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Tobacco control policies implementation and future lung cancer incidence in Saudi Arabia. A population-based study

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ABSTRACT

Background: Despite the implementation of the monitor tobacco products and prevention package (MPOWER) in Saudi Arabia since 2011, the impact of the policy implantation on smoking prevalence and lung cancer incidence have not been evaluated.
Objectives: We aimed to estimate the potential reduction in future lung cancer incidence in Saudi Arabia that could be prevented if the highest level of tobacco control policies MPOWER score were implemented.
Methods: Population-based lung cancer incidence data was used to predict lung cancer incidence in Saudi Arabia up to year 2039. We used hypothetical smoking prevalence that would be expected if countries had applied the highest-level implementation of MPOWER tobacco control policies score. We used potential impact fraction on the hypothetical smoking prevalence data to estimate the potentially preventable lung cancer cases taking into account latency periods between changes in smoking prevalence and development of cancer risks. After the hypothesized highest level of MPOWER tobacco policies implementation.
Results: the national tobacco smoking prevalence has declined by 55% from 13.17% in 2020 to 5.91% in 2039. If the highest-level MPOWER is implanted, more than half the tobacco smoker rate will be reduced, and a total of 9783 lung cancer cases would be potentially prevented in 2039.
Conclusion: Further implementation of effective messages is needed to reduce tobacco-related cancers. By doing so, we can gain valuable insights into the impact of these policies on public health outcomes in the broader context of the region and identify potential areas for further improvement and intervention.

1. Introduction

Lung cancer is a prominent contributor to cancer-related deaths worldwide, posing a substantial burden in Saudi Arabia as well. Over the past few decades, the incidence and mortality rates of lung cancer among the Saudi population have experienced a notable surge. Within a span of less than 30 years, the age-standardized incidence has risen by more than 3 to 5 folds-increase (Almatroudi, 2021; Da'ar et al., 2019; Althubiti and Eldein, 2018). Globally, lung cancer still stands as the most fatal cancer type, and leading cause of mortality causing the loss of over a million and a half lives annually (Thandra et al., 2021; Sung et al., 2021). Shockingly, lung cancer-specific mortality is projected to account for approximately 150 million deaths throughout the 21st century (Thandra et al., 2021; Sung et al., 2021). Consequently, international communities are actively striving to control and mitigate the projected increase in lung cancer cases, placing significant emphasis on one major preventable risk factor: smoking. While smoking is well recognized as a known carcinogen, the magnitude of smoking-related cancer risk varies among countries due to unique generational smoking patterns (World Health Organization, 2013; Gredner et al., 2021). Notably, smoking contributes to approximately 80% to 90% of lung cancer deaths in men and women, respectively (World Health Organization, 2013; Gredner et al., 2021). Historically, from 1990 to 2019, Saudi Arabia had a 39% increase in prevalence of age-standardized smoking rate among male and 45% increase among female (Reitsma et al., 2021). However, in the last decade, there has been a moderate decline in smoking prevalence.

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Saudi Arabia still faces a relatively high prevalence of smoking, estimated at 14.36% in 2019 when adjusted for gender and age (Reitsma et al., 2021; GBD, 2019).

In order to address the global epidemic of smoking and develop effective prevention strategies that account for socioeconomic differences among countries, the World Health Organization (WHO) introduced the Framework Convention on Tobacco Control (WHO FCTC) and MPOWER measures in 2008. These measures provide a comprehensive package of technical measures and resources that enable countries to implement six key interventions aimed at reducing the demand for tobacco products (World Health Organization, 2008). The MPOWER measures encompass various aspects, including monitoring tobacco use and prevention policies, protecting individuals from tobacco use, providing assistance to quit tobacco use, raising awareness about the dangers of tobacco, enforcing bans on tobacco advertising, promotion, and sponsorship, and increasing taxes on tobacco (World Health Organization, 2008).

One notable advantage of the MPOWER measures is their global applicability. They can be implemented by countries worldwide, and the impact can be evaluated using a composite score provided by the Monitor tobacco use and prevention policies (MPOWER) framework (Feliu et al., 2019; Husain et al., 2021). This composite score allows for comparability over time and enables the assessment of progress in implementing tobacco control policies. It further facilitates comparisons across different countries and enables an evaluation of the effectiveness of interventions over the years of implementation. Overall, the WHO FCTC and MPOWER measures serve as valuable tools for governments and public health organizations in tackling the global smoking epidemic. By implementing these evidence-based interventions and utilizing the MPOWER framework for evaluation, countries can make significant strides in reducing tobacco use and its associated health risks.

