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Health and economic burden of smoking in Indonesia

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ABSTRACT

Objectives: To estimate the impact of smoking in the Indonesian population of working-age 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 to 54 years, followed-up until 55 years (retirement age). Contemporary data on demographic, mortality and prevalence of smoking were derived from the Institute for Health Metrics and Evaluation. The population attributable risk, quality of life and reduction in productivity due to smoking were derived from published sources. The analysis was repeated but with the assumption the cohorts were non-smokers. The differences in results represented the losses incurred by smoking. Gross domestic product (GDP) per equivalent full-time worker (USD 11,765) was used for estimation of the cost of each PALY, and an annual discount rate of 6% was applied to all costs and outcomes.

Results: The prevalence of smoking among Indonesian working-age males and females were 67.0% and 7.9%, respectively. This study estimated that smoking caused 667,556 excess deaths, 1.6 million years of life lost (0.26%, 0.03 per person), 32.9 million QALYs lost (5.74%, 0.57 per person) and 11.9 million PALYs lost (2.16%, 0.21 lost per person). The total cost of productivity loss due to smoking amounted to USD 139.8 billion among working age population followed-up until retirement. Healthcare costs was predicted to be USD 1.6 trillion.

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

Strengths and limitations of this study

- This study utilised a new metric measure, 'productivity adjusted life years' (PALYs), to capture the productivity burden of smoking in Indonesia.
- We demonstrated a significant cumulative loss among smokers in Indonesia across their working lifetime.
- Smoking caused 667,556 excess deaths, 1.6 million years of life lost (0.26%, 0.03 per person), 32.9 million quality adjusted life years lost and 11.9 million PALYs lost.
- The findings highlight the importance of developing effective tobacco control strategies, which would benefit the country immensely, both in terms of health and wealth.
- For this study, we have used life table modelling, in which age-specific death rates and prevalence remain constant throughout the model time horizon.

INTRODUCTION

Smoking is one of the greatest risk factors that contribute to cardiovascular disease. Recently, 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 to 2016, peaking at 39.4%, which accounted for almost 103 million people (2). This was due to the fact that smoking is introduced at a younger age, mainly through advertisements and family influences.

Smoking is also associated with reduced productivity in the working-age population, due to work days 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 (USD 240 billion) (4), while in Malaysia the loss reached RM275.3 billion (USD 69.4 billion) (5). 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.

In the present study, we sought to estimate the impact of smoking on the 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 (6) 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 to 54 years) followed up until 55 years of age. While passive smokers were not considered in these estimates due to scarce 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, then repeated but 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 to smokers, while utilities and productivity indices 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 in discounted values, with annual discount rate of 6%, as suggested by the Bank Indonesia (7).

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 used (4).

Patient and Public Involvement

This is a modelling study, therefore patient and public was 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) (8). The number of deaths (from all causes) in Indonesia in 2017, stratified by five-year age group and sex, were derived from the Global Burden of Disease (GBD) Study by the IHME (9). 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 five-year age group was first plotted against the midpoint age for that age group (e.g., 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 (GATS): Indonesia Report 2011 (10). To estimate prevalence for age in single years, prevalence for each age group was first plotted against the midpoint age for that age group (e.g., 20 years for age group 15-24 years), and then polynomial functions were applied to describe the relationships between age in single years and prevalence (Appendix 1 and 2). Second step was to regroup age in single years prevalence to an average 5-year age prevalence as per Table 1a and 1b. 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 Appendix 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 percent (PAR%) for smoking (the proportion of all deaths that is attributable to smoking) and prevalence of smoking for each age and sex stratum from 2011, 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%= population attributable risk percentage (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 a 2004 World Health Organisation (WHO) report entitled "WHO Global Report: Mortality Attributable to Tobacco" (11). Sex-specific estimates of PAR% were available for people aged 30-44, 45-59 and 60-69 years. 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 (e.g., 37 years for age group 30-44 years), and then polynomial functions were applied to describe the relationships between age in single years and PAR% values (Appendix 3).

Quality of life and productivity

QALYs were derived from multiplications of years of life lived with age- and sex-specific utilities (Table 1a and 1b). Estimation of utility decrements due to smoking was based on a study by Jia and Lubetkin (12).

The productivity index (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 (i.e., productivity decrements) were estimated from a study by Bunn et al. (3). 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 to 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 work days of 9.9 days/year (6.7 plus 3.2) and non-smokers experiencing total missed work days 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* (BPS) in 2018 (13), 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 to 55 years. The weighted average of EFT workers across ages 15 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 (five 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 to 55 years (199.6 days). Thus, smokers were estimated to have 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 1a and 1b).

Cost of productivity loss

The cost of smoking-attributable productivity loss was estimated by multiplying PALYs lost with the cost of each PALY, which excluded the healthcare cost attributed to smoking-related illness.

The cost of each PALY was obtained by dividing the total Indonesian gross domestic product (GDP) in 2019 (USD 1,179,913 million or IDR 16,837,358,510 million) (14) with the estimated total Indonesian EFT workers from age 15 to 55 years in 2018 (100,289,529). Based on this, the cost of each PALY was estimated to be USD 11,765 (IDR 168,883,998), with an assumption that all GDP was produced by Indonesian workers aged 15 to 55 years (Table 1a and 1b). Furthermore, we have forecasted temporal trends in GDP growth within time horizon using World Bank data, applying an average annual growth of 5.17%.

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 (15). Healthcare costs per person per year were estimated by dividing the total healthcare spending devoted to smoking-related disease among the cohort (USD 2,177 million) by the number of smokers (992,330) in the cohort, which equated to USD 2,194 per person. It was assumed that non-smokers incurred no smoking-related healthcare costs (Table 1a and 1b).

Sensitivity analysis

Scenario analyses were undertaken with an assumption of reduction in the prevalence of smoking by 20, 30, 40 and 50%. We also assessed the impact of applying annual GDP growth, removing health care costs and PAR% for age 17 to 29 years in the model and implications of discounting might have on the final outcomes of interest such as years of life, QALYs and PALYs lost. We have now performed probabilistic sensitivity analyses to capture the uncertainty around PAR% estimates (±15% uniform distribution), costs (gamma distribution), utilities (beta distribution) and productivity indices (±15% uniform distribution).

RESULTS

The prevalence of smoking in the Indonesian working-age population was 37.4% (67% in male and 7.9% in female), equating to 57.2 million people (51.9 million male and 5.3 million female) between 15 years and retirement age who smoke (Table 1a and 1b).

Deaths

Table 2 summarises the estimated number of deaths arising from the smoking and the hypothetical non-smoking groups. With simulated follow up until retirement, the smoking cohort was predicted to incur 667,556 excess deaths, (611,288 among males and 56,268 among females). Smoking-attributable deaths accounted for 12.9% of all deaths among the Indonesian working-age population.

Years of life lived

Table 3 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 1,638,602 years of life lost (95% confidence intervals (CI): 1,880,912 to 2,397,789) (discounted), with 1,455,361 (0.25% among male smokers) years of life lost in males and 183,240 (0.38% among female smokers) in females. Overall, 0.03 years of life were estimated to be lost per smoker.

Quality-adjusted life years

Table 4 summarises the estimated QALYs lived by the smoking cohort and the hypothetical non-smoking cohort. In total, smoking was estimated to lead to 32,872,557 QALYs lost (95% CI: 27,069,740

to 38,293,191) (discounted), with 30,328,000 (5.7% among male smokers) QALYs lost in males and 2,544,557 (6.0% among female smokers) in females. Overall, 0.57 QALYs were estimated to be lost per smoker.

Productivity-adjusted life years

Table 5 summarises the estimated PALYs lived by the smoking cohort and the hypothetical non-smoking cohort. In total, smoking was estimated to lead to 11,879,479 PALYs lost (95% CI: 4,338,334 to 20,517,149) (discounted), with 11,040,931 (2.1% loss among male smokers) PALYs lost in males and 838,548 (2.3% loss among female smokers) in females. Overall, 0.21 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 USD 11,765. In total, smoking was associated with USD 139,762,862,094 loss in GDP (95% CI: 51, 040,200,000 to 241,400,100,000) (discounted), with USD 129,897,285,335 GDP lost in males and USD 9,865,576,760 in females (Table 6). GDP lost per smoker was estimated to reach USD 2,439 among working age population followed-up until retirement. All other undiscounted results were provided in the supplementary material Appendix 4, 5, 6 and 7.

Healthcare costs

Overall, discounted results showed that the smoking-attributable healthcare costs in Indonesia were estimated to be USD 1,573,558,483,714. Males incurred smoking-related healthcare costs of USD 1,457,276,289,848, while females incurred USD 116,282,193,866 among working age population followed-up until retirement (Appendix 8).

Scenario analyses

A number of scenario analyses were undertaken in which the prevalence of smoking was hypothetically reduced by 20%, 30%, 40% and 50%. In total, a halving of the current prevalence of smoking would return approximately 820,000 years of life, 16.4 million QALYs, 5.9 million PALYs, USD 70 billion in GDP and save USD 787 billion in smoking-related healthcare costs. All these scenario analyses with regards to prevalence are presented in the supplementary material (Appendix 9, 10, 11, 12 and 13). Furthermore, additional scenario analyses showed that discounting 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 73% and changing values of discounting from 6% to 3% increased life years lost and QALYs lost by 55% and 32% respectively compared to base-case values (Table 7). Of note, removing healthcare costs for age 17 to 29 years reduced total healthcare costs by 15.5%.

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 Indonesia smokers currently of working age was predicted to be 667,556, with 92% 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, 12.9% was attributable to smoking.

The above findings are in accord with data from around the world. A study from Australia by Owen et al., which also utilised life table modelling, showed that smoking caused 23.1% of all deaths occurring in the whole population (4). 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 (5). Despite the same methods, the other two studies found higher percentages of smoking-attributable deaths due to longer follow-up periods (e.g. 65 years in Malaysia and 70 years in Australia).

The present study predicted that 1,638,602 years of life (0.26% among smokers) would be lost by Indonesians of current working age followed-up until age 55 years, equivalent to 0.03 years of life lost per smoker.

Owen et al. predicted that smoking would cause approximately 3.1 million of years of life lost (4.2%) among Australian smokers currently aged 20 to 69 years if they were followed-up until 70 years, equivalent to 1.2 years of life lost per smoker (4). Indonesian smokers showed an overall lesser percentage of years of life lost compared to the Australian population largely due to a longer period of follow-up in the Australian study (70 years compared to 55 years), and the fact that mortality rises sharply from middle-age.

Furthermore, Owen et al 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 0.08 years of life lost per smoker.

Tan et al. predicted that 2,182,053 years of life (2.9% loss) would be lost by Malaysian male smokers, equivalent to 0.5 years of life lost per smoker (5). 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 quality-adjusted life years

The present study predicted that 32.9 million QALYs (5.7% among smokers) would be lost by Indonesians of current working age followed-up until age 55 years, equivalent to 0.57 QALYs lost per smoker. Again, the bulk of this burden in absolute terms occurred in male smokers, but the loss among females was greater in proportional terms. Owen et al. (4) 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 to 65 years) (5). The extent of QALYs lost per Indonesian smoker of working age was less than those predicted for working-age Australians and Malaysian males 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 to 54 years with follow-up until retirement, equated to a 2.2% loss or 0.21 PALYs lost per smoker. Similar with smoking impact on quality of life, males bore this burden more in absolute terms, but the loss among females was greater in proportional terms.

Owen et al. found that smoking caused 2.5 million PALYs lost (0.94 per smoker) among Australian working age smokers (4). Similarly, Tan et al. reported Malaysian smokers of working-age lost approximately 3.0 million PALYs due to smoking, which equated to 0.70 PALYs lost per smoker (5). This was higher, due to longer follow-up periods of the two cohorts, and their application of 0% and 3% annual discount rates, respectively.

We estimated the broader economic costs of smoking, in terms of lost GDP, to be US $2400 (0.21 PALYs) per smoker. In our other studies that have adopted the same methods, Owen et al. (4) estimated the economic impact to be US $102,000 (1.0 PALYs) per Australian smoker and Tan et al. (5) 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). In the present study, we also applied an annual discount rate of 6% to PALYs and costs, while these values were not discounted in the Australian study and were discounted at rate of 3% for the Malaysian study.

Smoking-related healthcare costs

The present study predicted that Indonesian smokers age 15 to 54 years would incur total healthcare costs of USD 1.6 trillion by the time they reached aged 55 years. Although no 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, USD 422 billion in healthcare costs was attributable to smoking globally, which was equivalent to 5.7% of the total healthcare expenditure (18). Another study in the US reported that smoking-attributable health problems amounted to approximately USD 170 billion (19).

Scenario analyses

Although the present study did not evaluate cost-effectiveness of individual smoking prevention strategies, the results provide a theoretical illustration of gains from reducing smoking prevalence. The mortality due to smoking is very large in the world and any smoking interventions (including education, behaviour and smoking cessation therapy) are likely to reduce the 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 programs and workplace-based interventions (20). A meta-analysis published by the Cochrane Library in 2013 indicated that the use of pharmacological treatments for preventing tobacco intake was effective (21). However, this approach may not be the most cost-effective strategy, considering the costs range from EUR 19.69 (USD 21.46) to EUR 624.47 (USD 680.67) per complete course of treatment (22).

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 (20). Increasing tobacco tax by 10% was proven to reduce smoking prevalence by between 4% and 8% (23, 24). 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 (25). The study estimated that there would be a 1.6% increase in QALYs lived among people aged 20 to 65 years, and savings of approximately NZD 10.6 million (USD 6.6 million) in healthcare costs. Non-price-based legislation may even be more effective, reducing smoking prevalence between 30% to 82% in the long-term (20). 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 (26).

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 programs, health warnings and bans on cigarette advertisements (26). 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 (26), compared to the worldwide benchmark of 70% (27).

Other challenges include a lack of awareness concerning the negative health and economic impact of tobacco smoking among people in Indonesia. By couching all the smoking-attributable losses and 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 programs.

STRENGTH 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 utilised a recently derived measure called PALYs, 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 a better insight into the potential gains from smoking prevention measures, and hence may help inform cost-effective cessation programs 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 (28-32). 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 to the present study. First, the analyses did not consider potential losses and gains from second-hand smoking-attributable mortality and morbidity, due to a lack of relevant data inputs from Indonesia.

Secondly, 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.

Thirdly, 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. Fourthly, 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 potential inaccuracies in the data inputs, especially with PAR% values being drawn from 2004 (the latest available) and utilities and productivity indices not being specific to Indonesia, nor to different sexes and types of work. Such information was not available. However, the overall conclusion would not have changed.

Finally, the present study assumed that GDP in Indonesia stayed constant over the time horizon of the modelled analysis. In reality, GDP in Indonesia is likely to grow into the future, as it has done over recent years. Hence the present study under-estimated the true burden of smoking on GDP. On the other hand, 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. We present an easy-to-apply smoking model that will help with decision-making in clinical practice, public health and health policy.

