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Assessing the impact of smoking on the health and productivity of the working-age Indonesian population using modelling

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ABSTRACT

Objectives To estimate the impact of smoking in the working-age Indonesian population in terms of costs, years of life, quality-adjusted life years (QALYs) and productivity-adjusted life years (PALYs) lost.

Methods Life table modelling of Indonesian smokers aged 15–54 years, followed up until 55 years (retirement age). Contemporary data on demographics, all-cause mortality, population attributable fractions and prevalence of smoking were derived from the Institute for Health Metrics and Evaluation. The quality of life and reduction in productivity due to smoking were derived from published sources. The analysis was repeated but with the assumption that the cohorts were non-smokers. The differences in results represented the losses incurred due to smoking. Gross domestic product (GDP) per equivalent full-time worker (US$11 765) was used for estimation of the cost of each PALY, and an annual discount rate of 3.0% was applied to all costs and outcomes.

Results The prevalences of smoking among Indonesian working-age men and women were 67.2% and 2.16%, respectively. This study estimated that smoking caused 846 123 excess deaths, 2.9 million years of life lost (0.40%), 41.6 million QALYs lost (5.9%) and 15.6 million PALYs lost (2.3%). The total cost of productivity loss due to smoking amounted to US$183.7 billion among the working-age population followed up until retirement. Healthcare cost was predicted to be US$1.8 trillion. Over a 1-year time horizon, US$10.2 billion was lost in GDP and 117 billion was lost in healthcare costs.

Conclusion Smoking imposes significant health and economic burden in Indonesia. The findings stress the importance of developing effective tobacco control strategies at the macro and micro levels, which would benefit the country both in terms of health and wealth.

Strengths and limitations of this study

- This study used a new metric measure, 'productivity adjusted life years' (PALYs), to estimate the productivity burden of smoking in Indonesia.
- The economic value of each PALY was equivalent to the annual gross domestic product per full-time worker.
- Scenario and second-order sensitivity analyses were undertaken to test the uncertainty around smoking-related inputs.
- The life table modelling followed best practice recommendations.
- Age-specific death rates and prevalence remained constant throughout the model time horizon.

INTRODUCTION

Smoking is one of the greatest risk factors that contribute to all non-communicable diseases. In recent times, the prevalence of smoking worldwide has decreased.[1] However, the prevalence of smoking in Indonesia is still high. World Bank data show that the proportion of people aged 15 years and over who smoked cigarettes in Indonesia increased throughout the period of 2010–2016, peaking at 39.4%, which accounted for almost 103 million people.[2] This high prevalence was due to the fact that smoking is introduced at a younger age, mainly through advertisements and family influences.

The healthcare costs of tobacco smoking are substantial. Data from the USA and India suggest that smoking-attributed healthcare costs range from 5.3% to 5.7% of the total health expenditure.[3 4] Smoking is also associated with reduced productivity in the working-age population, due to workdays lost to ill-health (absenteeism) and reduced efficiency at work (presenteeism).[3] The resulting loss of productivity can impose an economic burden on individuals, employers and governments through reduced earnings, tax revenue and gross domestic product (GDP). In Australia, the loss incurred by smoking-associated productivity reached $A338 billion (US$240 billion),[5] while in Malaysia the loss reached RM275.3 billion (US$69.4 billion).[6] However, these estimates were based on studies undertaken in Australia and Malaysia.

Estimates of productivity loss at a population level in Indonesia is important as it will inform the case for investment in its prevention and control at the macro and micro levels.

In the present study, we sought to estimate the impact of smoking on the working Indonesian population, both in terms of years of life, quality-adjusted life years (QALYs) and productivity-adjusted life years (PALYs) lost due to smoking.

METHOD

Life table modelling

The present study used life table modelling[7] with yearly cycles to estimate the health and productivity burden caused by smoking in Indonesia. Years of life, QALYs and PALYs lived were estimated for the cohort of Indonesian smokers of working age (15–54 years) followed up until 55 years of age, while passive smokers were not considered in these estimates due to paucity of data.

To estimate cumulative years of life, QALYs and PALYs lost due to smoking, the life table of Indonesian smokers of working age was first constructed, and then repeated but by assuming that the individuals were hypothetically not smokers. Probabilities of death were decreased in the latter group to reflect lesser risk of dying among non-smokers compared with smokers, while utilities and Productivity Indices (PIs) were both increased to reflect greater quality of life and productivity, respectively.

The differences in the outputs of the two life tables (one each for the 'smoking cohort' and the hypothetical 'non-smoking cohort') represented the years of life, QALYs and PALYs lost to smoking. All results were presented as discounted values, with an annual discount rate of 3.0%, as per the Indonesian Technology Assessment Committee.[8]

PALYs are of similar concept to QALYs, but instead of penalising years of life for time spent with reduced quality of life due to ill health, time spent with reduced work productivity was applied instead.[5 9 10]

Patient and public involvement

This is a modelling study, therefore patients and the public were not involved.

Data sources

Demographic profile and mortality

The demographic profile of the total Indonesian population was based on the 2017 population estimates from the Institute for Health Metrics and Evaluation (IHME).[11] The number of deaths (from all causes) in Indonesia in 2017, stratified by 5-year age groups and sex, were derived from the Global Burden of Disease Study by the IHME.[12] All-cause death rates were derived for each age and sex stratum by dividing the number of all-cause deaths by the number of people within that stratum.