In 2011, the Saudi government initially implemented a few modest measures based on the MPOWER framework, resulting in an estimated score of 11 on the MPOWER scale (Alshaer and Alonazi, 2023). However; between 2012 and 2017, the government in Saudi Arabia took more effective actions to control tobacco use by implementing additional MPOWER measures. These measures included a significant increase in tobacco taxes to 100%, expanding the smoking ban in public places, imposing penalties for violations of smoking regulations, and establishing effective smoking cessation services throughout the kingdom (Alshaer and Alonazi, 2023). This accelerated implementation of tobacco control policies is expected to lead to a decline in the number of tobacco users in the coming years. Previous research has demonstrated the effectiveness of MPOWER policies in reducing cigarette smoking among adults (Alshaer and Alonazi, 2023). It is important to note that not all MPOWER measures have an equal impact on the reduction of smoking prevalence. Research indicates that raising taxes on tobacco products is the most rapidly effective and impactful measure among the key interventions (Soerjomataram et al., 2010).

In order to assess the potential impact of implementing the highest level of tobacco control policies, the authors conducted an analysis to quantify the magnitude of this impact on future smoking prevalence. By implementing comprehensive tobacco control policies that align with the highest MPOWER score, it is anticipated that the prevalence of smoking will decrease significantly over time. This reduction in smoking rates would subsequently lead to a decline in the incidence of lung cancer, considering the well-established link between smoking and this particular form of cancer. The results of this analysis will provide valuable insights into the potential benefits of implementing robust tobacco control policies. It will help policymakers and public health authorities understand the potential magnitude of the impact and the importance of prioritizing such interventions to reduce the burden of smoking-related diseases, particularly lung cancer, in Saudi Arabia.

2. Methods

2.1. The model

To quantify the potential impact of six MPOWER measures tobacco control policies on future lung cancer incidence in Saudi Arabia, we used a previously validated (Gredner et al., 2021) model to estimate the potential impact fraction (PIF) (Soerjomataram et al., 2010; Marteau et al., 2021). This approach requires the following population-level measures: 1) annual lung cancer incidence rate by age, and gender; 2) the highest implementation level score of tobacco control policies; 3) the estimation of the effect of MPOWER tobacco control policies on smoking prevalence in Saudi Arabia; and 4) the prevalence of smoking standardized by age and gender.

3. Data Source

We obtained our data from the Global Burden of Disease (GBD) 2019, a reliable and comprehensive database. The GBD provides extensive epidemiological information on 369 diseases and injuries, including 87 risk factors such as smoking, in addition to population data of all countries including Saudi Arabia from 1990 to 2019. The database spans from 1990 to 2019 and encompasses 204 countries and territories, divided into 7 super-regions and 21 regions (Murray et al., 2020).

4. Smoking in Global burden of Disease

In the Global Burden of Disease (GBD) data, smoking refers to the act of inhaling and exhaling the smoke produced by burning tobacco products. It includes the use of cigarettes, cigars, pipes, and other tobacco-related products (Reitsma et al., 2015; Hyndman and Khandakar, 2008). The GBD data captures information related to smoking prevalence, exposure, and its association with various health outcomes and diseases. This includes measuring the number of smokers, the associated risks and harms, and the impact of smoking on mortality and disability (Reitsma et al., 2015; Hyndman and Khandakar, 2008). The GBD uses the definition of current smoking tobacco as use of any type of smoked tobacco product on a daily or occasional basis. Smoked tobacco products include manufactured cigarettes, hand-rolled cigarettes, cigars, cigarillos, pipes, shisha, and regional products such as bidis and kreteks (Reitsma et al., 2015; Hyndman and Khandakar, 2008).