Author contributions

ZA, DL and DM conceived the idea and contributed to the design of the work. RS, RU and ZA contributed to the acquisition, analysis or interpretation of data for the work. RS and ZA drafted the manuscript. ZA, DL, DM, RS and EZ critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work ensuring integrity and accuracy.

Conflicts of interest

RS, RU, ZA and DM have no conflicts of interest to declare. EZ has received grants from Amgen, AstraZeneca, Pfizer and Shire, outside the submitted work. DL declares grant support from Abbvie, Astellas, AstraZeneca, Bristol-Myers Squibb, CSL-Behring, Novartis, Pfizer, Sanofi and Shire, and past participation in advisory boards at Abbvie, Astellas, AstraZeneca, Bristol-Myers Squibb, Novartis, Pfizer and Sanofi outside the submitted work.

Ethics

Ethics approval not required as this study relied on published and publicly available data.

Data Availability Statement

Data are available in published form and costing data are presented in the electronic supplementary files. The model is available upon reasonable request.

Table 1a. Key inputs used in the model simulation for the Indonesian male population.

Age groups	Smoking prevalence (%)	Smoking population attributable risk percentage (PAR%)	Cost per PALY (USD)	Smoking				Non-smoking			
				Mortality rates (%)	Utilities	Productivity Indices	Smoking-related healthcare costs (USD)	Mortality rates (%)	Utilities	Productivity indices	Smoking-related Healthcare costs (USD)
15-19	46.58	7.42	11,765	0.012	0.893	0.664	2,194	0.011	0.935	0.677	No cost incurred
20-24	56.48	7.42		0.020	0.893	0.762		0.018	0.935	0.777	
25-29	64.38	7.42		0.033	0.864	0.846		0.029	0.913	0.863	
30-34	70.28	15.37		0.056	0.864	0.875		0.045	0.913	0.892	
35-39	74.18	16.71		0.093	0.864	0.880		0.074	0.913	0.897	
40-44	76.08	18.11		0.156	0.864	0.876		0.120	0.913	0.893	
45-49	75.98	19.55		0.260	0.809	0.864		0.197	0.860	0.881	
50-54	73.88	21.05		0.439	0.809	0.832		0.322	0.860	0.848	
Average	**67.23**	**14.13**		**0.134**	**0.865**	**0.825**		**0.102**	**0.911**	**0.841**	

Table 1b. Key inputs used in the model simulation for the Indonesian female population.

Age group	Smoking prevalence (%)	Smoking population attributable risk percentage (PAR%)	Cost per PALY (USD)	Smoking				Non-smoking (hypothetical)			
				Mortality rates (%)	Utilities	Productivity Indices	Smoking-related healthcare costs (USD)	Mortality rates (%)	Utilities	Productivity indices	Smoking-related Healthcare costs (USD)
15-19	1.09	4.10	11,765	0.023	0.893	0.637	2,194	0.005	0.935	0.649	No cost incurred
20-24	1.81	4.10		0.027	0.893	0.743		0.008	0.935	0.757	
25-29	3.21	4.10		0.032	0.864	0.801		0.014	0.913	0.817	
30-34	5.19	7.98		0.060	0.864	0.800		0.023	0.913	0.815	
35-39	7.70	7.65		0.080	0.864	0.786		0.039	0.913	0.801	
40-44	10.66	7.66		0.118	0.864	0.782		0.066	0.913	0.797	
45-49	13.98	8.03		0.183	0.809	0.756		0.113	0.860	0.771	
50-54	17.60	8.74		0.294	0.809	0.721		0.191	0.860	0.735	
Average	**7.65**	**6.55**		**0.102**	**0.865**	**0.753**		**0.057**	**0.911**	**0.768**	

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

Five-year age group	Male							
	Population	Number of smokers	Deaths in smoking cohort	Deaths in hypothetical non-smoking cohort	Excess deaths*	Deaths in population	%Smoker†	%Population‡
15-19	11,615,900	5,419,979	312,581	238,300	74,281	584,997	23.8%	12.70%
20-24	10,477,601	5,926,131	337,564	256,865	80,699	534,845	23.9%	15.09%
25-29	10,307,565	6,644,256	370,763	281,094	89,669	525,744	24.2%	17.06%
30-34	10,433,650	7,341,116	395,399	298,338	97,061	521,077	24.5%	18.63%
35-39	10,339,840	7,678,365	388,440	291,878	96,562	489,611	24.9%	19.72%
40-44	9,589,184	7,303,122	329,616	246,057	83,559	406,638	25.4%	20.55%
45-49	8,455,438	6,431,206	231,261	170,891	60,370	285,050	26.1%	21.18%
50-54	7,094,744	5,247,273	106,772	77,685	29,087	134,123	27.2%	21.69%
Male total	78,313,922	51,991,449	2,472,395	1,861,107	611,288	3,482,084	24.7%	17.56%
	Population	Number of smokers				**Female**		
15-19	11,186,945	118,436	5,149	2,971	2,178	282,834	42.3%	0.77%
20-24	10,345,786	184,693	7,805	4,580	3,225	259,800	41.3%	1.24%
25-29	10,207,474	324,771	13,276	7,895	5,381	253,512	40.5%	2.12%
30-34	10,192,667	527,287	20,467	12,384	8,083	247,476	39.5%	3.27%
35-39	10,059,746	773,061	27,519	17,092	10,427	232,849	37.9%	4.48%
40-44	9,334,423	993,295	30,902	19,620	11,282	195,660	36.5%	5.77%
45-49	8,260,705	1,153,830	28,066	18,144	9,923	139,819	35.4%	7.10%
50-54	7,043,260	1,238,853	16,737	10,968	5,769	68,124	34.5%	8.47%
Female total	76,631,005	5,314,227	149,923	93,655	56,268	1,680,074	37.5%	3.35%
Total	154,944927	57,305,676	2,622,318	1,954,762	667,556	5,162,158	25.5%	12.93%

*Excess deaths = deaths in hypothetical smoking cohort minus deaths in smoking cohort, †%Smoker = excess deaths / deaths in hypothetical smoking cohort, ‡%Population = excess deaths / deaths in population

Table 3. Discounted years of life lived in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, with simulated follow up until age 55 years. Years of life lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Five-year age group	Male						
	Years of life lived in smoking cohort	Years of life lived in hypothetical non-smoking cohort	Years of life lost*	Years of life lived in population	%Smoker†	%Population‡	Per smoker
15-19	85,341,988	85,447,255	105,267	183,022,155	0.12%	0.06%	0.02
20-24	89,540,778	89,684,114	143,336	158,421,222	0.16%	0.09%	0.02
25-29	94,782,406	94,981,428	199,022	147,150,385	0.21%	0.14%	0.03
30-34	96,514,934	96,774,394	259,460	137,282,316	0.27%	0.19%	0.04
35-39	89,589,442	89,874,950	285,508	120,741,896	0.32%	0.24%	0.04
40-44	70,907,309	71,160,359	253,050	93,182,296	0.36%	0.27%	0.03
45-49	45,727,436	45,889,607	162,171	60,171,259	0.35%	0.27%	0.03
50-54	19,096,672	19,144,220	47,549	25,837,011	0.25%	0.18%	0.01
Male total	591,500,965	592,956,326	1,455,361	925,808,540	0.25%	0.16%	0.03
			Female				
15-19	1,865,269	1,871,767	6,498	176,792,140	0.35%	0.00%	0.05
20-24	2,793,172	2,803,503	10,331	157,031,085	0.37%	0.01%	0.06
25-29	4,640,246	4,659,327	19,080	146,422,341	0.41%	0.01%	0.06
30-34	6,948,801	6,979,632	30,831	134,888,216	0.44%	0.02%	0.06
35-39	9,051,397	9,090,282	38,885	118,251,772	0.43%	0.03%	0.05
40-44	9,685,471	9,724,767	39,296	91,348,587	0.40%	0.04%	0.04
45-49	8,240,188	8,268,843	28,655	59,171,089	0.35%	0.05%	0.02
50-54	4,522,533	4,532,197	9,664	25,757,266	0.21%	0.04%	0.01
Female total	47,747,078	47,930,318	183,240	909,662,496	0.38%	0.02%	0.03
Total	639,248,043	640,886,645	1,638,602	1,835,471,036	0.26%	0.09%	0.03

Uncertainty (95 % confidence intervals for years of life lost	(1,880,912 to 2,397,789)

**Years of life lost = years of life lived in hypothetical smoking cohort minus years of life lived in smoking cohort*
†%Smoker = years of life lost / years of life lived in hypothetical smoking cohort
‡%Population = years of life lost / years of life lived in population

Table 4. Discounted quality-adjusted life years (QALYs) in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, followed-up until age 55 years. QALYs lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Five-year age group	Male						
	QALYs lived in smoking cohort	QALYs lived in hypothetical non-smoking cohort	QALYs lived in population	QALYs lost*	%Smoker†	%Population‡	Per smoker
15-19	74,297,747	78,339,891	163,853,036	4,042,144	5.16%	2.47%	0.75
20-24	77,159,224	81,580,392	139,815,734	4,421,169	5.42%	3.16%	0.75
25-29	80,854,256	85,710,930	128,110,949	4,856,674	5.67%	3.79%	0.73
30-34	81,851,361	86,863,331	118,443,589	5,011,969	5.77%	4.23%	0.68
35-39	75,245,733	79,962,189	102,962,226	4,716,455	5.90%	4.58%	0.61
40-44	58,499,396	62,292,597	77,998,549	3,793,201	6.09%	4.86%	0.52
45-49	36,993,496	39,465,062	49,415,184	2,471,566	6.26%	5.00%	0.38
50-54	15,449,207	16,464,029	21,245,899	1,014,822	6.16%	4.78%	0.19
Male total	500,350,421	530,678,420	801,845,166	30,328,000	5.71%	3.78%	0.58
			Female				
15-19	1,623,807	1,715,947	161,988,410	92,140	5.37%	0.06%	0.78
20-24	2,406,797	2,549,976	142,696,640	143,180	5.61%	0.10%	0.78
25-29	3,958,097	4,204,209	131,891,088	246,112	5.85%	0.19%	0.76
30-34	5,892,553	6,264,208	120,717,970	371,655	5.93%	0.31%	0.70
35-39	7,601,482	8,086,850	104,747,754	485,368	6.00%	0.46%	0.63
40-44	7,990,062	8,512,311	79,471,653	522,249	6.14%	0.66%	0.53
45-49	6,666,312	7,111,205	50,466,887	444,893	6.26%	0.88%	0.39
50-54	3,658,729	3,897,689	21,920,599	238,960	6.13%	1.09%	0.19
Female total	39,797,839	42,342,396	813,901,000	2,544,557	6.01%	0.31%	0.48
Total	540,148,259	573,020,816	1,615,746,166	32,872,557	5.74%	2.03%	0.57
Uncertainty (95 % confidence intervals			(27,069,740 to 38,293,191)				

for QALYs lost

**QALYs lost = QALYs lived in hypothetical smoking cohort minus QALYs lived in smoking cohort*
†%Smoker = QALYs lost / QALYs lived in hypothetical smoking cohort
‡%Population = QALYs lost / QALYs lived in population

Table 5. Discounted productivity-adjusted life years (PALYs) in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, followed up until age 55 years. PALYs lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Five-year age group	Male						
	PALYs lived in smoking cohort	PALYs lived in hypothetical non-smoking cohort	PALYs lived in population	PALYs lost*	%Smoker†	%Population‡	Per smoker
15-19	68,494,994	69,922,327	148,427,632	1,427,333	2.04%	0.96%	0.26
20-24	75,510,251	77,107,666	134,731,557	1,597,415	2.07%	1.19%	0.27
25-29	81,941,157	83,712,258	128,095,883	1,771,102	2.12%	1.38%	0.27
30-34	83,788,687	85,647,639	119,868,790	1,858,952	2.17%	1.55%	0.25
35-39	77,389,067	79,144,272	104,822,053	1,755,205	2.22%	1.67%	0.23
40-44	60,621,284	62,019,639	80,034,995	1,398,355	2.25%	1.75%	0.19
45-49	38,457,431	39,344,261	50,841,097	886,830	2.25%	1.74%	0.14
50-54	15,702,846	16,048,586	21,353,268	345,740	2.15%	1.62%	0.07
Male total	501,905,718	512,946,649	788,175,275	11,040,931	2.15%	1.40%	0.21
			Female				
15-19	1,395,203	1,427,474	134,800,414	32,271	2.26%	0.26%	0.27
20-24	2,169,529	2,219,879	124,298,697	50,350	2.27%	0.27%	0.27
25-29	3,628,623	3,714,131	116,648,668	85,508	2.30%	2.30%	0.26
30-34	5,374,541	5,502,950	106,245,786	128,409	2.33%	2.33%	0.24
35-39	6,902,589	7,066,555	91,792,198	163,966	2.32%	2.32%	0.21
40-44	7,256,548	7,427,239	69,626,312	170,691	2.30%	2.30%	0.17
45-49	6,012,347	6,150,463	43,895,353	138,116	2.25%	2.25%	0.12
50-54	3,198,158	3,267,396	18,506,911	69,237	2.12%	2.12%	0.06
Female total	35,937,538	36,776,087	705,814,339	838,548	2.28%	2.28%	0.16
Total	537,843,256	549,722,735	1,493,989,613	11,879,479	2.16%	0.8%	0.21
Uncertainty (95 % confidence			(4,338,334 to 20,517,149)				

intervals for PALYs lost	

**PALYs lost = PALYs lived in hypothetical smoking cohort minus PALYs lived in smoking cohort*
†%Smoker = PALYs lost / PALYs lived in hypothetical smoking cohort
‡%Population = PALYs lost / PALYs lived in population