To estimate mortality rates for age in single years, mortality rates for each 5-year age group was first plotted against the midpoint age for that age group (eg, 22 years for age group 20–24 years), and then polynomial functions were applied to describe the relationships between age in single years and mortality risk.

Prevalence of smoking

Data on the prevalence of smoking in Indonesia were gathered from the Global Adult Tobacco Survey:[13] Indonesia Report 2011.[13] To estimate prevalence for age in single years, prevalence for each age group was first plotted against the midpoint age for that age group (eg, 20 years for age group 15–24 years), and then polynomial and linear functions were applied to describe the relationships between age in single years and prevalence (online supplemental appendices 1 and 2). The second step was to regroup age in single-year prevalence to an average 5-year age prevalence as per table 1. The number of people who smoked (within separate age and sex strata) was calculated by multiplying the prevalence of smokers by the total population. Please refer to online supplemental appendices 1 and 2 for more information about estimated prevalence for age in single years.

Mortality among smokers and hypothetical non-smokers

Using the population-attributable risk percentage (PAR%) for smoking (the proportion of all deaths that is attributable to smoking) and prevalence of smoking for each age and sex stratum, it was possible to calculate mortality specifically for non-smokers according to the following equations:

$PAR\% = (Rt - Rns) / Rt$

$\rightarrow Rt - Rns = PAR\% * Rt$

$\rightarrow Rns = Rt - PAR\% * Rt$

where,

PAR% = number of all deaths in a population that is attributable to smoking

Rns = risk of mortality among non-smokers

Rt = risk of mortality in the total population (comprising both smokers and non-smokers), derived from 2017 mortality data.

To estimate the mortality risk for smokers, the following formula was used:

$Rt = p * Rs + (1 - p) * Rns$

$\rightarrow p * Rs = Rt - (1 - p) * Rns$

$\rightarrow Rs = (Rt - (1 - p) * Rns) / p$

where

Rs = risk of mortality among smokers

p = prevalence of smoking.

Data for smoking-related PAR% in Indonesia were drawn from IHME[14] for the year 2017. Sex and specific estimates of PAR% were available. To estimate PAR% for age in single years, PAR% values for each age group was first plotted against the midpoint age for that age group (eg, 32 years for age group 30–34 years), and then polynomial functions were applied to describe the relationships between age in single years and PAR% values (online supplemental appendix 3).

Table 1 Key inputs used in the model simulation for the working Indonesian male and female population

Age groups (years)	Smoking prevalence (%)	Smoking (PAR%)	Cost per PALY	Smoking				Non-smoking			
				Mortality rates (%)	Utilities	Productivity Indices	Smoking-related healthcare costs	Mortality rates (%)	Utilities	Productivity Indices	Related healthcare costs
Male											
15–19	46.6	6.6	11 765	0.012	0.893	0.664	2194	0.011	0.935	0.677	No cost incurred
20–24	56.5	6.6		0.020	0.893	0.762		0.018	0.935	0.777	
25–29	64.4	6.6		0.033	0.864	0.846		0.030	0.913	0.863	
30–34	70.3	15.2		0.056	0.864	0.875		0.045	0.913	0.892	
35–39	74.2	18.9		0.094	0.864	0.880		0.072	0.913	0.897	
40–44	76.1	22.8		0.158	0.864	0.876		0.114	0.913	0.893	
45–49	76.0	27.1		0.266	0.809	0.864		0.181	0.860	0.881	
50–54	73.9	30.0		0.452	0.809	0.832		0.287	0.860	0.848	
Average	67.2	**22.8**		**0.136**	**0.865**	**0.825**		**0.095**	**0.911**	**0.841**	
Female											
15–19	0.07	0.175	11 765	0.018	0.893	0.637	2194	0.005	0.935	0.649	No cost incurred
20–24	0.27	0.175		0.015	0.893	0.743		0.008	0.935	0.757	
25–29	0.95	0.175		0.017	0.864	0.801		0.014	0.913	0.817	
30–34	1.70	1.0		0.035	0.864	0.800		0.024	0.913	0.815	
35–39	2.45	1.7		0.068	0.864	0.786		0.041	0.913	0.801	
40–44	3.20	2.5		0.118	0.864	0.782		0.070	0.913	0.797	
45–49	3.95	3.0		0.196	0.809	0.756		0.119	0.860	0.771	
50–54	4.70	3.0		0.316	0.809	0.721		0.204	0.860	0.735	
Average	**2.16**	**2.2**		**0.098**	**0.865**	**0.753**		**0.061**	**0.911**	**0.768**	

Cost displayed in US$. Smoking PAR% for age group 15–29 years was assumed to be half of the PAR% for age 30 years.
PALY, productivity-adjusted life years; PAR%, population-attributable risk percentage .

Quality of life and productivity

QALYs were derived from multiplication of years of life lived with age-specific and sex-specific utilities (table 1). Estimation of utility decrements due to smoking was based on a study by Jia and Lubetkin.[15]

The PI describes the proportional work productivity of a person (or a group of people), and ranges in value from 0 (non-productive) to 1.0 (fully productive). The product of PI and years lived are PALYs (in the same manner that the product of utilities and years lived are QALYs).