5. Past and future lung cancer incidence, and prevalence of tobacco smoking

To predict the numbers and rates of incident lung cancer cases for the 20-year period from 2020 to 2039 adjusted for age and gender, we obtained the numbers of past national lung cancer incidence from 2000 to 2019 from GBD data. We used stepwise autoregressive method to estimate future national Saudi lung cancer incidence in 5-year interval periods (Barendregt and Veerman, 2010). This method integrates an autoregressive model with the time trend regression, then a stepwise method is used to select the lags to use for the autoregressive process. The number of predicted lung cancer cases and rates were calculated, using the previous annual interval period number of cases as basis. We further used Akaike information criterion (AIC) to examine the specified lags for the study period (Barendregt and Veerman, 2010). We calculated standardized incidence rates per 100,000 person-years for the population gender and aged 15 + using the Saudi population of 2019 as the reference year. For the model, we used GBD smoking prevalence data that include cigarettes, cigars, cigarillos, and pipe from the year 2000 to 2019 (Barendregt and Veerman, 2010; Méndez et al., 2013).

6. The outcome of tobacco control policies on the future national smoking prevalence in Saudi Arabia

To examine the possible outcome of implementing tobacco control policies on future smoking prevalence in Saudi Arabia that expected to be reduced upon the implementation of the highest level of tobacco control policies MPOWER score. Then, we estimated the population impact fraction (PIF) (Méndez et al., 2013). This was achieved using the prevalence of current smoking data and the relative risk of lung cancer related to smoking. We used Husain's highest level MPOWER average score (Husain et al., 2021). Husain's studies included all countries implemented MPOWER including Saudi Arabia (Husain et al., 2021). Husain's studies concluded that a 1-unit increase in the composite score reduces smoking prevalence by 0.25 percentage points for both genders (Husain et al., 2021). We used these findings to estimate the expected potential proportion of reduction while the highest score of MPOWER tobacco policies has been achieved. We multiplied the potential reduced percent 0.25 per one MPOWER score unit by the highest level MPOWER score 34. Then, we multiply it by smoking prevalence for each year that had an increase in MPOWER unite score to obtain the potential annual future reduction proportion of smoking prevalence adjusted for age and gender in Saudi Arabia from 2020 to 2039.

7. Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of King Abdullah International Medical Research Center (KAIMRC). The Biomedical ethics committee in KAIMRC approved this study with the reference number (**NRJ23J/108/04)**. All methods were performed in accordance with the relevant guidelines and regulations of KAIMRC.

7.1. Statistical analysis

The PIF estimates the proportional change in average lung cancer incidence after a change in the exposure of a related risk factor tobacco smoking (Méndez et al., 2013). We used the prevalence of tobacco smoking and the relative risk of that risk factor related to cancer to calculate the PIF, using the following formula:

$$PIF = \frac{\sum pRR - \sum p^{*}RR}{\sum pRR}$$

where p is the age- and gender-adjusted prevalence of smoking; p* is the prevalence of tobacco smoking after the intervention, and RR is the time dependent relative risk of exposed (90%) over non-exposed (10%) lung cancer individuals (Krist et al., 2021; Godtfredsen et al., 2005). As previous studies concluded, we assumed that 90% of lung cancer patients were attributed to smoking (Godtfredsen et al., 2005; Murali Sastry and Hicks, 2019). We further used the Autoregressive integrated moving average (ARIMA) model for forecasting future lung cancer incidence based on the preceding years. The ARIMA models were fitted to GBD data and used to estimate smoking prevalence, and lung cancer incidence rate expected to occur from 2020 to 2039.

The ARIMA models used a linear combination of lagged observations (autoregression) and a moving average of lagged errors to forecast future observations (Cheung and Lai, 1995). The general model building procedure consisted of the following steps. First, we needed to ensure that the ARIMA models could be applied, which requires the time series data to be stationary, with a constant mean, variance, and autocorrelation over time. To assess stationarity, we conducted augmented Dickey-Fuller tests (Box et al., 2015). Subsequently, we determined the appropriate orders of differencing that would help transform the data into a stationary format suitable for ARIMA modeling. In the second step of the model building procedure, we aimed to determine the combination of autoregression and lagged error terms that would minimize the Akaike information criterion (AIC). To achieve this, we conducted Ljung-Box Q tests to assess autocorrelation in the residuals of the model (xxxx). This test allowed us to examine whether any significant autocorrelation patterns remained in the residuals, which could indicate inadequacies in the model fit. Using the forecasted lung cancer incidence as a reference, we estimated the number of cancer cases that could be prevented if MPOWER tobacco control policies were to be implemented at the highest level in 2020 by multiplying the PIFs with the predicted number of lung cancers.

