

# Global lung cancer mortality trends and lifestyle modifications: preliminary analysis

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## Abstract

**Background:** According to the Independent High-level Commission on Non-communicable Diseases (NCD) of the World Health Organization (WHO), global reduction in lung cancer mortality has been achieved since the year 2000, although this effect is not sufficient to reach the 30% reduction of mortality from NCDs by the year 2030, as stipulated by the United Nations Sustainable Development Goal 3.4. The objective of this study was to analyze whether the lifestyle changes implemented by the WHO at country level could have an impact on mortality from this form of cancer.

**Methods:** WHO statistics, based on the unified mortality and causes-of-death reports of Member-State countries, were used to evaluate global lung cancer mortality trends and make comparisons and assessments of different types of community-based, country-wide interventions.

**Results:** The lung cancer mortality decline was associated with the anti-tobacco campaign initiated by the WHO in the last 15 to 20 years. Comprehensive tobacco control remained the major and most successful lifestyle modification measure. In countries with declining lung cancer mortality, 91% of countries had decreasing tobacco prevalence in males and 82% in females. Country-wide measures to increase physical activity had a strong tendency to be better implemented in countries with declining lung cancer mortality ( $t = 1.79$ ,  $P > 0.05$ ). Other WHO “best-buy” lifestyle modification campaigns (diet and alcohol) had been carried out for shorter periods, and their associations with lung cancer were less strong than tobacco. There was no significant difference between countries with declining and increasing lung cancer mortality in the measures for reduction of harmful alcohol use ( $t = 0.92$ ,  $P > 0.05$ ) and unhealthy diet reduction measures ( $t = 0.84$ ,  $P > 0.05$ ).

**Conclusion:** Following WHO “best-buys” should facilitate to move countries towards the NCD including lung cancer mortality reduction targets. Governments and communities must embrace these targets with coordinated effective action for better health.

**Keywords:** Lung cancer; Lifestyle modifications; Tobacco; Physical activity

## Introduction

Billions of people around the world suffer from non-communicable diseases (NCDs), which are responsible for 71% of the 57 million deaths globally. The NCD burden is the greatest within low- and middle-income countries, where 78% of all NCD deaths and 85% of premature deaths were registered. The most common NCDs are: cardiovascular diseases (31%), cancers (16%), chronic respiratory diseases (7%), and diabetes (3%). These four are largely preventable through public policies focusing on common risk factors: tobacco use, harmful use of alcohol, unhealthy diets, physical inactivity, and air pollution.<sup>[1]</sup> To control this enormous global burden, the World Health Organization (WHO) published the WHO Global NCD Action Plan 2013–2020<sup>[2]</sup> and WHO 13th General

Programme of Work 2019–2023.<sup>[3,4]</sup> The action plan set targets, which were developed jointly with ministries of health and other government sectors, including finance, trade, agriculture, education, and environment, to reduce the risk for NCD. Their global targets are aligned with those of the United Nations 2030 Agenda for sustainable development goals (SDG). SDG target 3.4 states, “by 2030, reduce by one-third premature mortality from NCDs through prevention and treatment, and promote mental health and well-being.”<sup>[5,6]</sup>

Five years after the adoption of NCD Action Plan and 3 years after formulation of SDG target 3.4, the WHO Director-General convened the WHO Independent High-level Commission on NCDs to provide bold recommendations on how countries can accelerate progress towards SDG target 3.4.<sup>[7]</sup> The commission stated that although the

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number of premature deaths had risen in the years from 2000 to 2015, the probability of dying from any of the four major NCDs is declining. This is mainly a result of two factors: a growing population aged 30 to 70 years, and falling mortality in only two categories, cardiovascular diseases and chronic respiratory diseases. However, the global rate of decline in deaths from NCDs, 17% between 2000 and 2015, is still not enough to meet the SDG target 3.4 by 2030.<sup>[7]</sup>

Cancers, a major cause of total mortality, have been categorized into 24 different forms in the WHO mortality reports.<sup>[8]</sup> Lifestyle factors have been considered as causes of cancer. For instance, it has been suggested that diet is responsible for about 30% of all cancers.<sup>[9]</sup> However, not all of them depend on the lifestyle modifications reflected in the WHO NCD Action Plan. This report will focus on lung cancer and its prevention.

Lung cancer, the most common lethal neoplasm in the world, kills 1.6 million people each year and accounts for 19.4% of the total deaths attributable to cancer.<sup>[10]</sup> Fifty-eight percent of these cases occurred in the less developed countries.<sup>[11]</sup> If lung cancer has spread to other organs, the 5-year survival rate is only about 13%.<sup>[12]</sup> This poor prognosis shows lack of effective treatment for patients with lung cancer.

Many studies have demonstrated a link between lung cancer and common modifiable risk factors.<sup>[13]</sup> In this article, we analyze whether the lifestyle changes implemented by the WHO at country level could have an impact on mortality from this form of cancer.