Table 6. Discounted cost of productivity in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, followed up until age 55 years. PALYs lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Age group	**Male**				
	Cost of productivity in smoking cohort (USD)	**Cost of productivity in hypothetical non-smoking cohort (USD)**	**Cost of productivity in population (USD)**	**Cost of productivity lost (USD)**	**Per smoker**
15-19	805,848,167,381	822,640,833,711	1,746,260,985,001	16,792,666,330	3098
20-24	888,383,139,326	907,176,831,317	1,585,125,741,031	18,793,691,990	3171
25-29	964,043,169,269	984,880,297,709	1,507,056,600,553	20,837,128,440	3136
30-34	985,779,491,330	1,007,650,179,776	1,410,264,302,708	21,870,688,446	2979
35-39	910,487,527,791	931,137,632,639	1,233,238,438,970	20,650,104,848	2689
40-44	713,213,448,977	729,665,188,981	941,617,048,049	16,451,740,004	2253
45-49	452,454,237,504	462,887,852,347	633,485,621,319	10,433,614,843	1622
50-54	184,745,035,028	188,812,685,463	251,222,621,960	4,067,650,435	775
Male total	5,904,954,216,608	6,034,851,501,943	9,308,271,359,591	129,897,285,335	2498
			Female		
15-19	16,414,656,177	16,794,322,348	1,585,935,847,987	379,666,172	3206
20-24	25,524,658,783	26,117,026,517	1,462,382,453,962	592,367,734	3207
25-29	42,690,993,139	43,697,001,960	1,372,379,349,947	1,006,008,821	3098
30-34	63,231,830,122	64,742,572,010	1,249,988,755,721	1,510,741,888	2865
35-39	81,209,421,587	83,138,494,303	1,079,941,323,043	1,929,072,715	2495
40-44	85,373,770,012	87,381,957,823	819,158,201,530	2,008,187,811	2022
45-49	70,735,658,161	72,360,606,705	516,431,758,751	1,624,948,544	1408
50-54	37,626,547,062	38,441,130,137	217,735,039,062	814,583,075	658
Female total	422,807,535,043	432,673,111,803	8,303,952,730,003	9,865,576,760	1856
Total	**6,327,761,751,651**	**6,467,524,613,745**	**17,612,224,089,594**	**139,762,862,094**	**2439**
Uncertainty (95 % confidence intervals for GDP lost			**(51, 040,000,000 to 241,400,000,000)**		

Results were derived by assuming a constant GDP per equivalent full-time (EFT) worker of USD 11,765

Table 7. Scenario Analyses

Description	Total Years of life lost	Total QALYs lost	Total PALYs lost	Total GDP lost	Total smoking health related (USD)
Base-case values with 6% discounting	1,638,602	32,872,557	11,879,479	139,762,862,094	1,573,558,483,714
Discounting 3% instead of 6%	2,544,742	43,397,964	15,868,461	186,693,503,337	1,935, 786,568,195
Percentage change from base-case	55.2%	32%	33.5%	33.5%	23%
Removing healthcare costs for age 17 to 29 in the model					1,329,232,474,452
Percentage change from base-case					-15.5%
Removing PAR% for age 17-29 years	1,583,054	32,823,594	11,832,106	139,205,510,813	1,573,616,847,691
Percentage change from base-case	-3.40%	-0.149%	-0.399%	-0.399%	0.004%
Applying annual GDP growth of 5.17%				242, 190,420,909	
Percentage change from base-case				73%	

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

REFERENCES

1. The World Bank. Smoking prevalence, total (ages 15+) [Internet]. The World Bank Data. [cited 2019 Mar 30]. Available from: https://data.worldbank.org/indicator/SH.PRV.SMOK?end=2016&start=2010&view=chart
2. The World Bank. Smoking prevalence (Indonesia), total (ages 15+) [Internet]. The World Bank Data. [cited 2019 Mar 30]. Available from: https://data.worldbank.org/indicator/SH.PRV.SMOK?end=2016&locations=ID&start=2010&view=chart
3. Bunn WB, Stave GM, Downs KE, Alvir JMJ, Dirani R. Effect of Smoking Status on Productivity Loss: J Occup Environ Med. 2006;48(10):1099–108.
4. Owen AJ, Maulida SB, Zomer E, Liew D. Productivity burden of smoking in Australia: a life table modelling study. Tobacco Control. 2018;0:1–8.
5. Tan QY, Zomer E, Owen AJ, Chin KL, Liew D. Impact of tobacco use on health and work productivity in Malaysia. Tob Control. 2019;0:1–7.
6. Diener-West M, Kanchanaraksa S. Life Tables. Johns Hopkins Bloomberg School of Public Health, 2008.
7. Bank Indonesia. Statistik ekonomi dan keuangan Indonesia (SEKI) [Internet]. Bank Indonesia. 2019. Available from: https://www.bi.go.id/id/statistik/seki/terkini/moneter/Contents/Default.aspx
8. Global Burden of Disease Collaborative Network. Global burden of disease study 2017 (GBD 2017) population estimates 1950-2017 [Internet]. Global Health Data Exchange (GHDx). 2019. Available from: http://ghdx.healthdata.org/record/ihme-data/gbd-2017-population-estimates-1950-2017
9. Institute for Health Metrics and Evaluation (IHME). GDB Compare|Viz Hub [Internet]. IHME. [cited 2019 Apr 3]. Available from: https://vizhub.healthdata.org/gbd-compare/

10. Kosen S, Hardjo H, Kadarmanto, Sinha DN, Palipudi KM, Wibisana W, et al. Global adult tobacco survey: Indonesia report 2011. Indonesia: World Health Organisation; 2012. 162 p.
11. Mathers C, Stevens G, d'Espaignet ET, Wolfenden L. WHO global report: mortality attributable to tobacco. Geneva: World Health Organisation; 2012. 181 p.
12. Jia H, Lubetkin EI. Trends in Quality-Adjusted Life-Years Lost Contributed by Smoking and Obesity. American Journal of Preventive Medicine. 2010;38(2):138–44.
13. Badan Pusat Statistik. Keadaan angkatan kerja di Indonesia (labor force situation in Indonesia): Agustus/August 2018. Indonesia: Badan Pusat Statistik; 2018. 229 p.
14. International Monetary Fund. World economic outlook database [Internet]. International Monetary Fund. 2017. Available from: https://www.imf.org/external/pubs/ft/weo/2017/02/weodata/weorept.aspx?pr.x=21&pr.y=9&sy=2015&ey=2022&scsm=1&ssd=1&sort=country&ds=.&br=1&c=536&s=NGDPD&grp=0&a=
15. Kristina SA, Endarti D, Wiedyaningsih C, Fahamsya A, Faizah N. Health Care Cost of Noncommunicable Diseases Related to Smoking in Indonesia, 2015. Asia Pacific Journal of Public Health. 2018 Jan;30(1):29–35.
16. Ma J, Siegel RL, Jacobs EJ, Jemal A. Smoking-attributable Mortality by State in 2014, U.S. Am J Prev Med. 2018;54(5):661–70.
17. Ostbye T, Taylor DH. The Effect of Smoking on Years of Healthy Life (YHL) Lost among Middle-Aged and Older Americans. Health Serv Res. 2004;39(3):531–52.
18. Goodchild M, Nargis N, Tursan d'Espaignet E. Global economic cost of smoking-attributable diseases. Tob Control. 2018;27(1):58–64.
19. Bach L. Toll of tobacco in United States of America [Internet]. Campaign for Tobacco-Free Kids. 2019 [cited 2019 Apr 4]. Available from: https://www.tobaccofreekids.org/assets/factsheets/0072.pdf
20. Ekpu VU, Brown AK. The Economic Impact of Smoking and of Reducing Smoking Prevalence: Review of Evidence. Tobacco Use Insights. 2015;8:1–35.

21. Cahill K, Stevens S, Perera R, Lancaster T. Pharmacological interventions for smoking cessation: an overview and network meta-analysis. Cochrane Tobacco Addiction Group, editor. Cochrane Database of Systematic Reviews. 2013;(5):1–43.

22. Trapero-Bertran M, Leidl R, Muñoz C, Kulchaitanaroaj P, Coyle K, Präger M, et al. Estimates of costs for modelling return on investment from smoking cessation interventions: Cost estimates for smoking cessation modelling. Addiction. 2018;113 (Suppl. 1):32–41.

23. Mackenzie TD, Bartecchi CE, Schrier RW. The human costs of tobacco use. N Engl J Med. 1994;330(14):975–980.

24. Jha F, Chaloupka FJ. The economics of global tobacco control. BMJ. 2000;321:358–361.

25. Cleghorn CL, Blakely T, Kvizhinadze G, Deen FS van der, Nghiem N, Cobiac LJ, et al. Impact of increasing tobacco taxes on working-age adults: short-term health gain, health equity and cost savings. Tob Control. 2018;27:e167–70.

26. World Health Organisation. WHO report on the global tobacco epidemic, 2019. Country profile: Indonesia [Internet]. World Health Organisation; 2019. Available from: https://www.who.int/tobacco/surveillance/policy/country_profile/idn.pdf

27. World Health Organisation. Tobacco free initiative (TFI): Taxation [Internet]. World Health Organisation. [cited 2019 Sep 26]. Available from: https://www.who.int/tobacco/economics/taxation/en/

28. Bolin K. Economic evaluation of smoking-cessation therapies: a critical and systematic review of simulation models. *PharmacoEconomics* 2012;30(7):551-64.

29. Ruger JP, Lazar CM. Economic evaluation of pharmaco- and behavioral therapies for smoking cessation: a critical and systematic review of empirical research. *Annu Rev Public Health* 2012;33:279-305.

30. Gordon L, Graves N, Hawkes A, et al. A review of the cost-effectiveness of face-to-face behavioural interventions for smoking, physical activity, diet and alcohol. *Chronic Illness* 2007;3:101 - 29.

31. Annemans L, Kristiaan N, Pierre B, et al. Cost Effectiveness of Varenicline in Belgium, Compared with Bupropion, Nicotine Replacement Therapy, Brief Counselling and Unaided Smoking Cessation: A BENESCO Markov Cost-Effectiveness Analysis. *Clinical Drug Investigation* 29:655-65.

32. Hurley SF, Matthews JP. The Quit Benefits Model: a Markov model for assessing the health benefits and health care cost savings of quitting smoking. *Cost Eff Resour Alloc* 2007;5:2.

Health and economic burden of smoking in Indonesia

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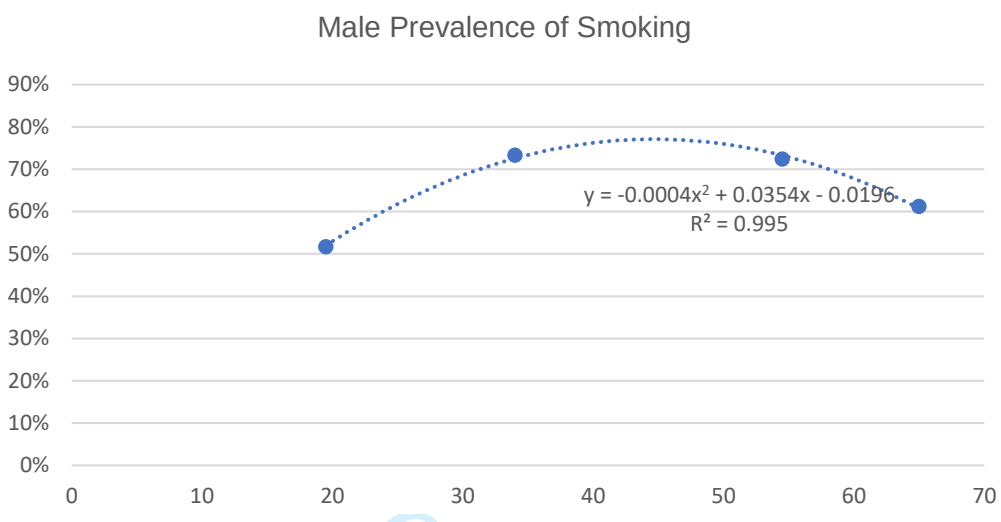
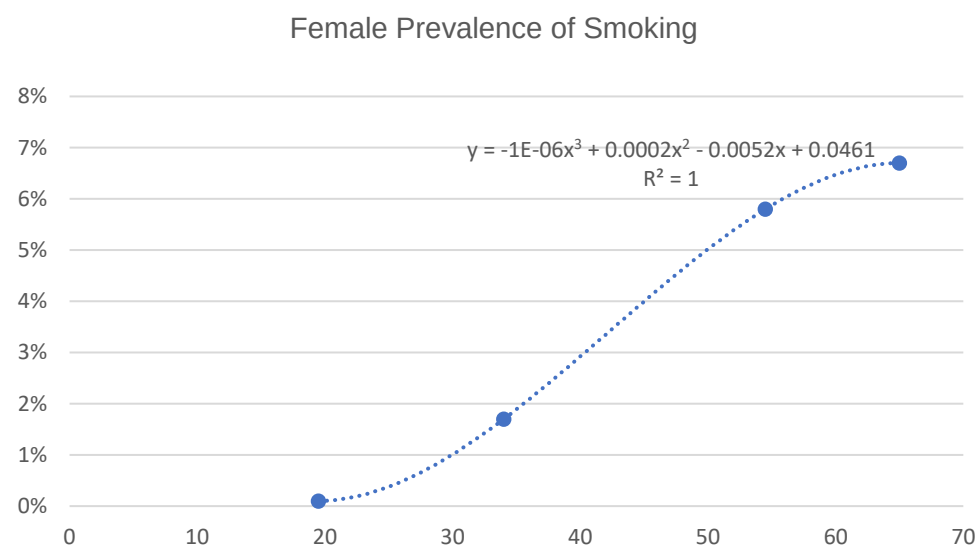
Appendix 1. Trends of smoking prevalence in Indonesian males and females, using polynomial function