Smoking-attributable productivity loss (ie, productivity decrements) were estimated from a study by Bunn *et al*.[16] This study estimated that smokers had more unattended days of work (absenteeism) (6.7 vs 4.4 days/year) and more days with decreased productivity during work (presenteeism) (3.2 vs 1.8 days/year) compared with non-smokers. The total working days missed in a year were quantified by combining days lost due to absenteeism and presenteeism, with smokers experiencing total missed workdays of 9.9 days/year (6.7 plus 3.2) and non-smokers experiencing total missed workdays of 6.2 days/year (4.4 plus 1.8). PIs were derived from dividing the days worked in a year (maximum working days in a year minus total missed working days) with the maximum working days in a year.

To estimate the maximum working days per year in Indonesia, the overall percentage of equivalent full-time (EFT) workers was first identified using the following formula:

Number of full-time workers + ((part-time weekly earnings/full-time weekly earnings) *number of part-time workers)

'Labour Force Situation in Indonesia' and 'Income Statistics' data from *Badan Pusat Statistik* in 2018,[17] which estimated the number of people who worked part-time and full-time, as well as their corresponding monthly salaries in Indonesia were used to estimate EFT workers from age 15 years to 55 years. The weighted average of EFT workers across ages 15 years to 55 years in Indonesia was 83.2%. Thus, the maximum working days in a year within this age range was assumed to be 199.6 days, derived from the multiplication of 240 days (5 working days per week times 48 working weeks per year) by 83.2%.

To derive PIs for smokers and non-smokers, the number of total working days missed in a year (total days of absenteeism and presenteeism combined) was determined as a percentage of the maximum working days in a year for people aged 15 years to 55 years (199.6 days). Thus, smokers were estimated to have a PI of 0.950 ((199.6–9.9)/199.6), while the PI of non-smokers were estimated to be 0.969 ((199.6–6.2)/199.6) (table 1).

Cost of productivity loss

We assumed that the economic value of each PALY was equivalent to the annual GDP per full-time worker. This excluded the healthcare cost attributed to smoking-related illness.

The cost of each PALY was obtained by dividing the total Indonesian GDP in 2019 (US$1179 913 million or IDR16 837 358 510 million)[18] with the estimated total Indonesian EFT workers from age 15–55 years in 2018 (100 289 529). Based on this, the cost of each PALY was estimated to be US$11 765 (IDR168 883 998), with an assumption that all GDP was produced by Indonesian workers aged 15–55 years (table 1). Furthermore, we have forecasted temporal trends in GDP growth within a time horizon using World Bank data, applying an average annual growth of 5.17%.[19]

Healthcare costs

To estimate the healthcare costs associated with smoking-related diseases, years of life lived (stratified by sex and age) were multiplied by smoking-related healthcare costs per person per year.

The total amount of smoking-related healthcare costs in Indonesia per person per year for smokers was estimated from a study by Kristina *et al* in 2018, using data from the year 2015.[20] Healthcare costs per person per year were estimated by dividing the total healthcare spending devoted to smoking-related disease among the cohort (US$2177 million) by the number of smokers (992 330) in the cohort, which equated to US$2194 per person. It was assumed that non-smokers incurred no smoking-related healthcare costs (table 1).

Sensitivity analysis

Scenario analyses were undertaken with an assumption of reduction in the prevalence of smoking by 20%, 30%, 40% and 50%. We assessed in the model the impact of applying temporal trends in annual GDP growth, removing healthcare costs for participants aged 17–29 years and 17–34 years, respectively, and removing effect of PAR% for participants aged 17–29 years might have on the final outcomes of interest. We also performed a scenario analysis with a 1-year time horizon.

To reflect uncertainty (95% CIs) of the input parameters in the model, a number of candidate distributions were selected. To capture the uncertainty around PAR%s and utilities, we have used beta distributions, while for PIs and costs, we applied uniform and gamma distributions, respectively. For utilities and costs, the SE was assumed to be 5% and 15% of the means and estimate, respectively. We ran the simulation for 10 000 iterations to capture uncertainty in the model using the software package @Risk V.7.5 (Palisade, Ithaca, New York, USA). Detailed information is provided in appendices 4 and 5.

RESULTS

The prevalence of smoking in the Indonesian working-age population was 34.7% (67% in men and 2.16% in women), equating to 53.4 million people (51.9 million men and 1.5 million women) between 15 years and retirement age who smoke (table 1).

Deaths

Table 2 summarises the estimated number of deaths in the smoking and the hypothetical non-smoking groups. With simulated follow-up until retirement, the smoking cohort was predicted to incur 846123 excess deaths, (830126 among men and 15998 among women). Smoking-attributable deaths accounted for 12.5% (22.8% among men and 2.2% among women) of all deaths among the Indonesian working-age population.

Years of life lived

Table 2 summarises the estimated years of life lived by the smoking cohort and the hypothetical non-smoking cohort. In total, smoking was estimated to lead to 2959 283 years of life lost (95% CI 2.5 to 3.3 million) (discounted), with 2893661 (0.4% among male smokers) years of life lost in men and 65622 (0.4% among female smokers) in women.

Quality-adjusted life years

Table 3 summarises the estimated QALYs lived by the smoking cohort and the hypothetical non-smoking cohort. In total, smoking was estimated to lead to 41629391 QALYs lost (95% CI 26.1 to 100 million) (discounted), with 40750543 (5.9% among male smokers) QALYs lost in men and 878848 (6.1% among female smokers) in women.

