6**	**500.8**	**126.6**	**420.7**	**547.3**	**1048.1**
Cancer	93.0	0.8	7.9	101.7	16.6	150.9	167.5	269.2
Circulatory	196.0	5.5	24.1	225.6	60.0	105.8	165.8	391.3
Other	123.6	3.4	46.5	173.5	50.0	88.8	138.8	312.3
External Causes	–	–	–	–	–	75.2	75.2	75.2

Note: * USD 1 equal to KRW 1180 as of 2020 (Bank of Korea, 2023).

Table 4
Sensitivity Analysis using Value of Statistical Life: Socioeconomic Cost of Smoking by Sex and Disease Group in South Korea, 2020.

	Number of Premature Deaths due to Smoking (Unit: Persons)	Socioeconomic Cost of Smoking (Unit: USD Million)			
		Our Study's Result		Viscusi (2021)'s VSL Applied	
		Productivity Loss due to Premature Deaths	Total Cost	Productivity Loss due to Premature Deaths	Total Cost
Total					
All Causes	**39,927**	**5709.9**	**10924.7**	**265713.2**	**270928.0**
Cancer	18,860	2822.2	4364.9	125510.9	127053.6
Circulatory	8,575	1159.7	3313.3	57066.6	59220.2
Other	2,691	948.2	2466.7	17908.6	19427.1
External Causes	9,801	779.8	779.8	65227.1	65227.1
Male					
All Causes	**35,680**	**5289.2**	**9876.6**	**237451.1**	**242038.5**
Cancer	17,802	2671.4	4095.7	118470.7	119895.0
Circulatory	7,185	1053.9	2922.0	47818.3	49686.4
Other	2,413	859.4	2154.4	16059.1	17354.2
External Causes	8,280	704.6	704.6	55103.0	55103.0
Female					
All Causes	**4,247**	**420.7**	**1048.1**	**28262.0**	**28889.4**
Cancer	1,058	150.9	269.2	7040.2	7158.5
Circulatory	1,390	105.8	391.3	9248.3	9533.8
Other	278	88.8	312.3	1849.4	2073.0
External Causes	1,521	75.2	75.2	10124.2	10124.2

Abbreviation: VSL, Value of Statistical Life.

Bank, 2023). Of these, cancer accounted for USD 127.1 billion (46.9 %), followed by USD 65.2 billion (24.1 %) for external causes and USD 59.2 billion (21.9 %) for circulatory diseases.

5. Discussion

The socioeconomic cost of direct smoking was USD 10.9 billion in 2020, with male costs accounting for 90.4 % of the total cost. This result is mainly because the smoking rate for males is higher than the smoking rates for females. The low rates of female smoking were partly attributable to female's hesitation to report smoking. Females tend to hide their smoking status, resulting in under-reporting (Jung-Choi et al., 2012; Park et al., 2014). On one hand, the cost of smoking may be higher when hidden smoking is considered. On the other hand, if data on

secondhand smoke from outdoors, homes, or work were available, the female cost of secondhand smoke could be larger than that of males (Komonpaisarn, 2022).

The socioeconomic cost of smoking may be lower than it would normally be due to the COVID-19 pandemic. COVID-19 patients took priority over others, even for declining health services due to fear of infection. According to the claims data from the National Health Insurance Service (NHIS), medical services declined by 11.3 % for length-of-stays in the hospital and 1.2 % in the number of outpatient visits in 2020 compared to those in 2019 based on our calculation. Closer attention to subsequent estimations is necessary when considering the likely recovery of health service utilization, as the WHO determined that COVID-19 will no longer be a public health emergency of international concern in May 2023.

The cost of smoking was equivalent to 0.67 % of the 2020 GDP and 8.0 % of current health expenditures in Korea (OECD, 2023). Although direct comparisons with results from other countries are difficult because of differences in smoking prevalence, relative risk, value of life, and health care systems, the results are comparable with those from other countries. A systematic review of the costs of smoking that included studies from 12 countries (Germany, India, the United Kingdom, Korea, Taiwan, China, Sweden, Thailand, Hong Kong, Vietnam, and Israel) found that smoking-related costs in these countries accounted for 0.22–0.88 % of GDP and 1.5–6.0 % of national health expenditures (Rezaei et al., 2016).