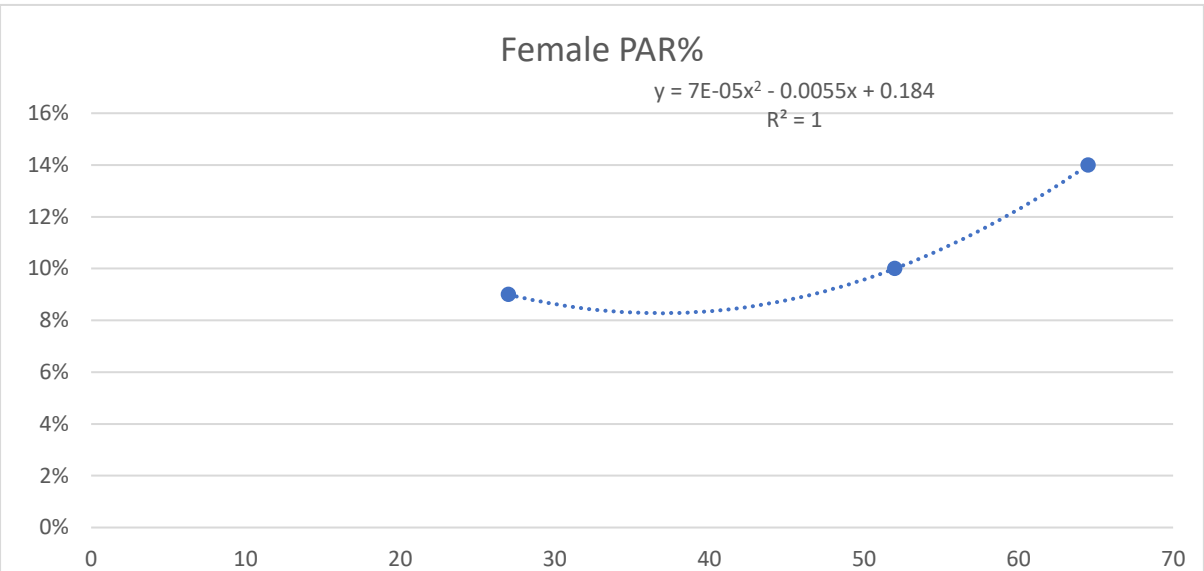


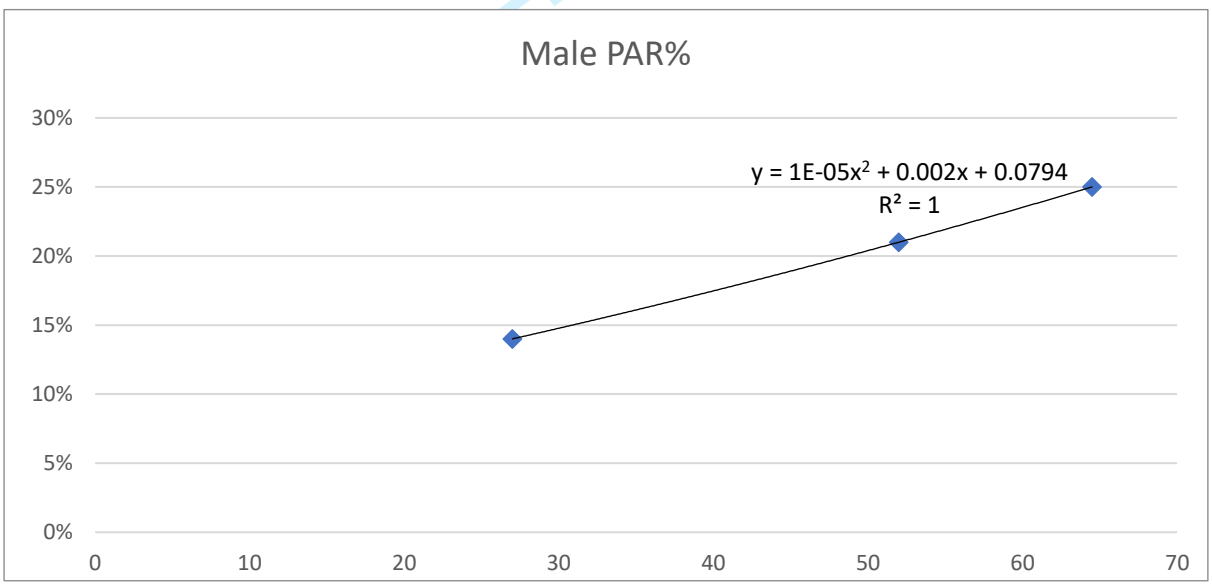
Appendix 2. Age- and sex-specific prevalence of smoking in Indonesian working-age population, derived from the polynomial function

Age	Male	Female
15	0.4214	0.009725
16	0.4444	0.010004
17	0.4666	0.010587
18	0.488	0.011468
19	0.5086	0.012641
20	0.5284	0.0141
21	0.5474	0.015839
22	0.5656	0.017852
23	0.583	0.020133
24	0.5996	0.022676
25	0.6154	0.025475
26	0.6304	0.028524
27	0.6446	0.031817
28	0.658	0.035348
29	0.6706	0.039111
30	0.6824	0.0431
31	0.6934	0.047309
32	0.7036	0.051732
33	0.713	0.056363
34	0.7216	0.061196
35	0.7294	0.066225
36	0.7364	0.071444
37	0.7426	0.076847

38	0.748	0.082428
39	0.7526	0.088181
40	0.7564	0.0941
41	0.7594	0.100179
42	0.7616	0.106412
43	0.763	0.112793
44	0.7636	0.119316
45	0.7634	0.125975
46	0.7624	0.132764
47	0.7606	0.139677
48	0.758	0.146708
49	0.7546	0.153851
50	0.7504	0.1611
51	0.7454	0.168449
52	0.7396	0.175892
53	0.733	0.183423
54	0.7256	0.191036
55	0.7174	0.198725

Appendix 3. The relationships between age in single years and population attributable risk percent (PAR%) values for females and males





Appendix 4. Undiscounted years of life lived in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, with simulated follow up until age 55 years. Years of life lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Age group	Male						
	Years of life lived in smoking cohort	Years of life lived in hypothetical non-smoking cohort	Years of life lived in population	Years of life lost*	%Smoker†	%Population‡	Per smoker
15-19	208,528,181	209,121,701	447,588,437	593,520	0.28%	0.13%	0.11
20-24	198,530,993	199,158,625	351,491,578	627,632	0.32%	0.18%	0.11
25-29	189,619,327	190,294,103	294,537,919	674,775	0.35%	0.23%	0.10
30-34	173,191,003	173,878,956	246,439,614	687,952	0.40%	0.28%	0.09
35-39	143,310,295	143,916,289	193,194,557	605,994	0.42%	0.31%	0.08
40-44	100,460,981	100,893,899	132,043,315	432,917	0.43%	0.33%	0.06
45-49	56,994,036	57,219,203	75,003,867	225,166	0.39%	0.30%	0.04
50-54	20,788,999	20,842,888	28,127,409	53,889	0.26%	0.19%	0.01
Male total	1,091,432,817	1,095,325,664	1,768,426,696	3,901,847	0.36%	0.22%	0.08
	Female						
15-19	4,564,055	4,592,596	433,767,270	28,541	0.62%	0.01%	0.24
20-24	6,202,310	6,240,335	349,521,420	38,026	0.61%	0.01%	0.21
25-29	9,297,089	9,354,472	293,951,224	57,383	0.61%	0.02%	0.18
30-34	12,487,206	12,562,756	242,767,492	75,550	0.60%	0.03%	0.14
35-39	14,496,876	14,576,097	189,597,630	79,221	0.54%	0.04%	0.10
40-44	13,734,779	13,800,790	129,626,036	66,011	0.48%	0.05%	0.07

45-49	10,275,596	10,315,141	73,810,417	39,545	0.38%	0.05%	0.03
50-54	4,923,935	4,934,878	28,045,352	10,943	0.22%	0.04%	0.01
Female total	75,981,845	76,377,066	1,741,086,842	395,221	0.52%	0.02%	0.07
Total	**1,167,405,662**	**1,171,702,729**	**3,509,513,537**	**4,297,068**	**0.37%**	**0.12%**	**0.07**

**Years of life lost = years of life lived in hypothetical smoking cohort minus years of life lived in smoking cohort*

†%Smoker = years of life lost / years of life lived in hypothetical smoking cohort

‡%Population = years of life lost / years of life lived in population

Appendix 5. Undiscounted quality-adjusted life years (QALYs) in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, followed-up until age 55 years. QALYs lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Age group	Male						
	QALYs lived in smoking cohort	QALYs lived in hypothetical non-smoking cohort	QALYs lived in population	QALYs lost*	%Smoker†	%Population‡	Per smoker
15-19	178,258,628	188,806,185	394,094,931	10,547,557	2.59%	2.68%	1.95
20-24	168,581,504	178,858,123	305,950,614	10,276,618	3.75%	3.36%	1.73
25-29	159,941,789	169,961,969	253,650,266	10,020,180	3.90%	3.95%	1.51
30-34	145,330,966	154,571,587	210,446,114	9,240,622	4.98%	4.39%	1.26
35-39	119,300,639	127,011,681	163,325,426	7,711,041	6.07%	4.72%	1.00
40-44	82,474,999	87,927,751	109,998,602	5,452,752	6.20%	4.96%	0.75
45-49	46,108,176	49,208,514	61,596,630	3,100,339	6.30%	5.03%	0.48
50-54	16,818,300	17,924,884	23,129,333	1,106,584	6.17%	4.78%	0.21
Male total	916,815,001	974,270,694	1,522,191,915	57,455,693	5.90%	3.77%	1.11
	Female						
15-19	3,901,127	4,145,850	391,353,469	244,723	5.90%	0.06%	2.07
20-24	5,266,081	5,603,495	313,548,696	337,414	6.02%	0.11%	1.83
25-29	7,841,132	8,353,934	262,049,174	512,803	6.14%	0.20%	1.58
30-34	10,477,279	11,166,424	215,162,247	689,145	6.17%	0.32%	1.31
35-39	12,066,832	12,862,572	166,583,235	795,740	6.19%	0.48%	1.03
40-44	11,275,029	12,026,448	112,266,363	751,419	6.25%	0.67%	0.76

45-49	8,312,958	8,871,021	62,952,904	558,064	6.29%	0.89%	0.48
50-54	3,983,463	4,243,995	23,867,882	260,531	6.14%	1.09%	0.21
Female total	63,123,901	67,273,740	1,547,783,969	4,149,839	6.17%	0.27%	0.78
Total	**979,938,903**	**1,041,544,434**	**3,069,975,884**	**61,605,531**	**5.91%**	**2.01%**	**1.08**

**QALYs lost = QALYs lived in hypothetical smoking cohort minus QALYs lived in smoking cohort*

†%Smoker = QALYs lost / QALYs lived in hypothetical smoking cohort

‡%Population = QALYs lost / QALYs lived in population

Appendix 6. Undiscounted productivity-adjusted life years (PALYs) in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, followed up until age 55 years. PALYs lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Age group	Male						
	PALYs lived in smoking cohort	**PALYs lived in hypothetical non-smoking cohort**	**PALYs lived in population**	**PALYs lost***	**%Smoker†**	**%Population‡**	**Per smoker**
15-19	173,474,018	177,368,520	376,235,202	3,894,503	2.04%	2.20%	1.04%
20-24	168,975,706	172,811,807	301,701,040	3,836,102	2.07%	2.22%	1.27%
25-29	163,236,642	167,000,910	255,312,539	3,764,269	2.12%	2.25%	1.47%
30-34	149,215,907	152,716,850	213,549,725	3,500,943	2.17%	2.29%	1.64%
35-39	122,888,356	125,803,245	166,494,275	2,914,889	2.22%	2.32%	1.75%
40-44	85,391,550	87,424,744	112,757,699	2,033,194	2.25%	2.33%	1.80%
45-49	47,765,809	48,886,805	63,153,005	1,120,996	2.25%	2.29%	1.78%
50-54	17,075,069	17,452,780	23,219,882	377,711	2.15%	2.16%	1.63%
Male total	928,023,057	949,465,663	1,512,423,369	21,442,606	2.15%	2.26%	1.42%
	Female						
15-19	3,454,476	3,543,688	334,631,526	89,213	2.26%	2.52%	0.03%
20-24	4,766,441	4,888,406	273,707,641	121,965	2.27%	2.49%	0.04%
25-29	7,148,524	7,331,498	230,244,087	182,973	2.30%	2.50%	0.08%
30-34	9,517,342	9,759,921	188,420,550	242,579	2.33%	2.49%	0.13%
35-39	10,925,063	11,197,256	145,436,238	272,192	2.32%	2.43%	0.19%
40-44	10,198,266	10,445,798	97,916,189	247,532	2.30%	2.37%	0.25%

45-49	7,461,050	7,635,233	54,489,310	174,183	2.25%	2.28%	0.32%
50-54	3,475,813	3,551,358	20,115,015	75,546	2.12%	2.13%	0.38%
Female total	56,946,974	58,353,158	1,344,960,555	1,406,183	2.28%	2.41%	0.10%
Total	**984,970,032**	**1,007,818,821**	**2,857,383,924**	**22,848,789**	**2.16%**	**2.27%**	**0.80%**

**PALYs lost = PALYs lived in hypothetical smoking cohort minus PALYs lived in smoking cohort*

†%Smoker = PALYs lost / PALYs lived in hypothetical smoking cohort

‡%Population = PALYs lost / PALYs lived in population

Appendix 7. Undiscounted cost of productivity in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, followed up until age 55 years. Cost of productivity in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Age group	Male				
	Cost of productivity in smoking cohort (USD)	Cost of productivity in hypothetical non-smoking cohort (USD)	Cost of productivity in population (USD)	Cost of productivity lost (USD)	Per smoker
15-19	2,040,933,377,470	2,086,752,460,344	4,426,432,225,193	45,819,082,874	8,454
20-24	1,988,010,438,704	2,033,142,428,931	3,549,532,841,688	45,131,990,227	7,616
25-29	1,920,489,965,430	1,964,776,840,170	3,003,769,036,166	44,286,874,740	6,665
30-34	1,755,535,087,482	1,796,723,920,318	2,512,426,744,649	41,188,832,836	5,611
35-39	1,445,789,701,343	1,480,083,565,295	1,958,816,242,828	34,293,863,952	4,466
40-44	1,004,637,279,945	1,028,557,944,009	1,326,601,846,453	23,920,664,064	3,275
45-49	561,967,931,517	575,156,518,501	742,999,315,332	13,188,586,984	2,051
50-54	200,889,325,891	205,333,121,415	273,183,464,366	4,443,795,524	847
Male total	10,918,253,107,783	11,170,526,798,984	17,793,761,716,675	252,273,691,201	4,852
	Female				
15-19	40,642,135,127	41,691,730,946	3,936,962,206,022	1,049,595,819	8,862
20-24	56,077,493,219	57,512,423,964	3,220,188,638,809	1,434,930,744	7,769
25-29	84,102,866,363	86,255,559,803	2,708,837,022,834	2,152,693,440	6,628
30-34	111,972,165,326	114,826,120,386	2,216,780,321,333	2,853,955,060	5,413
35-39	128,534,097,962	131,736,459,606	1,711,067,025,659	3,202,361,644	4,142
40-44	119,983,274,255	122,895,507,971	1,151,990,483,747	2,912,233,716	2,932