Productivity-adjusted life years

Table 3 summarises the estimated PALYs lived by the smoking cohort and the hypothetical non-smoking cohort. In total, smoking was estimated to lead to 15 616 260 PALYs lost (95% CI (13.0 to 16.0 million) (discounted)), with 15 327 492 (2.3% loss among male smokers) PALYs lost in men and 288768 (2.3% loss among female smokers) in women. Overall, 0.29 PALYs were estimated to be lost per smoker.

Cost of productivity loss

The cost of PALYs lost due to smoking was derived by assuming a constant GDP per full-time worker of US$11 765. In total, smoking was associated with US$183 726 339 465 loss in GDP (95 CI 148.4 to 164.3 billion) (discounted), with US$180 328 964 857 GDP lost in men and US$3397 374 608 in women (table 4). GDP lost per smoker was estimated to reach US$3435 among the working-age population followed up until retirement (table 4).

Healthcare costs

Overall, discounted results showed that the smoking-attributable healthcare costs in Indonesia were estimated to be US$1837 669 140 149 (95% CI 1.82 to 1.85 trillion). Men incurred smoking-related healthcare costs of US$1799 385 510 167, while women incurred US$38 283 629 982 among the working-age population followed-up until retirement (table 4).

All other undiscounted results are provided in the online supplemental appendices 6 and 7.

Scenario analyses

A number of scenario analyses were undertaken in which the prevalence of smoking was hypothetically reduced by 20%, 30%, 40% and 50% (figure 1 and appendix 8). In total, halving of the current prevalence of smoking would return approximately 1.4 million years of life, 20.3 million QALYs, 7.6 million PALYs, US$90 billion in GDP and save US$899 billion in smoking-related healthcare costs.

Running the model for 1 year only, lead to 10414 years of life lost, 2573566 QALYs lost, 874 136 PALYs lost, US$10.2 billion loss in GDP and 117 billion loss in healthcare costs (table 5). Furthermore, additional scenario analyses showed that removing healthcare costs and annual GDP growth had a major impact on final outcomes of interest. For example, applying an annual GDP growth of 5.17% increased total PALYs lost by 98% (table 5). Of note, removing healthcare costs for ages 17–29 years and 17–34 years reduced total healthcare costs by 15.5% and 25.3%, respectively.

DISCUSSION

The present study highlights the significant impact of tobacco smoking in Indonesia, the country with the highest prevalence of smoking in the world. This study focused on productivity; the estimates exclude the burden borne by people aged older than 55 years, whereby the estimated burden would be even larger if they had been included in the analysis.

Smoking impact on mortality and years of life lost

The total number of excess deaths among Indonesian smokers currently of working age was predicted to be 846 123, with 98% of these excess deaths occurring in male smokers. The latter reflects the extraordinarily high prevalence of smoking among Indonesian men. Of all deaths occurring among the cohort, 12.5% was attributable to smoking.

The above findings are in accordance with data from around the world. A study from Australia by Owen *et al*, which also used life table modelling, showed that smoking caused 23.1% of all deaths occurring in the whole population.[5] Furthermore, a Malaysian study by Tan *et al* also using the same method showed that smoking caused 45.0% excess deaths among working-age male smokers, which accounted for 23.5% of all deaths.[6] Despite the same methods, the other two studies found higher percentages of smoking-attributable deaths due to longer follow-up periods (eg, 65 years in Malaysia and 70 years in Australia).

The present study predicted that 2959 283 years of life (0.4% among smokers) would be lost by Indonesians of current working age followed up until age 55 years.

Owen *et al* predicted that smoking would cause approximately 3.1 millions of years of life lost (4.2%) among Australian smokers currently aged 20–69 years if they were followed up until 70 years.[5] Indonesian smokers showed an overall similar percentage of years of life lost

Table 2 Number of deaths and discounted years of life lived in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15–54 years with simulated follow-up until 55 years. Deaths in the smoking and non-smoking cohorts are presented based on age entering the simulation

Five-year age group	Population	Number of smokers	Deaths in smoking cohort	Deaths in non-smoking cohort	Excess deaths*	*YLL in smoking cohort	YLL in non-smoking cohort	Years of life lost*	%Smoker†
Male									
15–19	11 615 900	5419 979	318 805	220 033	98 772	126 123 437	126 408 651	285 214	0.2%
20–24	10 477 601	5926 131	344 404	236 847	107 557	127 565 545	127 914 286	348 741	0.3%
25–29	10 307 565	6644 256	378 480	258 567	119 914	129 648 743	130 083 628	434 885	0.3%
30–34	10 433 650	7341 116	404 010	273 264	130 747	126 211 904	126 729 758	517 854	0.4%
35–39	10 339 840	7678 365	397 418	265 750	131 668	111 497 485	112 029 897	532 413	0.5%
40–44	9589 184	7303 122	337 807	222 333	115 474	83 588 357	84 028 600	440 242	0.5%
45–49	8455 438	6431 206	237 588	152 960	84 628	50 807 739	51 070 494	262 755	0.5%
50–54	7094 744	5247 273	110 106	68 738	41 367	19 896 412	19 967 969	71 557	0.4%
Total	78 313 922	51 991 449	2528 618	1698 493	830 126	775 339 623	778 233 283	2 893 661	0.4%
Female									
15–19	11 186 945	7331	309	196	113	171 058	171 512	454	0.3%
20–24	10 345 786	20 692	854	546	308	446 938	448 158	1219	0.3%
25–29	10 207 474	96 971	3934	2511	1423	1899 506	1905 657	6152	0.3%
30–34	10 192 667	173 275	6847	4336	2512	2990 977	3003 050	12 073	0.4%
35–39	10 059 746	246 464	9181	5804	3378	3593 983	3610 415	16 431	0.5%
40–44	9334 423	298 702	9891	6287	3604	3433 867	3449 819	15 952	0.5%
45–49	8260 705	326 298	8505	5477	3028	2588 764	2599 157	10 393	0.4%
50–54	7043 260	331 033	4772	3140	1631	1258 941	1261 889	2948	0.2%
Total	76 631 005	1500 033	44 293	28 296	15 998	16 384 035	16 449 657	65 622	0.4%
Total	154 944 927	53 492 215	2572 911	1954 762	667 556	791 723 658	794 682 941	2959 283	**0.4%**
Uncertainty (95% CI) for total years of life lost			**(2529 000 to 3393 293**)						