Compared with previous studies in Korea, our estimates were relatively large. Using a prevalence-based and disease-specific approach, Park et al. (2008) estimated the economic burden of smoking to range from USD 2,799 million to USD 3,445 million in 2007. The most recent estimate was USD 9.6 billion in 2020 (Ra et al., 2024). Our result was due to major differences in the number of smoking-related diseases considered (Park et al., 2008) and the inclusion of productivity losses for the unemployed (Ra et al., 2024).

Government-level initiatives are essential to reduce smoking rates and prevent harmful health consequences. Adult male smoking rate in Korea has decreased from 43.3 % in 2012 to 31.3 % in 2021, whereas adult female smoking rate have changed insignificantly from 7.4 % in 2012 to 6.9 % in 2021 (Korea Centers for Disease Control and Prevention, 2023). Since the enactment of the Tobacco Business Act in 1986, Korea has steadily implemented tobacco control policies, including increasing selling prices, strengthening the indication of warning pictures and words, and imposing national health promotion charges on tobacco-like products (Lee et al., 2020; Cho et al., 2022). Recently, the government aimed to reduce smoking rates to 29 % for adult males and to 6 % for adult females by 2030 under the 5th National Health Plan (HP2030). Our study provides scientific evidence for more substantial tobacco policy measures to reduce smoking rates and meet the national goal.

Our study had some limitations. First, the cost of secondhand smoke could not be estimated owing to data limitations. Although the Korea National Health and Nutrition Examination Survey (KNHANES) collects data on indoor secondhand smoke among people who do not smoke at work, home, and public places, its reliability is low because it is based on the respondent's memory and is limited to the last seven days. Second, we did not consider the changes in smoking rates over time. The cost of smoking may have changed in accordance with the changes in smoking rates over the last 30 years, especially in males. Third, we targeted a population aged over 30 years considering the long-term pathogenesis of smoking-related diseases. Future research should examine age-specific costs to account for the potentially different effects of smoking in different age groups. Finally, the cost of female may be underestimated due to the under-reporting of female smoking in Korea.

Despite these limitations, this study makes several contributions to literature. First, we comprehensively estimated the cost of smoking, covering not only direct medical but also non-medical costs. Second, we used various nationally representative and reliable data sources. Third, we estimated the cost of smoking according to 41 smoking-related diseases in detail. Finally, we performed a sensitivity analysis of productivity loss due to premature death using the value of statistical life (Viscusi, 2021).

6. Conclusion

The cost of direct smoking in Korea was USD 10.9 billion, or 0.67 % of the GDP in 2020. The cost of productivity loss due to premature death accounted for the largest proportion, taking up 52.3 % of the total cost. Owing to the high smoking rate, costs attributed to males accounted for 90.4 % of total costs.

Periodic monitoring of socioeconomic costs of smoking is crucial for promoting tobacco control policies. Long-term and consistent estimates of smoking-related costs must be considered to provide vital evidence for implementing tobacco control measures.

Ethical approval

This study was approved by the IRB (IRB no. E2202/004-010) of Seoul National University, Republic of Korea.

Funding source

This work is supported by the Korea Disease Control and Prevention Agency (KDCA), South Korea (Research no. 2023-12-104) as part of the research project 'Study on attributable mortality and socioeconomic burden of smoking in South Korea.' The funder was not involved and did not have any input in the design, analysis and reporting of this study.

9. Authorship contribution statement

KNK and KL equally contributed to this paper. K.N. Kwon: Conceptualization, Data Curation, Writing – original draft. K. Lee: Conceptualization, Formal analysis, Writing – original draft. W. Chung: Conceptualization, Methodology, Formal analysis, Writing – review & editing, Supervision.

10. Disclaimer

The authors alone are responsible for the views expressed in this article, and they do not necessarily represent the views, decisions or policies of the institutions with which they are affiliated.