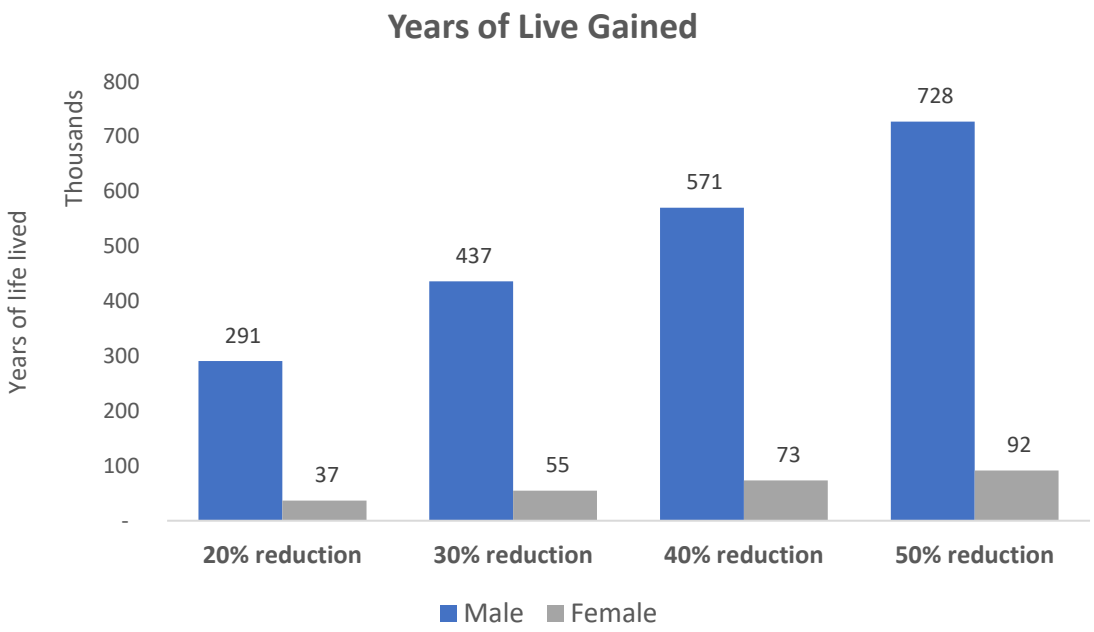
45-49	87,779,751,152	89,829,020,079	641,070,357,632	2,049,268,926	1,776
50-54	40,893,166,125	41,781,965,179	236,654,495,577	888,799,055	717
Female total	669,984,949,529	686,528,787,934	15,823,550,551,614	16,543,838,405	3,113
Total	**11,588,238,057,312**	**11,857,055,586,918**	**33,617,312,268,288**	**268,817,529,606**	**4,691**

Results were derived by assuming a constant GDP per equivalent full-time worker of USD 11,765

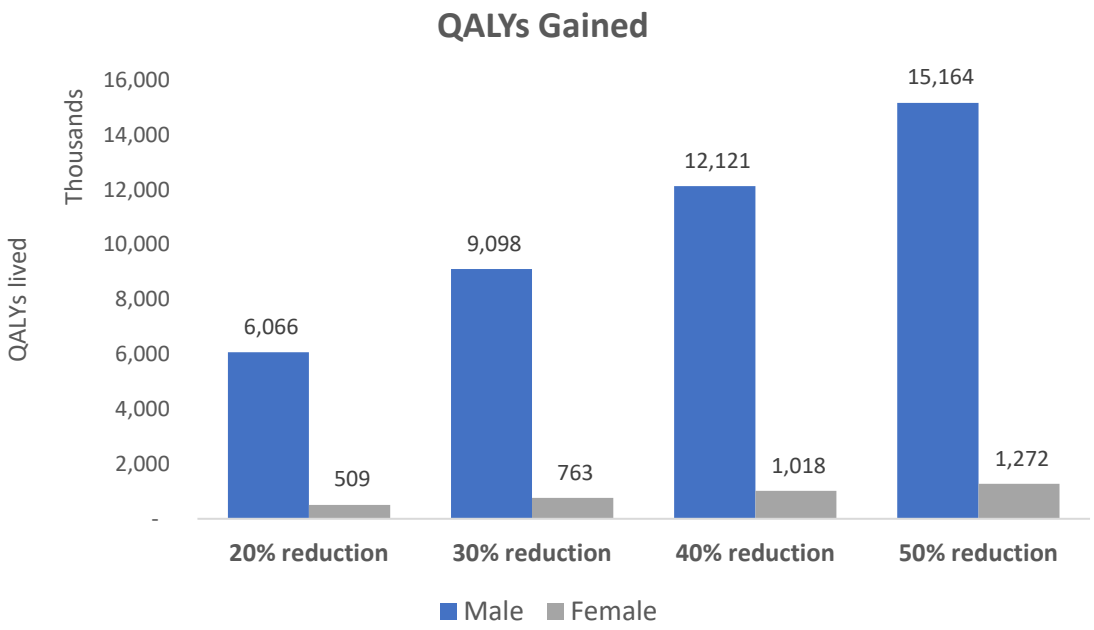
Appendix 8. Discounted smoking-attributable healthcare expenditures in the smoking cohort of Indonesians aged 15 to 54 years, followed up until age 55 years. Attributable healthcare expenditures in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Age group	**Smoking-related healthcare costs (USD)**	
	Male	**Female**
15-19	187,225,527,813	4,092,076,397
20-24	196,436,945,339	6,127,735,349
25-29	207,936,168,449	10,179,896,275
30-34	371,362,742,837	26,777,847,756
35-39	196,543,705,110	19,857,195,744
40-44	155,558,344,935	21,248,245,437
45-49	100,318,067,978	18,077,543,455
50-54	41,894,787,387	9,921,653,452
Total	1,457,276,289,848	116,282,193,866
Total	1,573,558,483,714	
Uncertainty (95 % confidence intervals for smoking health related healthcare lost	158,300,000,000 to 5, 383,000,000,000	

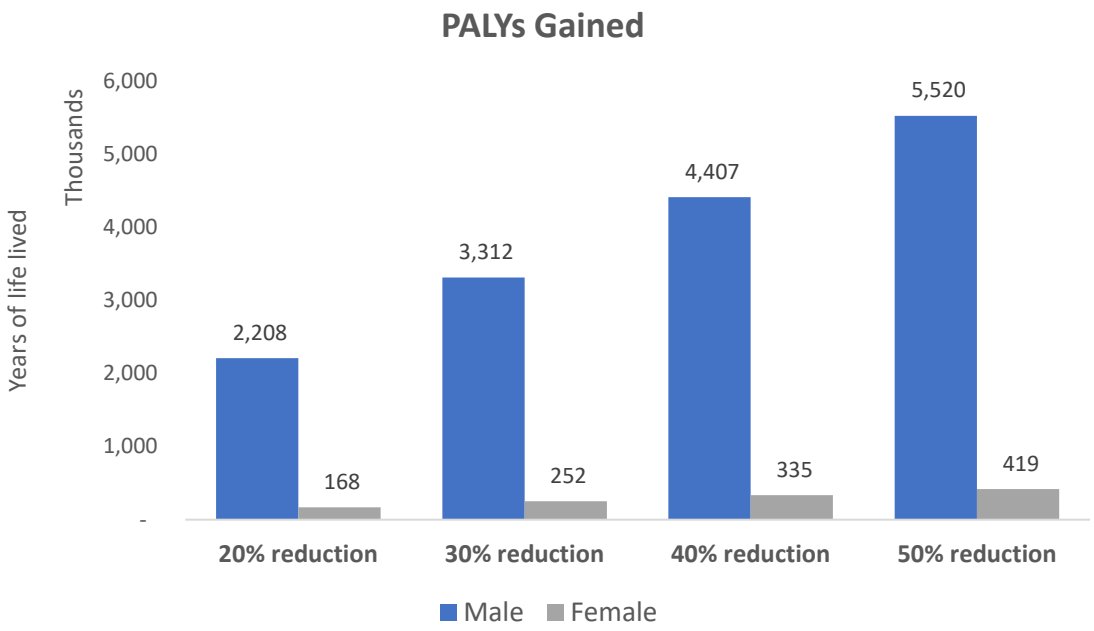
Appendix 9. Total discounted years of life gained in the hypothetical smoking cohort with 20%, 30%, 40% and 50% reduction in the smoking prevalence.



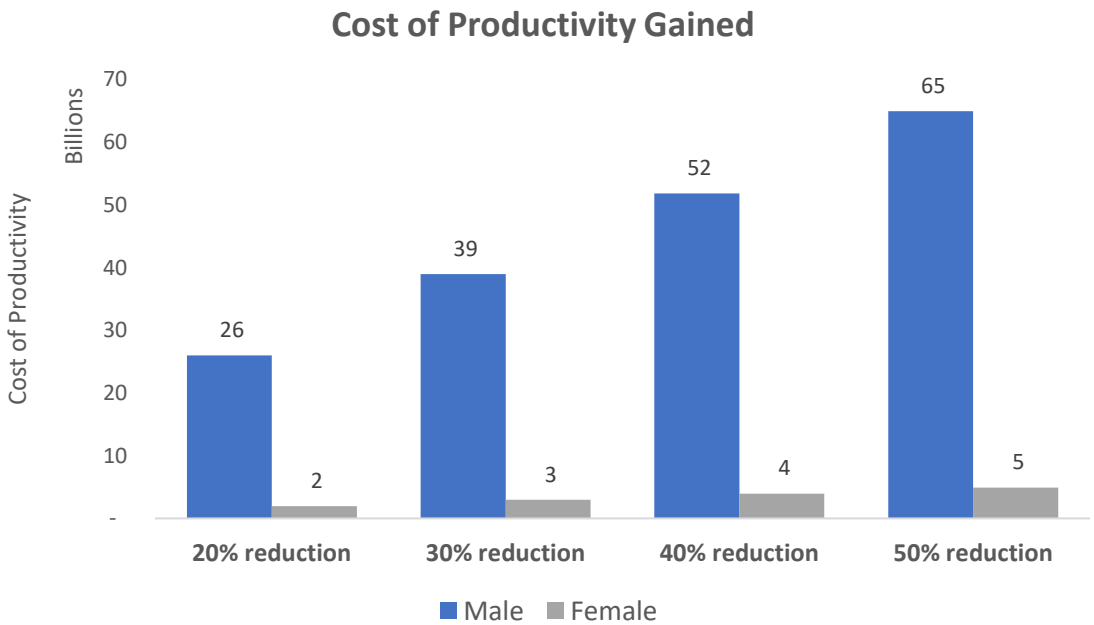
Appendix 10. Total discounted QALYs gained in the hypothetical smoking cohort with 20%, 30%, 40% and 50% reduction in the smoking prevalence.



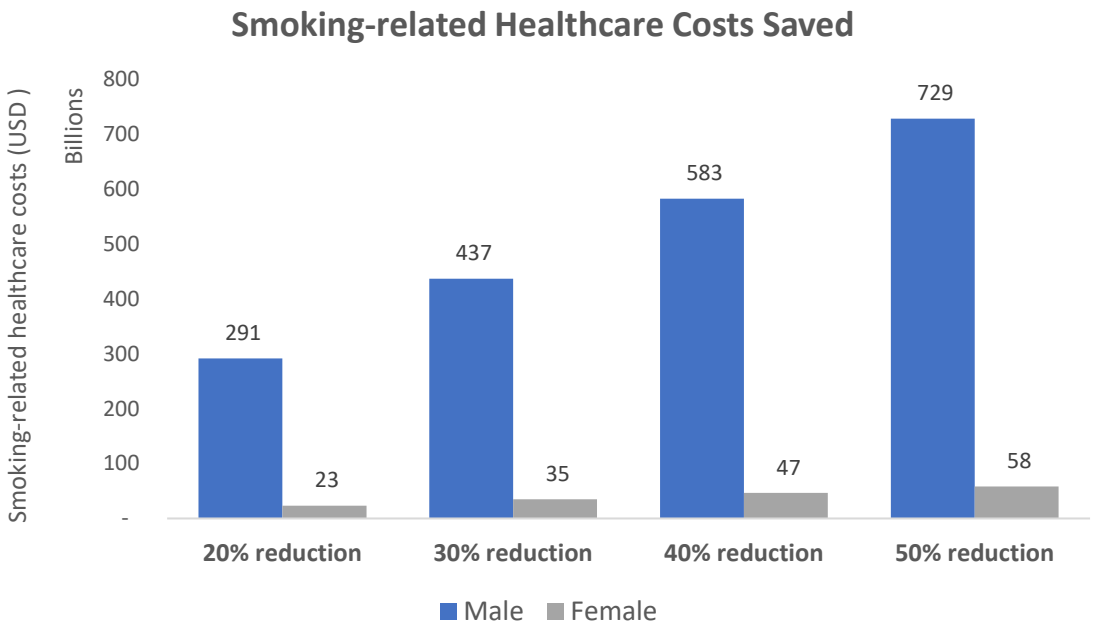
Appendix 11. Total discounted PALYs gained in the hypothetical smoking cohort with 20%, 30%, 40% and 50% reduction in the smoking prevalence.



Appendix 12. Total discounted cost of productivity gained in the hypothetical smoking cohort with 20%, 30%, 40% and 50% reduction in the smoking prevalence.



Appendix 13. Total discounted smoking-attributable healthcare costs saved in the hypothetical smoking cohort with 20%, 30%, 40% and 50% reduction in the smoking prevalence.



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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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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 Indonesian population of working-age 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 to 54 years, followed-up until 55 years (retirement age). Contemporary data on demographic, 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 the cohorts were non-smokers. The differences in results represented the losses incurred by smoking. Gross domestic product (GDP) per equivalent full-time worker (USD 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 prevalence of smoking among Indonesian working-age males and females 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 USD 183.7 billion among working age population followed-up until retirement. Healthcare costs was predicted to be USD 1.8 trillion. Over one-year time horizon, there were USD 10.2 billion loss in GDP and 117 billion lost in healthcare costs.

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

Strengths and limitations of this study

- This study utilised 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 (GDP) 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. Recently, 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 to 2016, peaking at 39.4%, which accounted for almost 103 million people (2). This was due to the fact that smoking is introduced at a younger age, mainly through advertisements and family influences. equivalent to 5.3% of

The healthcare costs of tobacco smoking are substantial. Data from the US and India suggests that smoking attributed healthcare costs range from 5.3% to 5.7% of 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 (USD 240 billion) (5), while in Malaysia the loss reached RM275.3 billion (USD 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 level.

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 to 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, then repeated but 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 to smokers, while utilities and productivity indices 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 in discounted values, with 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 patient and public was 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 five-year age group and sex, were derived from the Global Burden of Disease (GBD) 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 five-year age group was first plotted against the midpoint age for that age group (e.g., 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 (GATS): 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 (e.g., 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 (Appendix 1 and 2). Second step was to regroup age in single years 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 Appendix 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 percent (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%= population attributable risk percentage (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 the 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 (e.g., 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 (Appendix 3).

Quality of life and productivity

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

The productivity index (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 (i.e., 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 to 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* (BPS) 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 to 55 years. The weighted average of EFT workers across ages 15 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 (five 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 to 55 years (199.6 days). Thus, smokers were estimated to have 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 annual gross domestic product (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 (USD 1,179,913 million or IDR 16,837,358,510 million)(18) with the estimated total Indonesian EFT workers from age 15 to 55 years in 2018 (100,289,529). Based on this, the cost of each PALY was estimated to be USD 11,765 (IDR 168,883,998), with an assumption that all GDP was produced by Indonesian workers aged 15 to 55 years (Table 1). Furthermore, we have forecasted temporal trends in GDP growth within 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 (USD 2,177 million) by the number of smokers (992,330) in the cohort, which equated to USD 2,194 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 the impact of applying annual GDP growth, removing health care costs for participants aged 17 to 29 years and 17 to 34 years, respectively, and implications of removing effect of PAR% for participants aged 17 to 29 years might have on the final outcomes of interest. We also performed a scenario analysis with a one-year time horizon.