*Excess deaths = deaths in the hypothetical smoking cohort minus deaths in the smoking cohort. *Years of life lost = years of life lived in the hypothetical smoking cohort minus years of life lived in the smoking cohort.
†%Smoker = years of life lost/years of life lived in the hypothetical non-smoking cohort.
YLL, years of life lived.

Table 3 Discounted quality-adjusted life years (QALYs) and productivity-adjusted life years (PALYs) in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15–54 years, followed up until age 55 years

Five-year age group	QALYs lived in the smoking cohort	QALYs lived in the non-smoking cohort	QALYs lost*	%Smoker†	PALYs lived in the smoking cohort	PALYs lived in the non-smoking cohort	PALYs lost‡	%Smoker§	Per smoker
Male									
15–19	108 906 689	115 105 595	4042 144	5.4%	103 212 855	105 472 025	2259 170	2.1%	0.42
20–24	109 195 323	115 685 051	4421 169	5.6%	108 185 924	110 596 969	2411 046	2.2%	0.41
25–29	110 036 056	116 840 051	4856 674	5.8%	111 914 564	114 472 360	2 557 796	2.2%	0.38
30–34	106 505 204	113 232 602	5 011 969	5.9%	109 195 873	111 771 270	2 575 397	2.3%	0.35
35–39	93 241 034	99 278 188	4 716 455	6.1%	95 982 758	98 310 942	2 328 184	2.4%	0.30
40–44	68 790 374	73 390 317	3 793 201	6.3%	71 264 497	73 028 980	1 764 483	2.4%	0.24
45–49	41 103 461	43 920 625	2 471 566	6.4%	42 657 518	43 710 680	1 053 162	2.4%	0.16
50–54	16 096 197	17 172 453	1 014 822	6.3%	16 351 488	16 729 743	378 255	2.3%	0.07
Total	653 874 339	694 624 883	30 328 000	5.9%	658 765 476	674 092 968	15 327 492	2.3%	0.29
Female									
15–19	147 691	156 162	8471	5.4%	129 004	131 866	2862	2.2%	0.39
20–24	382 537	405 277	22 740	5.6%	345 782	353 450	7668	2.2%	0.37
25–29	1612 001	1711 507	99 507	5.8%	1474 106	1507 503	33 396	2.2%	0.34
30–34	2523 708	2682 989	159 281	5.9%	2297 696	2351 603	53 907	2.3%	0.31
35–39	3005 213	3199 213	194 000	6.1%	2725 542	2790 987	65 445	2.3%	0.27
40–44	2825 775	3012 918	187 143	6.2%	2561 633	2623 378	61 746	2.4%	0.21
45–49	2094 310	2235 275	140 965	6.3%	1884 414	1928 716	44 303	2.3%	0.14
50–54	1018 484	1085 225	66 741	6.1%	889 508	908 948	19 440	2.1%	0.06
Total	13 609 719	14 488 567	878 848	6.1%	12 307 684	12 596 452	288 768	2.3%	0.19
Total	667 484 058	709 113 450	41 629 391	**5.9%**	671 073 160	686 689 420	15 616 260	**2.3%**	**0.29**
Uncertainty (95 % CI) for total QALY and PALY lost	(**26 145 659 to 100 093 701**)				(**13 028 888 to16 062 306**)				

*QALYs lost = QALYs lived in the hypothetical smoking cohort minus QALYs lived in the smoking cohort.
†%Smoker = QALYs lost / QALYs lived in the hypothetical non-smoking cohort.
‡PALYs lost = PALYs lived in the hypothetical smoking cohort minus PALYs lived in the smoking cohort.
§%Smoker = PALYs lost / PALYs lived in the hypothetical non-smoking cohort.