8. Sensitivity analysis

To account for potential biased effect estimates and the uncertainties in the model assumptions due to the lag lung cancer risk need to be developed, we followed Gredner's study and used the concept of LAT (Latency period) and LAG (Lag period) times in our model (Gredner et al., 2021; Heydari et al., 2017). LAT refers to the duration in which the cancer risk remains steady following alterations in exposure to a cancer risk factor. On the other hand, LAG represents the time during which the risk among individuals previously exposed to the risk factor decreases to the same level as those who have not been exposed (Gredner et al., 2021; Heydari et al., 2017). For our model, we defined the LAT time to be 5 years and the LAG time to be 15 years assuming an exponential decline in cancer risk (Fig. 1,2). In our study, we made the assumption that individuals who quit smoking would maintain the same risk for developing cancer for the next 5 years after quitting. After this initial 5-year period, we projected a gradual decline in cancer risk over the subsequent 15 years until it reached the level observed in individuals who had never smoked (with a relative risk of 1). We used model diagnostics and a sensitivity analysis that involved applying the model in different latency and lag time, and different expected tobacco smoking prevalence reduction scenarios (Heydari et al., 2017). As assumed, lower reduction percent, and a longer lag time resulted in a lower proportion of potentially preventable lung cancer cases. All analyses were performed using SAS statistical software version 9.4 (SAS Institute Inc. Cary, NC).Fig. 2..

9. Results

Between 2000 and 2019, the overall standardized smoking prevalence increased nearly 8% from 13.32% in 2000 to 14.36% in 2019. From 2000 to 2012 before the MPOWER implementation, there was a consistent annual increase in the smoking prevalence rate among the Saudi population. (Table.1). From 2000 to 2012 before the MPOWER implementation, lung cancer incidence rate per 100,000 has increased more than double from 4.4% to 10.1%. (Table.1, Fig. 3) The sharp decline in lung cancer incidence rate per 100,000 started in 2014 to 2019 from 10.4% to 6% respectively. (Table.1, Fig. 3) As higher MPOWER score implemented, low proportions for both tobacco smoking prevalence and lung cancer incidence rate per 100,000 has been observed. (Table.1). After MPOWER implementation in 2012, there was a slight decline in the smoking prevalence. From 2012 to 2019 MPOWER has been implemented in different score levels (19, 23, 26, and 32 respectively), there was a slight but consistent annual decline in the smoking prevalence rate. (Table.1, Fig. 3).

After the hypothesized highest score achievement of MPOWER tobacco policies implementation, the national tobacco smoking prevalence has a substantial 55% decline from (13.17%) in 2020 to (5.91%) in 2039 (Table.2, Fig. 4). When the highest score of MPOWER tobacco policies is implemented, we would expect a 5.91% national smoking prevalence in 2039. Table.2 also presents the predicted future lung cancer incidence along with potential preventable lung cancer incidence per 100,000 for the hypothesized highest-level implementation of monitor tobacco use and prevention policies (MPOWER) scenario over the 20-year period (2020—2039). Lung cancer incidence rate was expected to increase by nearly double from 7.49% in 2020 to 13.87% in 2039. (Table.2, Fig. 4) While, under our hypothesis of the highest-level