To reflect uncertainty (95% confidence intervals) 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 productivity indices and costs, we applied uniform and gamma distributions, respectively. For utilities and costs, the standard error was assumed to be 5% and 15% of the means, estimate respectively. We run the simulation for 10,000 iterations to capture uncertainty in the model using the software package @Risk 7.5 (Palisade, Ithaca, NY). Detailed information is provided in Appendix 4 and 5.

RESULTS

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

Deaths

Table 2 summarises the estimated number of deaths arising from the smoking and the hypothetical non-smoking groups. With simulated follow up until retirement, the smoking cohort was predicted to incur 846,123 excess deaths, (830,126 among males and 15,998 among females). Smoking-attributable deaths accounted for 12.5% (22.8% among males and 2.2% among females) 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 2,959,283 years of life lost (95% CI: 2.5 to 3.3 million) (discounted), with 2,893,661 (0.4% among male smokers) years of life lost in males and 65,622 (0.4% among female smokers) in females.

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 41,629,391 QALYs lost (95% CI: 26.1 to 100 million) (discounted), with 40,750,543 (5.9% among male smokers) QALYs lost in males and 878,848 (6.1% among female smokers) in females.

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 males and 288,768 (2.3% loss among female smokers) in females. 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 USD 11,765 In total, smoking was associated with USD 183,726,339,465 loss in GDP (95 CI: 148.4 to 164.3 billion) (discounted), with USD 180,328,964,857 GDP lost in males and USD 3,397,374,608 in females (Table 4). GDP lost per smoker was estimated to reach USD 3,435 among 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 USD 1,837,669,140,149 (95% CI: 1.82 to 1.85 trillion). Males incurred smoking-related healthcare costs of USD 1,799,385,510,167, while females incurred USD 38,283,629,982 among working age population followed-up until retirement (Table 4).

All other undiscounted results are provided in the supplementary material (Appendix 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, a halving of the current prevalence of smoking would return approximately 1.4 million years of life, 20.3 million QALYs, 7.6 million PALYs, USD 90 billion in GDP and save USD 899 billion in smoking-related healthcare costs.

Running the model for one year only, lead to 10,414 years of life lost 2,573,566 QALY lost, 874,136 PALYs lost, USD 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 age 17 to 29 years and 17 to 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 Indonesia 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 accord with data from around the world. A study from Australia by Owen et al., which also utilised 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 (e.g. 65 years in Malaysia and 70 years in Australia).

The present study predicted that 2,959,283 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 to 69 years if they were followed-up until 70 years (5). Indonesian smokers showed an overall similar percentage of years of life lost compared to 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 to 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 2,182,053 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 quality-adjusted life years

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 females was greater in proportional terms (0.58 QALYs lost in females). 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 to 65 years) (6). The extent of QALYs lost per Indonesian smoker of working age was less than those predicted for working-age Australians and Malaysian males 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 to 54 years with follow-up until retirement, equated to a 2.3% loss or 0.29 PALYs lost per smoker. Similar with smoking impact on quality of life, males bore this burden more in absolute terms, but the loss among females 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 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 (i.e. 15.6 million), but in proportional terms was higher in Australia and Malaysia, due to longer follow-up periods of the two cohorts.

We estimated the broader economic costs of smoking, in terms of lost GDP, to be US $3,435(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 age 15 to 54 years would incur total healthcare costs of USD 1.83 trillion by the time they reached aged 55 years. Even when healthcare costs were removed for participants aged 15 to 34 years, smokers in Indonesia still incurred 1.37 trillion by the time they reached aged 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, USD 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 2017-18 for age above 35 years and found that total economic costs attributed to tobacco was USD 27.5 billion, equivalent to 5.3% of total health expenditure (4). Using similar age bracket as the recent study from India our annual estimated costs amounted USD 77.3 billion. In Thailand, total cost of smoking contributed for 0.78% of countries national GDP (21).

Implications

Although the present study did not evaluate cost-effectiveness of individual smoking prevention strategies, the results provide a theoretical illustration of gains from reducing smoking prevalence. The mortality due to smoking is very large in the world and any smoking interventions (including education, behaviour and smoking cessation therapy) are likely to reduce the 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 programs 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 EUR 19.69 (USD 21.46) to EUR 624.47 (USD 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 to 65 years, and savings of approximately NZD 10.6 million (USD 6.6 million) in healthcare costs. Non-price-based legislation may even be more effective, reducing smoking prevalence between 30% to 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 programs, 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 to the worldwide benchmark of 70% (29).

Other challenges include a lack of awareness concerning the negative health and economic impact of tobacco smoking among people in Indonesia. By couching all the smoking-attributable losses and 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 programs.

STRENGTH 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 utilised a recently derived measure called PALYs (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 a better insight into the potential gains from smoking prevention measures, and hence may help inform cost-effective cessation programs 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 to the present study. First, the analyses did not consider potential losses and gains from second-hand smoking-attributable mortality and morbidity, due to a lack of relevant data inputs from Indonesia.

Secondly, 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.

Thirdly, 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. Fourthly, 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 steamed from lack of gender 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 level. 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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Author contributions

ZA, DL and DM conceived the idea and contributed to the design of the work. ZA, RS and RU and contributed to the acquisition, analysis or interpretation of data for the work. RS and ZA drafted the manuscript. ZA, DL, DM, RS and EZ critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work ensuring integrity and accuracy.

Conflicts of interest

RS, RU, ZA and DM have no conflicts of interest to declare. EZ has received grants from Amgen, AstraZeneca, Pfizer and Shire, outside the submitted work. DL declares grant support from Abbvie, Astellas, AstraZeneca, Bristol-Myers Squibb, CSL-Behring, Novartis, Pfizer, Sanofi and Shire, and past participation in advisory boards at Abbvie, Astellas, AstraZeneca, Bristol-Myers Squibb, Novartis, Pfizer and Sanofi outside the submitted work.

Ethics

Ethics approval not required as this study relied on published and publicly available data.

Data Availability Statement

Data are available in published form and costing data are presented in the electronic supplementary files. The model is available upon reasonable request.

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

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

Age groups	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	2,194	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	2,194	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**	

PAR%-population attributable risk percentage, Cost displayed in the USD. Smoking PAR% for age group 15-29 years was assumed to be half of the PAR% for age 30 years.

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 to 54 years with simulated follow up until 55 years. Deaths in the smoking cohort and non-smoking cohort 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	5,419,979	318,805	220,033	98,772	126,123,437	126,408,651	285,214	0.2%
20-24	10,477,601	5,926,131	344,404	236,847	107,557	127,565,545	127,914,286	348,741	0.3%
25-29	10,307,565	6,644,256	378,480	258,567	119,914	129,648,743	130,083,628	434,885	0.3%
30-34	10,433,650	7,341,116	404,010	273,264	130,747	126,211,904	126,729,758	517,854	0.4%
35-39	10,339,840	7,678,365	397,418	265,750	131,668	111,497,485	112,029,897	532,413	0.5%
40-44	9,589,184	7,303,122	337,807	222,333	115,474	83,588,357	84,028,600	440,242	0.5%
45-49	8,455,438	6,431,206	237,588	152,960	84,628	50,807,739	51,070,494	262,755	0.5%
50-54	7,094,744	5,247,273	110,106	68,738	41,367	19,896,412	19,967,969	71,557	0.4%
Total	78,313,922	51,991,449	2,528,618	1,698,493	830,126	775,339,623	778,233,283	2,893,661	0.4%
				Female					
15-19	11,186,945	7,331	309	196	113	171,058	171,512	454	0.3%
20-24	10,345,786	20,692	854	546	308	446,938	448,158	1,219	0.3%
25-29	10,207,474	96,971	3,934	2,511	1,423	1,899,506	1,905,657	6,152	0.3%
30-34	10,192,667	173,275	6,847	4,336	2,512	2,990,977	3,003,050	12,073	0.4%
35-39	10,059,746	246,464	9,181	5,804	3,378	3,593,983	3,610,415	16,431	0.5%
40-44	9,334,423	298,702	9,891	6,287	3,604	3,433,867	3,449,819	15,952	0.5%
45-49	8,260,705	326,298	8,505	5,477	3,028	2,588,764	2,599,157	10,393	0.4%
50-54	7,043,260	331,033	4,772	3,140	1,631	1,258,941	1,261,889	2,948	0.2%
Total	76,631,005	1,500,033	44,293	28,296	15,998	16,384,035	16,449,657	65,622	0.4%
Total	**154,944927**	**53,492,215**	**2,572,911**	**1,954,762**	**667,556**	**791,723,658**	**794,682,941**	**2,959,283**	**0.4%**
Uncertainty (95 % CI) for years of life lost								**(2,529,100 to 3,393,293)**	

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

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 to 54 years, followed-up until age 55 years.

Five-year age group	QALYs lived in smoking cohort	QALYs lived in non-smoking cohort	QALYs lost*	%Smoker†	PALYs lived in smoking cohort	PALYs lived in non-smoking cohort	PALYs lost*	%Smoker†	Per smoker
				Male					
15-19	108,906,689	115,105,595	4,042,144	5.4%	103,212,855	105,472,025	2,259,170	2.1%	0.42
20-24	109,195,323	115,685,051	4,421,169	5.6%	108,185,924	110,596,969	2,411,046	2.2%	0.41
25-29	110,036,056	116,840,051	4,856,674	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	8,471	5.4%	129,004	131,866	2,862	2.2%	0.39
20-24	382,537	405,277	22,740	5.6%	345,782	353,450	7,668	2.2%	0.37
25-29	1,612,001	1,711,507	99,507	5.8%	1,474,106	1,507,503	33,396	2.2%	0.34
30-34	2,523,708	2,682,989	159,281	5.9%	2,297,696	2,351,603	53,907	2.3%	0.31
35-39	3,005,213	3,199,213	194,000	6.1%	2,725,542	2,790,987	65,445	2.3%	0.27
40-44	2,825,775	3,012,918	187,143	6.2%	2,561,633	2,623,378	61,746	2.4%	0.21
45-49	2,094,310	2,235,275	140,965	6.3%	1,884,414	1,928,716	44,303	2.3%	0.14
50-54	1,018,484	1,085,225	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 QALY and PALY lost			**(26,145,659 to 100,093,701)**				**(13,028,888 to 16,062,306)**		

**QALYs lost = QALYs lived in hypothetical smoking cohort minus QALYs lived in smoking cohort. †%Smoker = QALYs lost / QALYs lived in hypothetical non-smoking cohort. *PALYs lost = PALYs lived in hypothetical smoking cohort minus PALYs lived in smoking cohort†%Smoker = PALYs lost / PALYs lived in 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 to 54 years, followed up until age 55 years.

Age group	Male			
	Cost of productivity in smoking cohort	**Cost of productivity in hypothetical non-smoking cohort**	**Cost of productivity lost**	**Smoking related healthcare costs**
15-19	1,214,306,114,180	1,240,885,399,020	26,579,284,841	276,692,956,505
20-24	1,272,814,602,920	1,301,180,714,900	28,366,111,981	279,856,693,096
25-29	1,316,682,298,476	1,346,774,938,142	30,092,639,667	284,426,867,754
30-34	1,284,696,723,401	1,314,996,436,239	30,299,712,838	375,311,821,468
35-39	1,129,243,542,337	1,156,634,782,986	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	4,450,192,007	43,649,278,866
Total	7,750,419,726,231	7,930,748,691,088	180,328,964,857	1,799,385,510,167
	Female			
15-19	1,517,741,108	1,551,416,368	33,675,260	375,270,778
20-24	4,068,147,650	4,158,366,769	90,219,118	980,505,287
25-29	17,342,957,460	17,735,869,272	392,911,812	4,167,186,004
30-34	27,032,543,815	27,666,766,544	634,222,729	8,901,582,447
35-39	32,066,183,386	32,836,151,578	769,968,191	7,884,576,747
40-44	30,137,777,395	30,864,219,081	726,441,686	7,533,309,724
45-49	22,170,253,558	22,691,475,789	521,222,230	5,679,299,738
50-54	10,465,115,880	10,693,829,461	228,713,580	2,761,899,256
Total	144,800,720,253	148,198,094,860	3,397,374,608	38,283,629,982
Total	**7,895,220,446,484**	**8,078,946,785,948**	**183,726,339,465**	**1,837,669,140,149**
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 USD 11,765, all costs are expressed in USD. Non-smoking related healthcare costs are zero.

Table 5. Scenario Analyses

Description	Total Years of life lost	Total QALYs lost	Total PALYs lost	Total GDP lost	Total smoking health related (USD)
Base case	2,959,283	41,629,391	15,616,260	183,726,339,465	1,837,669,140,149
One-year time horizon	10,414	2,573,566	874,136	10,284,268,975	117,276,697,420
Male	9,989	2,498,596	851,417	10,016,975,640	113,986,765,799
Female	425	74,971	22,719	267,293,335	3,289,931,620
Removing healthcare costs for participants aged 17 to 29 in the model					1,556,764,540,624
Percentage change from base-case					-15.3%
Removing healthcare costs for participants aged 17 to 34 in the model					1,371,023,610,646
Percentage change from base-case					-25.4%
Halved healthcare costs from USD 2,194 to USD 1,097 per person					918,834,570,074
Percentage change from base-case					-50%
Removing effect of PAR% for participants aged 17-29 years	2,892,708	41,572,735	15,559,206	183,055,100,112	1,837,815,194,535
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: QALYs-quality adjusted life years: PAR% - population attributable risk percentage.