Table 4 Discounted cost of productivity and healthcare costs in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15–54 years, followed up until age 55 years

Age group	Cost of productivity in the smoking cohort	Cost of productivity in the hypothetical non-smoking cohort	Cost of productivity lost	Smoking-related healthcare costs
Male				
15–19	1214 306 114 180	1240 885 399,020	26,579,284,841	276,692,956,505
20–24	1272 814 602 920	1301 180 714 900	28 366 111 981	279 856 693 096
25–29	1316 682 298 476	1346 774 938 142	30 092 639 667	284 426 867 754
30–34	1284 696 723 401	1314 996 436 239	30 299 712 838	375 311 821 468
35–39	1129 243 542 337	1156 634 782 986	27 391 240 649	244 606 153 617
40–44	838 431 551 420	859 190 813 212	20 759 261 791	183 378 365 925
45–49	501 868 547 094	514 259 068 177	12 390 521 083	111 463 372 935
50–54	192 376 346 403	196 826 538 410	4450 192 007	43 649 278 866
Total	7750 419 726 231	7930 748 691 088	180 328 964 857	1799 385 510 167
Female				
15–19	1517 741 108	1551 416 368	33 675 260	375 270 778
20–24	4068 147 650	4158 366 769	90 219 118	980 505 287
25–29	17 342 957 460	17 735 869 272	392 911 812	4167 186 004
30–34	27 032 543 815	27 666 766 544	634 222 729	8901 582 447
35–39	32 066 183 386	32 836 151 578	769 968 191	7884 576 747
40–44	30 137 777 395	30 864 219 081	726 441 686	7533 309 724
45–49	22 170 253 558	22 691 475 789	521 222 230	5679 299 738
50–54	10 465 115 880	10 693 829 461	228 713 580	2761 899 256
Total	144 800 720 253	148 198 094 860	3397 374 608	38 283 629 982
Total	**7895 220 446 484**	**8078 946 785 948**	**183 726 339 465**	**1837 669 140 149**
Uncertainty (95 % CI)	**(148.4 to 164.3 billion) (1.82 to 1.85 trillion)**			

Results were derived by assuming a constant GDP per equivalent full-time (EFT) worker of US$11 765, all costs are expressed in US$. Non-smoking related healthcare costs are zero.

compared with the Australian population, even though Australian years of life lost were largely due to a longer period of follow-up in the Australian study (70 years compared with 55 years), and the fact that mortality rises sharply from middle age. Furthermore, Owen *et al*[5] did not apply discounting to their predictions of years of life lost. In the present study, if discounting was not applied, the loss predicted in years of life was 5.03 million.

Tan *et al* predicted that 2182 053 years of life (2.9% loss) would be lost by Malaysian male smokers.[6] The results are not directly comparable because as mentioned, the follow-up periods were greater in the Malaysian study. Unlike Owen *et al*, Tan *et al* did apply discounting to estimated years of life lived, but this was only 3% per year,[5] half of that assumed in the present study.

Smoking impact on QALYs

The present study predicted that 59.4 million QALYs (6.0% among smokers) would be lost by Indonesians of current working age followed up until age 55 years, equivalent to 0.77 QALYs lost per smoker. Again, the bulk of this burden in absolute terms occurred in male smokers, but the loss among women was greater in proportional terms (0.58 QALYs lost in women). Owen *et al*[5] predicted that smoking would lead to a loss of 2.8 QALYs undiscounted per Australian smoker of working age, while Tan *et al* predicted that 1.3 QALYs would be lost per Malaysian male smoker of working age (15–65 years).[6] The extent of QALYs lost per Indonesian smoker of working age was less than those predicted for working-age Australian and Malaysian men because follow-up periods for the latter two cohorts were longer.

Smoking impact on productivity

The total smoking attributable PALYs lost in Indonesian smokers, aged 15–54 years with follow-up until retirement, equated to a 2.3% loss or 0.29 PALYs lost per smoker. Similarly with smoking impact on quality of life, men bore this burden more in absolute terms, but the loss among women was similar in proportional terms.

Owen *et al* found that smoking caused 2.5 million PALYs lost (0.94 per smoker) among Australian working-age smokers.[5] Similarly, Tan *et al* reported Malaysian smokers of working age lost approximately 3.0 million PALYs