CRediT authorship contribution statement

Kristine Namhee Kwon: Writing – original draft, Data curation, Conceptualization. **Kangyeon Lee:** Writing – original draft, Formal analysis, Conceptualization. **Wankyo Chung:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data may be obtained from a third party and are not publicly available. This study mainly utilized the National Health Claims Data, which was obtained from the National Health Insurance Service after a careful review of the study protocol. Other data is publicly available and included in the article.

Acknowledgements

The authors would like to thank Professor Sung-il Cho (Seoul National University), and Professor Jieun Hwang (Dankook University), and Professor Sun Ha Jee (Yonsei University) for their sharing of hazard ratios.

References

Bank of Korea. 2023. Currency. https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_2KAA811&conn_path=I2 (Accessed 1 Mar 2023).
Boachie, M.K., Rossouw, L., Ross, H., 2021. The economic cost of smoking in South Africa, 2016. Nicotine Tob. Res. 23, 286–293.
Bundhamcharoen, K., Aungkulanon, S., Makka, N., et al., 2016. Economic burden from smoking-related diseases in Thailand. Tob. Control 25, 532–537.
Callum, C., Boyle, S., Sandford, A., 2011. Estimating the cost of smoking to the NHS in England and the impact of declining prevalence. Health Econ. Policy Law 6, 489–508.
Castillo-Riquelme, M., Bardach, A., Palacios, A., et al., 2020. Health burden and economic costs of smoking in Chile: the potential impact of increasing cigarettes prices. PLoS One 15, e0237967.
Causes of Death Statistics. 2020. Daejeon: Statistics Korea.
Cheon, E., et al., 2024. Smoking-attributable mortality in Korea, 2020: A meta-analysis of 4 databases. J. Prev. Med. Public Health 57, 327–338.
Cho, H., Kim, S., Kim, G., et al., 2022. How Far has Korea's Tobacco Control Policy Come? Korea Health Promotion Institute (04 2022-016-09), Seoul.
Chung, W., 2014. Economic Value of Health Promotion Through Medical R&D. Korea Development Institute.
Dixon, P., Sallis, H., Munafo, M., et al., 2022. The causal effect of cigarette smoking on healthcare costs. medRxiv. https://doi.org/10.1101/2022.07.05.22277228.
Feirman, S.P., Glasser, A.M., Teplitskaya, L., Holtgrave, D.R., Abrams, D.B., Niaura, R.S., Villanti, A.C., 2016. Medical costs and quality-adjusted life years associated with smoking: a systematic review. BMC Public Health 16, 1.
Goodchild, M., Nargis, N., Tursan d'Espaignet, E.T., 2018. Global economic cost of smoking-attributable diseases. Tob. Control 27, 58–64.
Health Insurance Patients' Medical Expenditure Survey. 2020. Wonju-si: National Health Insurance Service.
Health Insurance Review and Assessment Service. 2021. Guidelines for the economic evaluation of pharmaceuticals. (G000DB6-2021-25). https://repository.hira.or.kr/handle/2019.oak/2541.
Hoang Anh, P.T.H., Thu, H., Ross, H., et al., 2016. Direct and indirect costs of smoking in Vietnam. Tob. Control 25, 96–100.
John, R.M., Sinha, P., Munish, V.G., et al., 2021. Economic costs of diseases and deaths attributable to tobacco use in India, 2017–2018. Nicotine Tob. Res. 23, 294–301.
Jung-Choi, K.H., Khang, Y.H., Cho, H.J., 2012. Hidden female smokers in Asia: a comparison of self-reported with cotinine-verified smoking prevalence rates in representative national data from an Asian population. Tob. Control 21, 536–542.
Kim, H., Park, T., Jee, S., et al., 2001. Analysis of socioeconomic costs of smoking in Korea. Korean J Prev Med 34, 183–190.
Komonpaisarn, T., 2022. Economic cost of tobacco smoking and secondhand smoke exposure at home in Thailand. Tob. Control 31, 714–722.
Korea Centers for Disease Control and Prevention, 2021. Korea Health Statistics 2021: Korea National Health and Nutrition Examination Survey (KNHANES VIII-3). Korea Centers for Disease Control and Prevention, Sejong Cheongju, Korea.