REFERENCES

1. Smoking prevalence and attributable disease burden in 195 countries and territories, 1990-2015: a systematic analysis from the Global Burden of Disease Study 2015. Lancet. 2017;389(10082):1885-906.
2. The World Bank. Smoking prevalence (Indonesia), total (ages 15+) [Internet]. The World Bank Data. [cited 2019 Mar 30]. Available from: https://data.worldbank.org/indicator/SH.PRV.SMOK?end=2016&locations=ID&start=2010&view=chart.
3. Goodchild M, Nargis N, Tursan d'Espaignet E. Global economic cost of smoking-attributable diseases. Tob Control. 2018;27(1):58-64.
4. John RM, Sinha P, Munish VG, Tullu FT. Economic Costs of Diseases and Deaths Attributable to Tobacco use in India, 2017-18. Nicotine & Tobacco Research. 2020.
5. Owen A, Maulida S, Zommer E, Liew D. Productivity burden of smoking in Australia: a life table modelling study. Tob Control. 2018;0:1.
6. Tan Q, Zommer E, Owen A, Chin K, Liew D. Impact of tobacco use on health and work productivity in Malaysia. Tob Control. 2019;0:2.
7. Diener-West M, Kanchanaraksa S. Life Tables. Johns Hopkins Bloomberg School of Public Health, 2008. .
8. Indonesian Health Technology Assessment Committee (InaHTAC), Ministry of Health of the Republic of Indonesia. Health Technology Assessment (HTA) Guideline. Available from: http://adphealth.org/upload/resource/FINAL_HTA_ENG_-1.pdf. Accessed June 23, 2020.
9. Hird T, Zommer E, Owen A, Magliano D, Liew D, Ademi Z. Productivity burden of hypertension in Australia: a life table modeling study. American Heart Association. 2019;2.
10. Hird T, Zommer E, Owen A, Chen L, Ademi Z, Magliano D, Liew D. The impact of diabetes on productivity in China. Springer. 2019;2.
11. Global Burden of Disease Collaborative Network. Global burden of disease study 2017 (GBD 2017) population estimates 1950-2017 [Internet]. Global Health Data Exchange (GHDx). 2019. Available from: http://ghdx.healthdata.org/record/ihme-data/gbd-2017-population-estimates-1950-2017.
12. Institute for Health Metrics and Evaluation (IHME). GDB Compare|Viz Hub [Internet]. IHME. [cited 2019 Apr 3]. Available from: https://vizhub.healthdata.org/gbd-compare/.
13. Kosen S, Hardjo H, Kadarmanto, Sinha DN, Palipudi KM, Wibisana W, et al. Global adult tobacco survey: Indonesia report 2011. Indonesia: World Health Organisation; 2012. 162 p.
14. Global Health Data Exchange. Available through: http://ghdx.healthdata.org/gbd-results-tool?params=gbd-api-2017-permalink/53e0c6ae61d96a91d9b079eb629fa941.
15. Jia H, Lubetkin EI. Trends in quality-adjusted life-years lost contributed by smoking and obesity. Am J Prev Med. 2010;38(2):138-44.
16. Bunn WB, 3rd, Stave GM, Downs KE, Alvir JM, Dirani R. Effect of smoking status on productivity loss. J Occup Environ Med. 2006;48(10):1099-108.
17. Badan Pusat Statistik. Keadaan angkatan kerja di Indonesia (labor force situation in Indonesia): Agustus/August 2018. Indonesia: Badan Pusat Statistik; 2018. 229 p.
18. International Monetary Fund. World economic outlook database [Internet]. International Monetary Fund. 2017. Available from: https://www.imf.org/external/pubs/ft/weo/2017/02/weodata/weorept.aspx?pr.x=21&pr.y=9&sy=2015&ey=2022&scsm=1&ssd=1&sort=country&ds=.&br=1&c=536&s=NGDPD&grp=0&a=.
19. The World Bank Data. Available through: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=ID.

20. Kristina SA, Endarti D, Wiedyaningsih C, Fahamsya A, Faizah N. Health Care Cost of Noncommunicable Diseases Related to Smoking in Indonesia, 2015. Asia Pac J Public Health. 2018;30(1):29-35.
21. Bundhamcharoen K, Aungkulanon S, Makka N, Shibuya K. Economic burden from smoking-related diseases in Thailand. Tob Control. 2016;25(5):532-7.
22. Ekpu VU, Brown AK. The Economic Impact of Smoking and of Reducing Smoking Prevalence: Review of Evidence. Tobacco Use Insights. 2015;8:1–35.
23. Cahill K, Stevens S, Perera R, Lancaster T. Pharmacological interventions for smoking cessation: an overview and network meta-analysis. Cochrane Database Syst Rev. 2013(5):Cd009329.
24. Trapero-Bertran M, Leidl R, Muñoz C, Kulchaitanaroaj P, Coyle K, Präger M, et al. Estimates of costs for modelling return on investment from smoking cessation interventions. Addiction. 2018;113 Suppl 1(Suppl Suppl 1):32-41.
25. Bartecchi CE, MacKenzie TD, Schrier RW. The human costs of tobacco use (1). N Engl J Med. 1994;330(13):907-12.
26. Jha P, Chaloupka FJ. The economics of global tobacco control. Bmj. 2000;321(7257):358-61.
27. Cleghorn CL, Blakely T, Kvizhinadze G, van der Deen FS, Nghiem N, Cobiac LJ, et al. Impact of increasing tobacco taxes on working-age adults: short-term health gain, health equity and cost savings. Tob Control. 2018;27(e2):e167-e70.
28. World Health Organisation. WHO report on the global tobacco epidemic, 2019. Country profile: Indonesia [Internet]. World Health Organisation; 2019. Available from: https://www.who.int/tobacco/surveillance/policy/country_profile/idn.pdf.
29. World Health Organisation. Tobacco free initiative (TFI): Taxation [Internet]. World Health Organisation. [cited 2019 Sep 26]. Available from: https://www.who.int/tobacco/economics/taxation/en/.
30. Bolin K. Economic evaluation of smoking-cessation therapies: a critical and systematic review of simulation models. Pharmacoeconomics. 2012;30(7):551-64.
31. Ruger JP, Lazar CM. Economic evaluation of pharmaco- and behavioral therapies for smoking cessation: a critical and systematic review of empirical research. Annu Rev Public Health. 2012;33:279-305.
32. Gordon L, Graves N, Hawkes A, Eakin E. A review of the cost-effectiveness of face-to-face behavioural interventions for smoking, physical activity, diet and alcohol. Chronic Illn. 2007;3(2):101-29.
33. Annemans L, Nackaerts K, Bartsch P, Prignot J, Marbaix S. Cost effectiveness of varenicline in Belgium, compared with bupropion, nicotine replacement therapy, brief counselling and unaided smoking cessation: a BENESCO Markov cost-effectiveness analysis. Clin Drug Investig. 2009;29(10):655-65.
34. Hurley SF, Matthews JP. The Quit Benefits Model: a Markov model for assessing the health benefits and health care cost savings of quitting smoking. Cost Eff Resour Alloc. 2007;5:2.

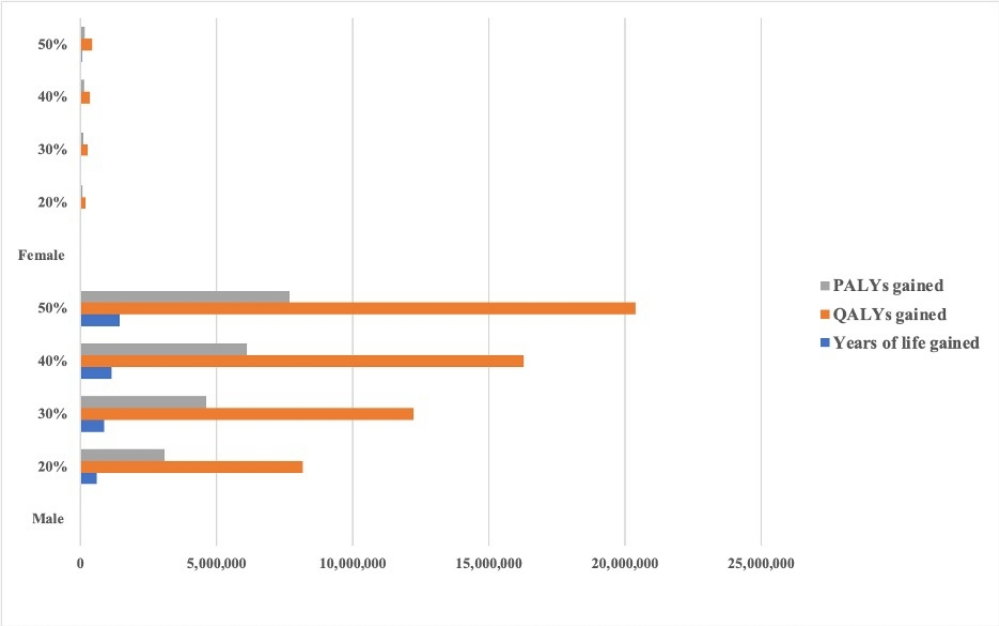

Figure 1. Gains in terms of years of life, productivity adjusted life years saved, and quality adjusted life years gained in which prevalence of smoking was hypothetically reduced by 20%, 30%, 40% and 50%.

165x103mm (144 x 144 DPI)

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

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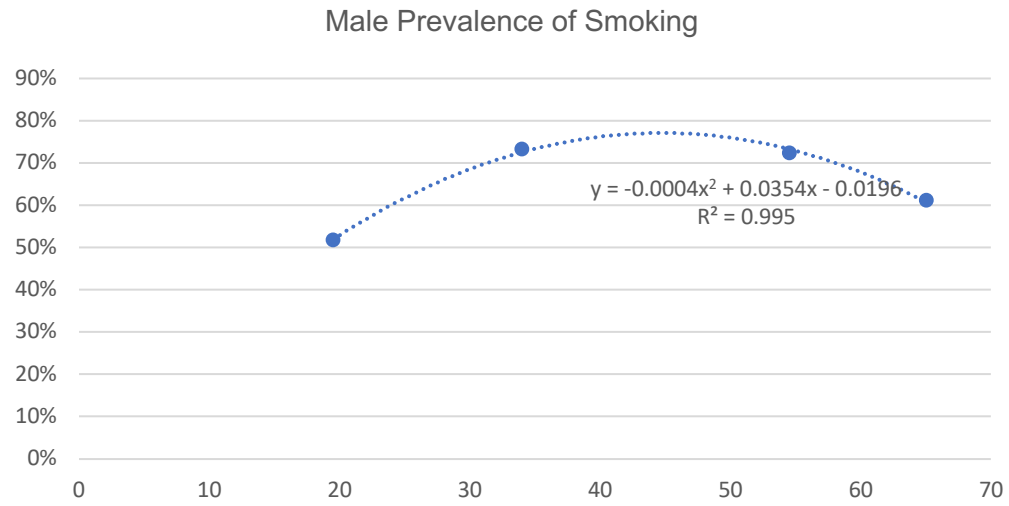
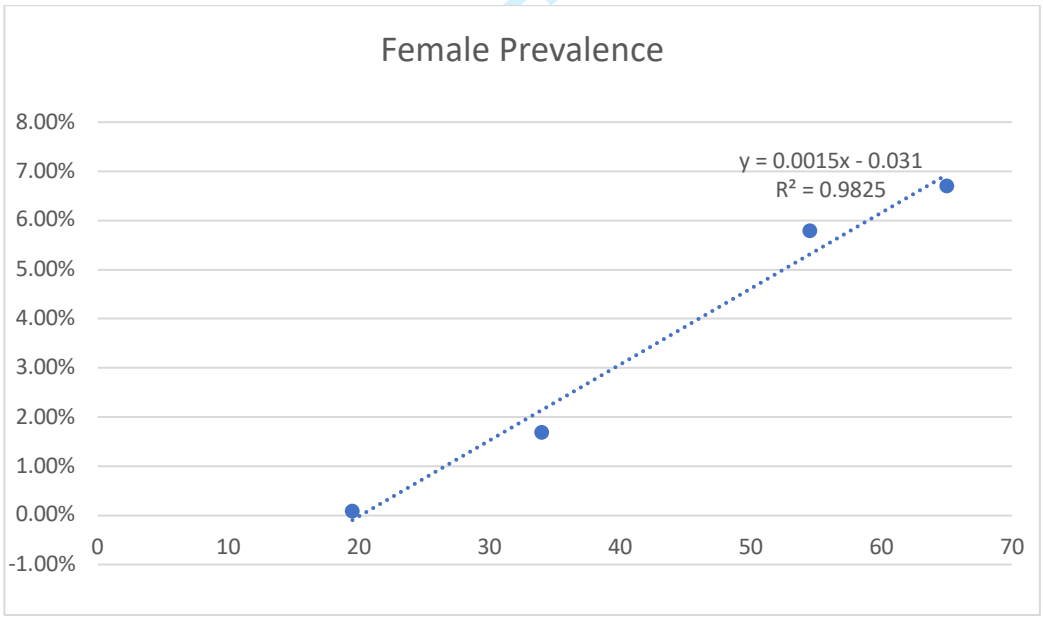
Contents

Appendix 1. Trends of smoking prevalence in Indonesian males and females, using polynomial function for men and linear function for female