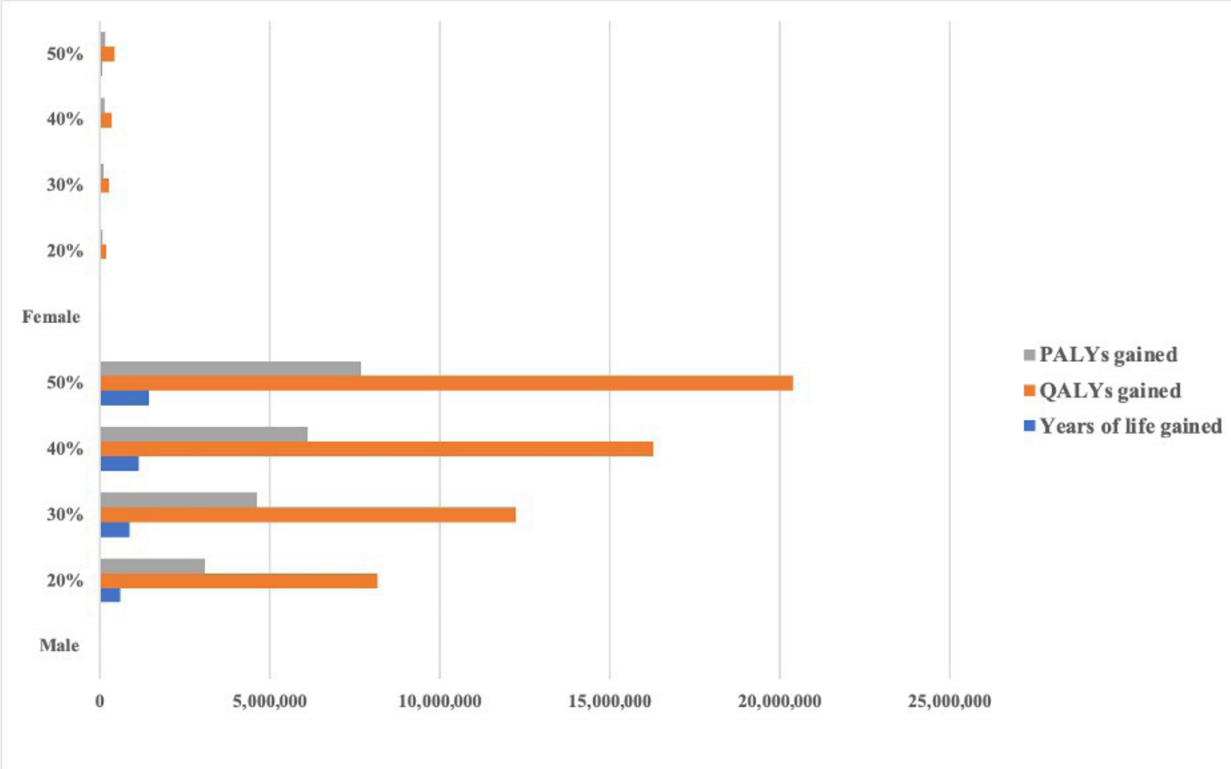

Figure 1 Gains in terms of years of life, productivity-adjusted life years (PALYs) saved, and quality-adjusted life years (QALYs) gained in which prevalence of smoking was hypothetically reduced by 20%, 30%, 40% and 50%.

due to smoking, which equated to 0.70 PALYs lost per smoker.[6] In absolute terms smoking attributable PALYs lost were much higher in Indonesia (ie, 15.6 million), but in proportional terms was higher in Australia and Malaysia, due to the longer follow-up periods of the two cohorts.

Table 5 Scenario analyses

Description	Total years of life lost	Total QALYs lost	Total PALYs lost	Total GDP lost	Total smoking health-related costs (US$)
Base case	2959283	41629391	15616260	183 726 339 465	1837 669 140 149
One-year time horizon	10414	2573566	874136	10 284 268 975	117 276 697 420
Male	9989	2498596	851417	10 016 975 640	113 986 765 799
Female	425	74971	22719	267293335	3289 931 620
Removing healthcare costs for participants aged 17–29 years in the model					1556 764 540 624
Percentage change from base case					−15.3%
Removing healthcare costs for participants aged 17–34 years in the model					1371 023 610 646
Percentage change from base case					−25.4%
Halved healthcare costs from US$2194 to US$1097 per person					918 834 570 074
Percentage change from base case					−50%
Removing effect of PAR% for participants aged 17–29 years	2892708	41572735	15559206	183 055 100 112	1837 815 194 535
Percentage change from base case	−0.022	−0.001	−0.004	−0.004	0.0
Applying annual GDP growth of 5.17%					364 886 237 501
Percentage change from base case					+98%

GDP, gross domestic product; PALY, productivity adjusted life years; PAR%, population-attributable risk percentage; QALYs, quality adjusted life years.

We estimated the broader economic costs of smoking, in terms of lost GDP, to be US$3435 (0.29 PALYs) per smoker. In our other studies that have adopted the same methods, Owen *et al*[5] estimated the economic impact to be US$102 000 (1.0 PALYs) per Australian smoker and Tan *et al*[6] estimated the economic impact to be US$17 600 (0.75 PALYs) per male Malaysian smoker. The differences reflect major differences in GDP per capita for the three countries, as well as assumed retirement ages (Indonesia 55 years, Malaysia 65 years and Australia 70 years).

Smoking-related healthcare costs

The present study predicted that Indonesian smokers aged 15–54 years would incur total healthcare costs of US$1.83 trillion by the time they reached age 55 years. Even when healthcare costs were removed for participants aged 15–34 years, smokers in Indonesia still incurred 1.37 trillion by the time they reached age 55 years. No previous study has estimated smoking-related healthcare costs using life table modelling; many studies have described the significant economic burden in terms of healthcare expenditure caused by smoking using varying methods. In 2012, US$422 billion in healthcare costs was attributable to smoking globally, which was equivalent to 5.7% of the total healthcare expenditure.[3] Similarly, a recent study from India assessed the economic costs of tobacco use for the year 2017–2018 for age above 35 years and found that the total economic cost attributed to tobacco was US$27.5 billion, equivalent to 5.3% of the total health expenditure.[4] Using a similar age bracket as in a recent study from India our annual estimated costs amounted to US$77.3 billion. In Thailand, the total cost of smoking constituted 0.78% of the country's national GDP.[21]

Implications

Although the present study did not evaluate the cost-effectiveness of individual smoking prevention strategies, the results provide a theoretical illustration of gains from reduced smoking prevalence. Mortality due to smoking is very large in the world and any smoking-related interventions (including education, behaviour and smoking cessation therapy) are likely to reduce future mortality and related healthcare costs in Indonesia.