Korea Health Panel Annual Data, 2019. Sejong-si; Wonju-si, Korea Institute for Health and Social Affairs; National Health Insurance Service, 2020.
Koronaiou, K., Al-Lawati, J.A., Sayed, M., et al., 2021. Economic cost of smoking and secondhand smoke exposure in the Gulf Cooperation Council countries. Tob. Control 30, 680–686.
Lee, Y., Kim, K.H., Kang, H., et al., 2020. An evidence-based literature review and evaluation of tobacco control policy in Korea: policy implications for young adults. Health Soc Welf Rev 40, 616–650.
Life Table. 2020. Daejeon: Statistics Korea.
Local Area Labour Force Survey. 2020. Daejeon: Statistics Korea.
Max, W., Sung, H.Y., Shi, Y., et al., 2016. The cost of smoking in California. Nicotine Tob. Res. 18, 1222–1229.
Medical Service Experience Survey. 2020. Sejong-si: Korea Institute for Health and Social Affairs.
Meilissa, Y., Nugroho, D., Luntungan, N.N., et al., 2022. The 2019 economic cost of smoking-attributable diseases in Indonesia. Tob. Control 31 (Suppl 2), s133–s139.
Ministry of Economy and Finance. 2019. Guidance for preliminary feasibility test.
Murray, C.J., Lopez, A.D., 1997. Alternative projections of mortality and disability by cause 1990–2020: Global Burden of Disease Study. Lancet 349, 1498–1504.
Nam, J., Choi, J., Kim, T., et al., 1995. Health awareness behavior of Koreans 1995. Survey on National Health and Health Awareness Behavior. Korea Institute for Health and Social Affairs.
National Health Insurance Claims Data. 2022. Wonju-si: National Health Insurance Service.
OECD Health Statistics. 2023. https://stats.oecd.org/Index.aspx?ThemeTreeId=9 (Accessed Jul 20, 2023).
Office of the Surgeon General (US); Office on Smoking and Health (US). 2004. The Health Consequences of Smoking: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and Prevention (US).
Park, M.B., Kim, C.B., Nam, E.W., et al., 2014. Does South Korea have hidden female smokers: discrepancies in smoking rates between self-reports and urinary cotinine level. BMC Womens Health 14, 156.
Park, S., Song, H., Kim, C., et al., 2008. Economic burden of smoking in Korea, 2007. Korean J. Health Promot. 8, 219–227.
Pichon-Riviere, A., Alcaraz, A., Palacios, A., et al., 2020. The health and economic burden of smoking in 12 Latin American countries and the potential effect of increasing tobacco taxes: an economic modelling study. Lancet Glob. Health 8, e1282–e1294.
Ra, G., Ghang, H., Eom, T., Lee, S., 2024. A study on the socioeconomic cost and policy priority of health risk factors. Kor. J. Health Econ. Policy 30, 21–50.
Reitsma, M.B., Kendrick, P.J., Ababneh, E., 2021. Spatial, temporal, and demographic patterns in prevalence of smoking tobacco use and attributable disease burden in 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. Lancet 397, 2337–2360.
Rezaei, S., Sari, A.A., Arab, M., Majdzadeh, R., Poorasl, A.M., 2016. Economic burden of smoking: a systematic review of direct and indirect costs. Med. J. Islam Repub. Iran 30, 397.
Viscusi, W.K., 2008. How to value a life. J Econ Finance 32, 311–323.
Viscusi, W.K., 2021. Economic lessons for COVID-19 pandemic policies. South Econ. J. 87, 1064–1089.
World Bank. Currency. 2023. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KR (Accessed 15 Mar, 2023).
World Health Organization. 2011. Economics of tobacco toolkit: assessment of the economic costs of smoking. https://www.who.int/publications/i/item/economics-of-tobacco-toolkit-assessment-of-the-economic-costs-of-smoking.
Xu, X., Shrestha, S.S., Trivers, K.F., et al., 2021. US healthcare spending attributable to cigarette smoking in 2014. Prev. Med. 150, 106529.
Yoo, I.S., 2018. The study on the social expenditure of medical care and medical expenditure by smoking. J. Con. Cul. Tech. 4 (4), 187–199.