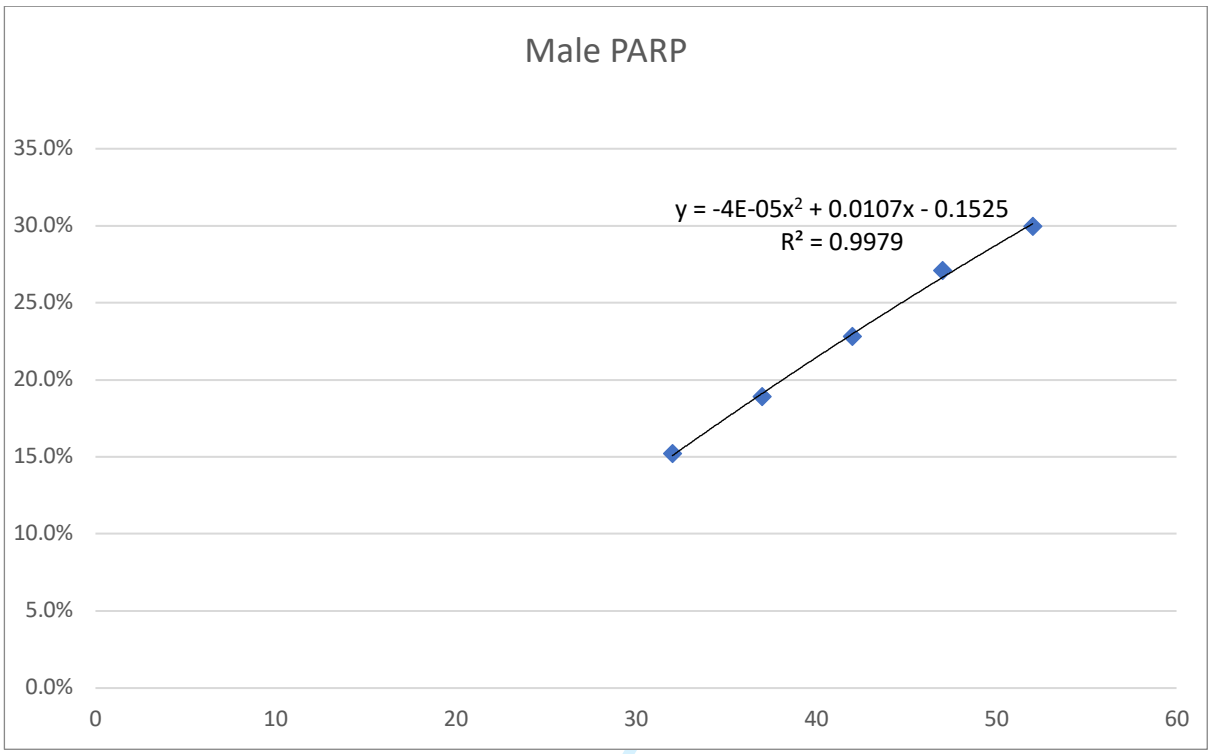


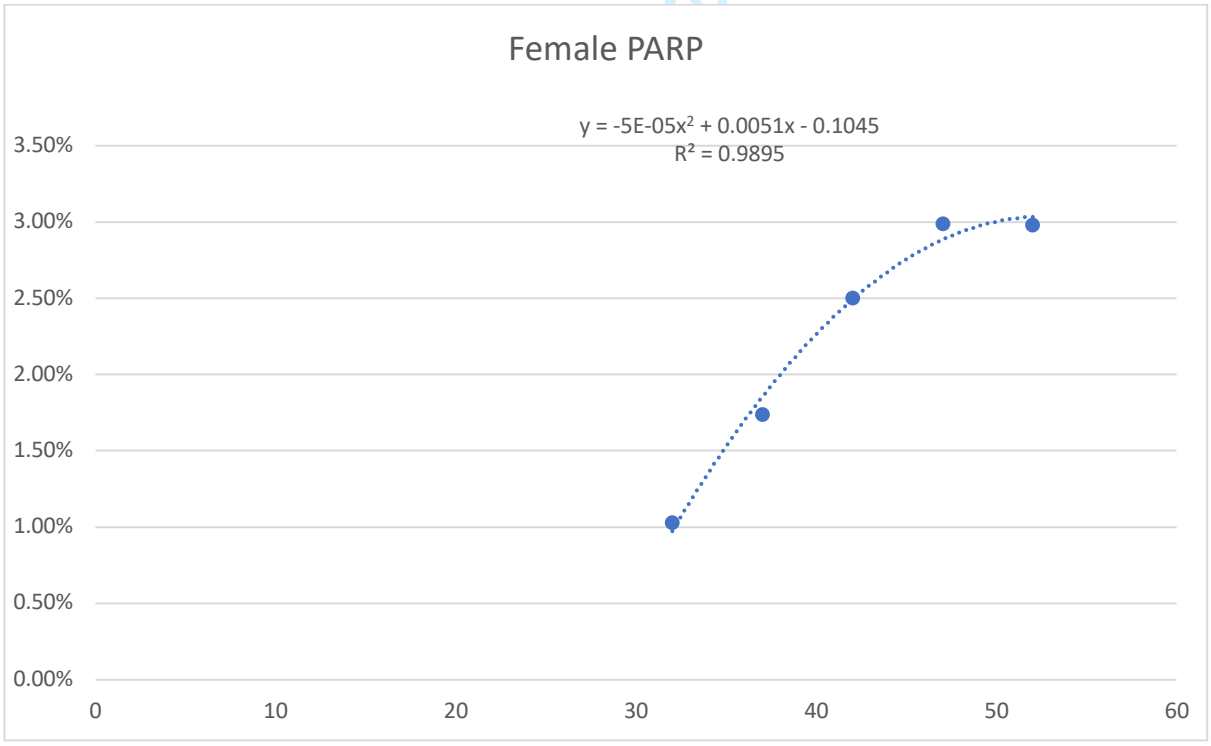
Appendix 2. Age- and sex-specific prevalence of smoking in Indonesian working-age population

Age	Male	Female
15	0.4214	0.0004
16	0.4444	0.0005
17	0.4666	0.0007
18	0.488	0.0008
19	0.5086	0.0010
20	0.5284	0.0013
21	0.5474	0.0016
22	0.5656	0.0020
23	0.583	0.0035
24	0.5996	0.0050
25	0.6154	0.0065
26	0.6304	0.0080
27	0.6446	0.0095
28	0.658	0.0110
29	0.6706	0.0125
30	0.6824	0.0140
31	0.6934	0.0155
32	0.7036	0.0170
33	0.713	0.0185
34	0.7216	0.0200
35	0.7294	0.0215
36	0.7364	0.0230
37	0.7426	0.0245
38	0.748	0.0260
39	0.7526	0.0275
40	0.7564	0.0290
41	0.7594	0.0305
42	0.7616	0.0320
43	0.763	0.0335
44	0.7636	0.0350
45	0.7634	0.0365

46	0.7624	0.0380
47	0.7606	0.0395
48	0.758	0.0410
49	0.7546	0.0425
50	0.7504	0.0440
51	0.7454	0.0455
52	0.7396	0.0470
53	0.733	0.0485
54	0.7256	0.0500
55	0.7174	0.0515

Appendix 3. The relationships between age in single years and population attributable risk percent (PAR%) values for females and males using polynomial function





Appendix 4. Model inputs and their distribution for smoking cohort.

	Smoking cohort													
Age groups	Smoking (PAR%) *	SE	Alpha	Beta	Utilities*	SE	Alpha	Beta	Productivity indices†	Distribution	Costs ‡	SE	Alpha	Beta
Male														
15-19	6.6	-	-	-	0.893	0.0446	41.9	1.74	0.664	± 10	2,194	329	44.4	49.3
20-24	6.6	-	-	-	0.893	0.0446	41.9	1.74	0.762	± 10				
25-29	6.6	-	-	-	0.864	0.0432	53.5	3.22	0.846	± 10				
30-34	15.2	0.00791	313	1747	0.864	0.0432	53.5	3.22	0.875	± 10				
35-39	18.9	0.00827	425	1820	0.864	0.0432	53.5	3.22	0.880	± 10				
40-44	22.8	0.00939	455	1541	0.864	0.0432	53.5	3.22	0.876	± 10				
45-49	27.1	0.01041	493	1328	0.809	0.0405	75.5	8.96	0.864	± 10				
50-54	30.0	0.01199	437	1022	0.809	0.0405	75.5	8.96	0.832	± 10				
Female														
15-19	0.175	-	-	-	0.893	0.0446	41.9	1.74	0.637	± 10	2,194	329	44.4	49.3
20-24	0.175	-	-	-	0.893	0.0446	41.9	1.74	0.743	± 10				
25-29	0.175	-	-	-	0.864	0.0432	53.5	3.22	0.801	± 10				
30-34	1.0	0.00194	28	2683	0.864	0.0432	53.5	3.22	0.800	± 10				
35-39	1.7	0.00311	31	1733	0.864	0.0432	53.5	3.22	0.786	± 10				
40-44	2.5	0.00449	30	1178	0.864	0.0432	53.5	3.22	0.782	± 10				
45-49	3.0	0.00520	32	1038	0.809	0.0405	75.5	8.96	0.756	± 10				
50-54	3.0	0.00510	33	1077	0.809	0.0405	75.5	8.96	0.721	± 10				

*Beta distribution; † Uniform distribution; ‡Gamma distribution. PAR%-population attributable risk percentage; SE- standard error.

Appendix 5. Model inputs and their distribution for non-smoking cohort.

Non-smoking cohort						
Age groups Male	Utilities*	SE	Alpha	Beta	Productivity indices†	Distribution
15-19	0.935	0.0467	25.06	1.74	0.677	± 10
20-24	0.935	0.0467	25.06	1.74	0.777	± 10
25-29	0.913	0.0456	33.88	3.22	0.863	± 10
30-34	0.913	0.0456	33.88	3.22	0.892	± 10
35-39	0.913	0.0456	33.88	3.22	0.897	± 10
40-44	0.913	0.0456	33.88	3.22	0.893	± 10
45-49	0.860	0.0430	55.14	8.97	0.881	± 10
50-54	0.860	0.0430	55.14	8.97	0.848	± 10
Female						
15-19	0.935	0.0467	25.06	1.74	0.649	± 10
20-24	0.935	0.0467	25.06	1.74	0.757	± 10
25-29	0.913	0.0456	33.88	3.22	0.817	± 10
30-34	0.913	0.0456	33.88	3.22	0.815	± 10
35-39	0.913	0.0456	33.88	3.22	0.801	± 10
40-44	0.913	0.0456	33.88	3.22	0.797	± 10
45-49	0.860	0.0430	55.14	8.97	0.771	± 10
50-54	0.860	0.0430	55.14	8.97	0.735	± 10

*Beta distribution; † Uniform distribution; SE- standard error.

Appendix 6. Undiscounted years of life lived and quality-adjusted life years (QALYs) in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, with simulated follow up until age 55 years. Years of life lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Age group	Years of life lived in smoking cohort	Years of life lived in non-smoking cohort	Years of life lived in population	Years of life lost*	QALYs lived in smoking cohort	QALYs lived in hypothetical non-smoking cohort	QALYs lived in population	QALYs lost*
Male								
15-19	208,499,084	209,215,975	716,891	0.3%	178,235,078	188,887,476	10,652,398	5.6%
20-24	198,498,012	199,262,960	764,948	0.4%	168,554,762	178,948,135	10,393,373	5.8%
25-29	189,581,033	190,413,124	832,091	0.4%	159,910,694	170,064,714	10,154,020	6.0%
30-34	173,146,782	174,014,475	867,693	0.5%	145,295,005	154,688,679	9,393,674	6.1%
35-39	143,265,124	144,054,959	789,835	0.5%	119,263,932	127,131,426	7,867,494	6.2%
40-44	100,424,357	101,006,172	581,814	0.6%	82,445,328	88,024,435	5,579,106	6.3%
45-49	56,972,398	57,283,525	311,127	0.5%	46,090,670	49,263,831	3,173,162	6.4%
50-54	20,783,023	20,859,305	76,282	0.4%	16,813,466	17,939,003	1,125,537	6.3%
Total	1,091,169,812	1,096,110,494	4,940,682	0.5%	916,608,934	974,947,698	58,338,764	6.0%
Female								
15-19	283,123	284,194	1,070	0.4%	241,994	256,551	14,557	5.7%
20-24	696,224	698,849	2,625	0.4%	591,124	627,537	36,413	5.8%
25-29	2,780,230	2,791,878	11,648	0.4%	2,344,840	2,493,289	148,449	6.0%
30-34	4,106,478	4,126,405	19,927	0.5%	3,445,535	3,667,798	222,263	6.1%
35-39	4,620,828	4,644,870	24,042	0.5%	3,846,312	4,098,869	252,557	6.2%
40-44	4,127,289	4,148,184	20,896	0.5%	3,388,170	3,614,879	226,709	6.3%
45-49	2,903,556	2,915,813	12,257	0.4%	2,348,977	2,507,599	158,622	6.3%
50-54	1,315,122	1,318,262	3,140	0.2%	1,063,934	1,133,705	69,772	6.2%
Total	20,832,849	20,928,455	95,606	0.5%	17,270,886	18,402,228	1,129,342	6.1%
Total	1,112,002,660	1,117,038,949	5,036,288	0.5%	933,879,820	993,349,926	59,468,106	6.0%

**Years of life lost = years of life lived in hypothetical smoking cohort minus years of life lived in smoking cohort *QALYs lost = QALYs lived in hypothetical smoking cohort minus QALYs lived in smoking cohort.*

Appendix 7. Undiscounted productivity-adjusted life years (PALYs) in the smoking cohort and in the hypothetical non-smoking cohort of Indonesians aged 15 to 54 years, followed up until age 55 years. PALYs lived in the smoking cohort and non-smoking cohort are presented based on age entering the simulation.

Age group	Male					
	PALYs lived in smoking cohort	**PALYs lived in hypothetical non-smoking cohort**	**PALYs lost**	**Cost of productivity in smoking cohort**	**Cost of productivity in hypothetical non-smoking cohort**	**Cost of productivity lost**
15-19	173,449,812	177,448,632	3,998,819	2,040,648,600,737	2,087,694,974,623	47,046,373,886
20-24	168,948,257	172,900,480	3,952,223	1,987,687,501,718	2,034,185,669,307	46,498,167,590
25-29	163,204,739	167,102,111	3,897,373	1,920,114,627,505	1,965,967,476,641	45,852,849,136
30-34	149,179,014	152,832,187	3,653,173	1,755,101,036,418	1,798,080,862,215	42,979,825,797
35-39	122,850,702	125,921,181	3,070,479	1,445,346,690,758	1,481,471,083,461	36,124,392,703
40-44	85,361,151	87,519,836	2,158,685	1,004,279,627,755	1,029,676,697,666	25,397,069,912
45-49	47,747,999	48,940,816	1,192,817	561,758,393,411	575,791,961,286	14,033,567,875
50-54	17,070,219	17,466,371	396,152	200,832,262,861	205,493,014,374	4,660,751,513
Male total	927,811,892	950,131,613	22,319,720	10,915,768,741,163	11,178,361,739,573	262,592,998,410
15-19	214,300	219,288	4,988	2,521,252,239	2,579,939,571	58,687,332
20-24	535,047	547,456	12,409	6,294,862,228	6,440,857,191	145,994,963
25-29	2,137,726	2,188,153	50,428	25,150,483,475	25,743,769,618	593,286,143
30-34	3,129,877	3,205,833	75,957	36,823,208,176	37,716,842,279	893,634,103
35-39	3,482,412	3,568,216	85,804	40,970,806,149	41,980,299,606	1,009,493,457
40-44	3,064,648	3,139,801	75,153	36,055,783,825	36,939,968,164	884,184,338
45-49	2,108,292	2,158,297	50,005	24,804,191,966	25,392,507,727	588,315,761
50-54	928,353	948,685	20,332	10,922,138,987	11,161,344,551	239,205,564
Female total	15,600,653	15,975,730	375,077	183,542,727,045	187,955,528,706	4,412,801,660
Total	943,412,546	966,107,343	22,694,797	11,099,311,468,209	11,366,317,268,279	267,005,800,070

**PALYs lost = PALYs lived in hypothetical smoking cohort minus PALYs lived in smoking cohort. Results were derived by assuming a constant GDP per equivalent full-time worker of USD 11,765. Costs expressed in the USD.*

Appendix 8. Gains in terms of years of life, productivity adjusted life years saved, quality adjusted life years, cost of PALYs and healthcare costs gained in which prevalence of smoking was hypothetically reduced by 20%, 30%, 40% and 50%.

	Years of life gained	QALYs gained	PALYs gained	Cost of PALYs gained	Cost of Healthcare Expenditure gained
Male					
20%	578,732	8,150,109	3,065,498	$ 36,065,792,971	$ 359,877,102,033
30%	868,098	12,225,163	4,598,248	$ 54,098,689,457	$ 539,815,653,050
40%	1,140,063	16,285,253	6,116,671	$ 71,963,037,908	$ 719,754,204,067
50%	1,446,830	20,375,272	7,663,746	$ 90,164,482,428	$ 899,692,755,083
Female					
20%	13,124	175,770	57,754	$ 679,474,922	$ 7,656,725,996
30%	19,687	263,654	86,630	$1,019,212,382	$ 11,485,088,995
40%	26,249	351,539	115,507	$1,358,949,843	$ 15,313,451,993
50%	32,811	439,424	144,384	$1,698,687,304	$19,141,814,991

QALYs-quality adjusted life years; PALYs-productivity adjusted life years.