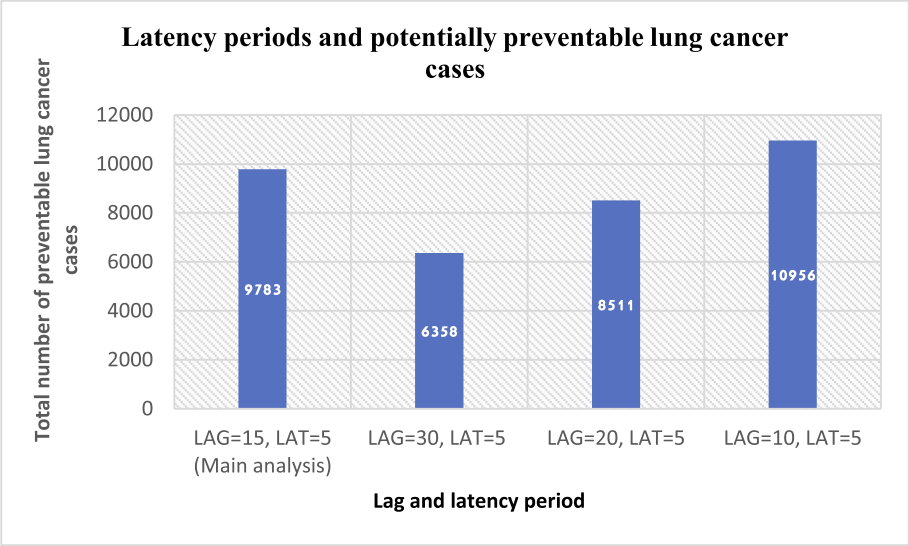

Fig. 1. Total number of potentially preventable lung cancer cases by highest-level implementation of tobacco control policies over a 20-year period (2020–2039) using different latency periods (LAT and LAG),

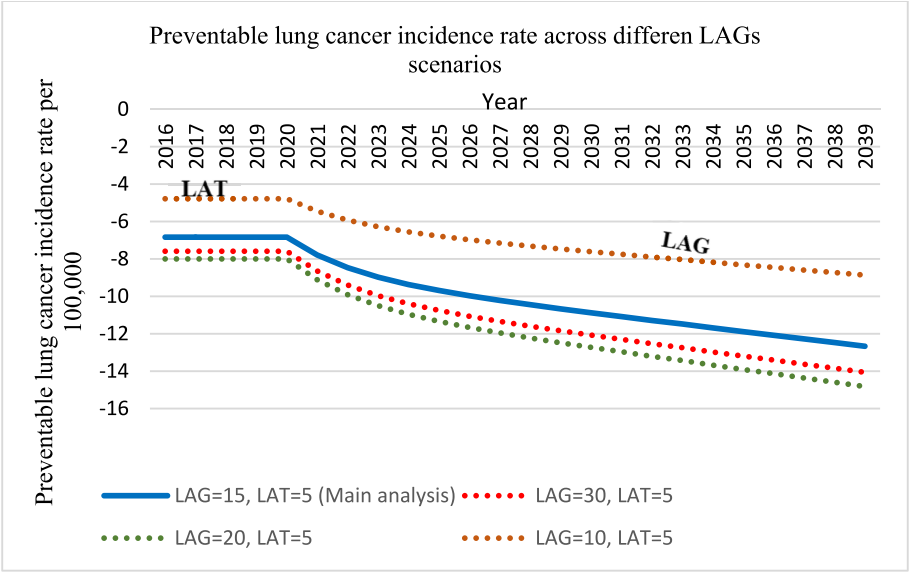

Fig. 2. Illustration of declining excess cancer incidence rate assumed for main analysis and different sensitivity analyses.

implementation of MPOWER, a total of 9783 potential preventable lung cancer cases across the 20-year period was observed. (Table.2, Fig. 4) We observed a consistent decline in the annual lung cancer incidence rates from 6.84 preventable lung cancer incidence rate per 100,000 in 2020 to 12.67 preventable lung cancer incidence rate per 100,000 in 2039.

10. Discussion

The findings of the current study suggest that the implementation of MPOWER policy measures in Saudi Arabia has the potential to significantly reduce the tobacco smoking rate by more than half in the year 2039. This reduction in smoking prevalence is expected to lead to a notable decline in smoking-related diseases and mortality rates. Prior to the implementation of MPOWER, the study identified a consistent annual increase in the smoking prevalence rate among the Saudi population. However, after the MPOWER policies were put in place, there was a consistent annual decline in the smoking prevalence rate, albeit a slight one. This indicates that the MPOWER measures have had a positive impact on reducing tobacco smoking in the country. Moreover, the study found that the implementation of higher MPOWER scores resulted in lower proportions of both tobacco smoking prevalence and lung cancer incidence rates. This demonstrates the effectiveness of MPOWER tobacco control policies when implemented at a higher level in Saudi Arabia.

The MPOWER measures in Saudi Arabia were implemented in two major stages, with the first stage occurring in 2011 and the second, more comprehensive stage taking place in 2017. In 2012, the government introduced a law mandating health warnings on tobacco packages, including rotating graphic images. Additionally, national anti-tobacco mass media campaigns were launched to further raise awareness about the harms of smoking (Itumalla and Aldhmadi, 2020; Evaluation, 2019). A pivotal factor in the second acceleration stage of MPOWER policy measures in Saudi Arabia occurred in 2017 when a 100% tax increase was imposed on all tobacco products. Researchers have consistently emphasized that raising taxes to elevate the price of tobacco

Table 1
Standardized smoking prevalence (15 + years), estimated number of cases and standardized incidence rates for lung cancer over the 20 years period (2000 to 2019) [A], and monitor tobacco use and prevention policies (MPOWER)[B] in Saudi Arabia.