Several preventive measures are known to be effective, such as the use of pharmacological treatments, price-based and non-price-based policy measures, smoking cessation classes, school-based smoking prevalence programmes and workplace-based interventions.[22] A meta-analysis published by the Cochrane Library in 2013 indicated that the use of pharmacological treatments for preventing tobacco intake was effective.[23] However, this approach may not be the most cost-effective strategy, considering the costs range from €19.69 (US$21.46) to €624.47 (US$680.67) per complete course of treatment.[24]

Among the aforementioned preventive measures, price-based policy approaches (such as increasing tobacco taxes) and non-price-based legislation (such as prohibiting smoking in public places and workplaces, age-restriction rules and bans on advertisements) have been shown to be the most cost-effective.[22] Increasing tobacco tax by 10% was proven to reduce smoking prevalence by between 4% and 8%.[25,26] A study by Cleghorn *et al* in 2017 modelled the benefits of increasing tobacco taxes by 10% annually from 2011 to 2020 in New Zealand.[27] The study estimated that there would be a 1.6% increase in QALYs lived among people aged 20–65 years, and savings of approximately NZ$10.6 million (US$6.6 million) in healthcare costs. Non-price-based legislation may even be more effective, reducing smoking prevalence between 30% and 82% in the long term.[22] In reality, a multifaceted approach to tobacco control and smoking prevention is required.

Although the Indonesian government has implemented a number of strategies to reduce the number of smokers (with most of the measures being legislative-based restrictions and bans), these strategies have not been well reinforced. Indonesia is the only country in Asia that has not yet signed and ratified the WHO framework convention on tobacco control, and as a consequence of this Indonesia has a very weak tobacco control policy.[28]

A report by the WHO in 2019 using the MPOWER measures (Monitor tobacco use and prevention policies, Protect people from tobacco use, Offer help to quit tobacco use, Warn about the dangers of tobacco, Enforce bans on tobacco advertising, promotion and sponsorship and Raise taxes on tobacco) indicated that Indonesia was still behind in terms of smoking prevention policies and programmes, health warnings and bans on cigarette advertisements.[28] Furthermore, the price of cigarettes in Indonesia was found to be consistently low over many years, with a taxation of just 58.5% on retail prices,[28] compared with the worldwide benchmark of 70%.[29]

Other challenges include lack of awareness concerning the negative health and economic impacts of tobacco smoking among people in Indonesia. By quantifying all the smoking-attributable losses and highlighting the benefits of reducing the prevalence of smoking (especially in terms of the broader economy), the present study will provide greater motivation to the government and policy makers for implementing tobacco control programmes.

STRENGTHS AND LIMITATIONS

The present study is the first to estimate the burden of smoking and its impact on the health and the larger economy of Indonesia. The study also used a recently derived measure called PALY,[9] which permits productivity to be quantified using accessible national data as well as evaluation of various smoking prevention measures. Such information provides policy makers with better insight into the potential gains from smoking prevention measures, and hence may help inform cost-effective cessation programmes and appropriate allocation of scarce healthcare resources.

In the past, other studies have attempted to model the burden of smoking in terms of smoking-related diseases.[30–34] However, modelling the benefits of smoking cessation in this manner is limited by uncertainty arising from having to estimate its net impact mediated via the multiple smoking-related conditions. In particular, there would be significant interaction that cannot be accurately captured. Our approach minimises this uncertainty by applying the benefit of smoking cessation on the summary measures of mortality, quality of life and productivity.

The versatility of our model is a strength. Presently we demonstrate the functionality of our model using a hypothetical example of improving smoking prevalence in the Indonesian setting. However, our model can be applied in any setting as long as data exist for population mortality, PAR% due to smoking and smoking prevalence.

There are a number of limitations of the present study. First, the analyses did not consider potential losses and gains from secondhand smoking-attributable mortality and morbidity, due to a lack of relevant data inputs from Indonesia.

Second, the period of follow-up was relatively short, with simulation only until age 55 years, the official retirement age in Indonesia. This precedes the age range within which the bulk of smoking-attributable disease manifests. The present study sought to quantify the impact of smoking among Indonesians of working age, rather than all Indonesians.

Third, despite using life table modelling, which is a commonly used tool in epidemiological and demographical studies, this approach has a well-known limitation called the life table assumption, in which age-specific death rates remain constant throughout the model time horizon. However, given that this assumption was applied to both the smoking cohort and the hypothetically non-smoking cohort, it would not have substantially affected the results, and the overall conclusion that smoking causes significant health and economic burden. Fourth, it was assumed that there was no movement of people into or out of the smoking cohort over time. That is, smokers did not quit, nor did non-smokers take up smoking within the model time horizon. While the possibility of smoking uptake after young adulthood is low, cessation does occur over time. Hence, the assumption would have led to an overestimation in the total number of smokers, and consequently the burden of smoking. The next major limitation stemmed from lack of gender-specific and age-specific healthcare costs. Therefore, the current estimates might overestimate the total healthcare costs attributed to smoking.

Finally, the present study did not consider the contribution of the local tobacco industry to Indonesia's GDP. Any changes in the prevalence of smoking would of course also affect GDP to some extent via its effect on the tobacco industry.

CONCLUSION

Smoking exerts a significant burden on both the health and economy of Indonesia. The findings of the present study stress the importance of funding effective tobacco control strategies at the macro and micro levels. We present an easy-to-apply smoking model that will help with decision making in clinical practice, public health and health policy.

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