	Smoking prevalence [A]	Lung cancer cases per entire population [A]	Incidence rate per 100,000[A]	MPOWER [B]
				NA[C]
2000	13.32	949	4.4	
2001	13.51	707	3.2	
2002	13.69	1109	4.9	
2003	13.85	1250	5.4	
2004	14.02	1396	5.9	
2005	14.18	1830	7.5	
2006	14.32	1802	7.1	
2007	14.44	2323	8.8	
2008	14.53	2112	7.7	
2009	14.61	2307	8.1	
2010	14.64	2529	8.6	
2011	14.66	2925	9.7	19
2012	14.65	3113	10.1	
2013	14.62	2928	9.3	23
2014	14.56	3341	10.4	
2015	14.51	3144	9.6	23
2016	14.47	2941	8.8	
2017	14.43	2804	8.2	26
2018	14.4	2486	7.1	
2019	14.36	2150	6	32

A- Data source the Global Burden of Disease study data 2019.
B- monitor tobacco use and prevention policies (MPOWER).
C- Not available.

products is the most effective population-level tobacco control policy (Schabath and Cote, 2019; Levy et al., 2018). This finding aligns with the continuous decrease in smoking prevalence observed in the current study; particularly after 2017. Previous studies; employing projection models to evaluate the impact of MPOWER on smoking prevalence, have arrived at similar conclusions regarding the effectiveness of these policies (Dubray et al., 2015; Sharma, 2022). The research suggests that the implementation of MPOWER; coupled with the strategic use of taxation, can have a profound impact on public health by discouraging tobacco use and preventing premature deaths caused by smoking-related diseases. To maximize the benefits of MPOWER, it is essential to continue enforcing these policies and exploring additional measures that can further enhance tobacco control efforts.

In light of the recent acceleration in implementing higher-level MPOWER tobacco control policies in Saudi Arabia, our study aimed to assess the potential impact of achieving the highest score of tobacco control policies on future lung cancer incidence in the country. The findings of our study indicate that if the highest-score MPOWER policies were implemented, a significant number of lung cancer cases could be prevented in 2039, with a projected total of 9,783 cases averted. By achieving the highest level of MPOWER, we could observe a notable reduction in the incidence of lung cancer by nearly 13% at the end of the study period in 2039. Although the current lung cancer incidence rate is relatively low in Saudi Arabia, our projections suggest that it is expected to nearly double by the end of the study period in 2039. As it's also shown in the world, by 2050, the lung cancer incidence rate will be substantially increased to reach nearly double in some regions (Gredner et al., 2020). However, the implementation of effective key measures of MPOWER tobacco control policies has the potential to minimize and prevent this anticipated rise in lung cancer incidence [35]. These findings emphasize the importance of continued efforts to strengthen tobacco control policies in Saudi Arabia. By achieving and maintaining the highest level of MPOWER, significant progress can be made in reducing the burden of lung cancer and improving public health outcomes. The study highlights the potential benefits of comprehensive tobacco control strategies in preventing the future escalation of lung cancer cases and underscores the need for sustained commitment to tobacco control measures. It is worth noting that while our study focuses on lung cancer incidence, the impact of MPOWER policies extends beyond this specific outcome. Effective tobacco control efforts have the potential to reduce the overall burden of smoking-related diseases and mortality rates, improving the well-being of individuals and the population as a whole.

The findings of the current study align with Gredner's study, which used data from 30 European countries to estimate the potential percentage of lung cancer cases that could be prevented over a 20-year period if these countries reached the highest score of MPOWER (Gredner et al., 2021). Gredner's study reported a range of potential prevented lung cancer cases between 9.9% and 33%. In comparison, the current study found that the potential prevented lung cancer rate in Saudi Arabia was 13.87%. These variations could be attributed to differences in the history and current level of implementing tobacco control policies. Some European countries-initiated tobacco control measures long before Saudi Arabia and implemented specific interventions to address the burden of smoking (Gredner et al., 2021).

10.1. Strengthens and limitations

To our knowledge, this is the first modeling study to estimate the impact of applying the highest-level of MPOWER tobacco control

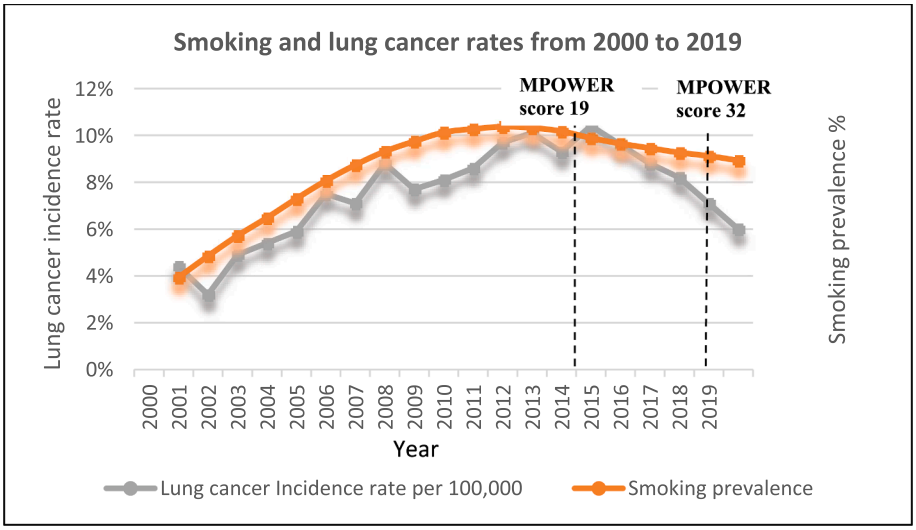

Fig. 3. Smoking and lung cancer incidence rate.

Table 2
Lung cancer incidence predicted future by highest-level implementation of monitor tobacco use and prevention policies (MPOWER = 34) over a 20-year period (2020 to 2039) LAT = 5 years, LAG = 15 years [B].

Year	Smoking prevalence [A]	Predicted lung cancer [C]		Preventable lung cancer incidence based on the hypothesized tobacco prevalence reduction, and future population projection in 2039 [D]	
		Lung incidence rate per 100,000	Lung cancer cases	Incidence rate per 100,000	Lung cancer cases
2020	13.17	7.49	2607	6.84	179
2021	13.14	8.53	3014	7.79	235
2022	12.05	9.27	3323	8.47	282
2023	12.02	9.83	3571	8.98	321
2024	11.03	10.26	3775	9.37	354
2025	11.00	10.61	3952	9.69	383
2026	10.09	10.92	4116	9.97	411
2027	10.07	11.19	4265	10.22	436
2028	9.23	11.44	4408	10.45	461
2029	9.21	11.68	4547	10.67	485
2030	8.45	11.91	4683	10.88	510
2031	8.43	12.13	4815	11.08	534
2032	7.73	12.36	4952	11.29	559
2033	7.71	12.57	5080	11.48	584
2034	7.07	12.79	5212	11.69	609
2035	7.05	13.01	5344	11.89	635
2036	6.47	13.22	5470	12.08	661
2037	6.45	13.44	5600	12.28	688
2038	5.92	13.65	5726	12.47	714
2039	5.91	13.87	5855	12.67	742
Total					9783

A- smoking prevalence, the expected potential proportion of reduction while the highest score of MPOWER tobacco policies has been achieved.
B- LAT: number of years the cancer risk remains constant after reduction in smoking prevalence; LAG: number of years taken for the risk among former smoker to reduce to the level of never smoker.
C- the result from the Autoregressive integrated moving average (ARIMA) model, the model for only future lung cancer prediction based on previous years.
D- we estimated the number of cancer cases that could be prevented if MPOWER tobacco control policies were to be implemented at the highest level in 2020 by multiplying the PIFs with the predicted number of lung cancers. This was calculated based on the expected population size in 2039, the population size data was obtained from the Global Burden of Disease projection of the world population up to 20,100 (https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30677–2/fulltext?ref = themilsource.com).

policies on future lung cancer incidence in a Middle Eastern country, Saudi Arabia, by employing 20-year tobacco smoking prevalence data and risk estimates. On the other hand, population level observational studies are subject to several limitations. First, unavailability of confounding factors that might affect the study's outcome. The resultant bias can weaken, or completely reverse the true exposure-outcome association. Second, we were unable to employ a more detailed modeling approach that considers specific smoking-related factors, such as smoking intensity, duration, and age at smoking cessation. This limitation arose due to the limited availability of suitable data, which led us to make the assumption of homogeneity in smoking patterns. However, observing the impact of the implementation of a control policy at the national level estimates its capability to strengthen tobacco control policy and minimize lung cancer future incidence.

11. Conclusion

The current study provides a projection of the future tobacco smoking prevalence, and an assessment of the implementation of MPOWER tobacco control policy on the future burden of lung cancer in Saudi Arabia taking into consideration the lag time for cancer risk to decline after reducing or quitting smoking. The current findings provide a future projection overview of applying the highest level of MPOWER tobacco control polices in Saudi that could potentially prevent a large number of the future lung cancer cases. If the highest level of MPOWER tobacco policies was implemented, the national tobacco smoking prevalence will decrease by 55% and a total of 9783 lung cancer cases would be potentially prevented in 2039. However, further implementation of effective messages is needed to reduce tobacco-related cancers. By doing so, we can gain valuable insights into the impact of these policies on public health outcomes in the broader context of the region and identify potential areas for further improvement and intervention.

CRediT authorship contribution statement

Majed Ramadan: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Supervision, Software, Validation, Writing – review & editing. **Noara Alhusseini:** Supervision, Software, Validation, Writing – review & editing. **Lara Samhan:** Visualization, Investigation. **Sara Samhan:** Visualization, Investigation. **Tasnim Abbad:** Visualization, Investigation.

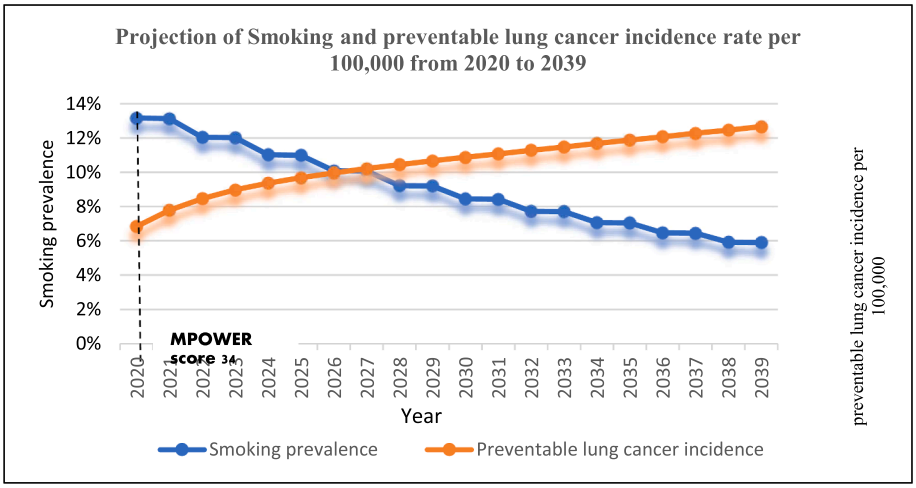

Fig. 4. Projection of Smoking and preventable lung cancer incidence rates, - The data for smoking is the result of the population impact fraction (PIF) after applying the highest level of MPOWER score. - The data for preventable lung cancer incidence shows the prediction result of the Autoregressive integrated moving average (ARIMA) model.

Declaration of Competing Interest

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

Data availability

The data that supports the findings of this study are available from [Global cancer statistics 2020, and Global burden of disease study 2019]. No restrictions apply to the availability of these data, which were used under Public Use Files (PUF) data. Data are available [at https://ghdx.healthdata.org/gbd-2019/data-input-sources, https://www.healthdata.org/gbd/2019].

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Competing interests

"The authors declare that they have no competing interests"

Ethics and consent

"N/A"

Consent for publication

"N/A"

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What this study adds.

If the highest level of MPOWER tobacco policies was implemented, the national tobacco smoking prevalence will be declined by 55%, and a total of 9783 lung cancer cases can be prevented by 2039. This study provides an assessment of the evident impact of MPOWER policy package implementation on smoking prevalence in Saudi Arabia. However, further implementation of effective measures is needed if tobacco-related cancers were to be reduced.

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