## Methods

### Mortality trends

WHO statistics, based on unified mortality and causes-of-death reports of the Member-State countries, are the best source of data for analyzing global NCD mortality trends and making comparisons and assessments of different types of community-based, country-wide interventions.<sup>[8]</sup> Mortality trends from 2000 to the beginning of 2018 are based on analysis of the latest available national information on mortality and its cause submitted to WHO together with the latest available information from global WHO programs for causes of death of public health importance. Analysis includes estimates of age-standardized death rates per 100,000 population by cause, sex, and age for Member States. Only countries with multiple years of national death registration data and high completeness and quality of cause-of-death assignments were included in the analysis. Estimates for these countries may be compared, and time series may be used for priority setting and policy evaluation.<sup>[8]</sup> Due to changes in data and methods, these estimates are not comparable to previously-released WHO estimates. The preparation of these statistics was undertaken by the WHO Department of Information, Evidence, and Research in collaboration with WHO technical programs. Documentation and regional-level summary tables are available on the WHO website.<sup>[8]</sup>

### Lifestyle modifications and risk factors

To address the growing burden of NCD, WHO identified a package of 16 NCD management and lifestyle “best buy” interventions that are cost-effective, affordable, feasible, and scalable in all settings. The “best buys” were well described when introduced in 2010<sup>[14]</sup> and were updated in 2017 based on the latest evidence of intervention impact and costs.<sup>[15]</sup> Implementing all 16 “best buys” in all countries between 2018 and 2025 would avoid 9.6 million premature deaths, thus moving countries appreciably towards the NCD mortality reduction targets.<sup>[1]</sup>

We assumed that lung cancer attributable “best buys” concerned tobacco use, unhealthy diet, physical inactivity, and harmful use of alcohol. This last “best buy” is linked with other behavioral risk factors, such as smoking and diet. Lung cancer management and availability of essential medicines and basic technologies are not reflected in WHO’s “best buy” NCD approach because of the cost of lung cancer treatments and poor prognosis; the 5-year survival rate in the US is only 15.6%.<sup>[16]</sup>

Obesity control is not on the “best buy” list, but this risk factor could be an indicator of physical inactivity and unhealthy diet.<sup>[17]</sup> Air pollution both indoor and outdoor should be also taken into account as a major public health problem and one of the key underlying causes of death due to lung cancer.<sup>[1]</sup>

To quantify the level of lifestyle modification achievements, we gave 2 points for fully achieved activities, 1 point for partially achieved, and no points for not achieved, no response, or “don’t know.” We analyzed the following activities.

### Tobacco demand reduction measures

Implementation by a Member State of the five demand-reduction measures of the WHO Framework Convention on Tobacco Control: (1) reduction of affordability by increasing excise taxes and prices of tobacco products; (2) elimination of exposure to second-hand tobacco smoke in all indoor workplaces, public places, and public transport; (3) implementation of plain or standardized packaging or large graphic health warnings on all tobacco packages; (4) enactment and enforcement of comprehensive bans on tobacco advertising, promotion, and sponsorship; (5) implementation of effective mass media campaigns that educate the public about the harms of smoking, tobacco use, and second-hand smoke. Country can obtain maximum 10 points in case of full achievement of all five demand-reduction measures.

### Harmful use of alcohol reduction measures

Member State has implemented, as appropriate according to national circumstances, the following three measures to reduce the use of alcohol as per the WHO global strategy to reduce the harmful use of alcohol: (1) enactment and enforcement of restrictions on the physical availability of retailed alcohol (via reduced hours of sale); (2) advertising bans (across multiple types of media), or comprehensive

restrictions; (3) increase in excise taxes on alcoholic beverage. Country can obtain maximum 6 points in case of full achievement of all 3 demand-reduction measures.

### Unhealthy diet reduction measures

Member State has implemented the following measures to reduce unhealthy diets: (1) adoption of national policies to reduce population salt (sodium) consumption; (2) adoption of national policies that limit saturated fatty acids and virtually eliminate industrially produced trans fatty acids in the food supply. Country can obtain maximum 4 points in case of full achievement of two demand-reduction measures.

### Public education and awareness campaign on physical activity

Member State has implemented at least one recent national public awareness and motivational communication for physical activity, including mass media campaigns for physical activity behavioral change. Country can obtain maximum 2 points in case of full achievement of this demand-reduction measure.

### Assessment of obesity, harmful use of alcohol, insufficient physical activity status, and air pollution

Obesity in 2016 was defined in adults as the percentage of the population aged 18 years and older having a body mass index  $\geq 30$  kg/m<sup>2</sup> and in adolescents as the percentage of the population aged 10 to 19 years who are more than two standard deviations above the median of the WHO growth reference for children and adolescents.<sup>[1]</sup>

Alcohol consumption was assessed as total alcohol per capita consumption in liters of pure alcohol.<sup>[1]</sup>

Insufficient physical activity was assessed as percentage of population aged 18 years and older who were physically inactive defined as not meeting the WHO recommendations on physical activity for health.<sup>[1]</sup>

Ambient air pollution in 2016 was assessed as the exceedance of the WHO guideline level for the annual mean concentration of particles of  $\leq 2.5$   $\mu$ m in diameter (PM<sub>2.5</sub>) in the air. Household air pollution in 2016 was assessed by the percentage of the population with primary reliance on polluting fuels and technologies.<sup>[1]</sup>

### Mortality estimates

Total lung cancer mortality from 2000 to 2016 was analyzed in 49 countries with the interim analysis in 2010 and 2015. Thirty-six countries (Australia, Austria, Bahamas, Belgium, Brunei Darussalam, Canada, Chile, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Republic of Korea, Slovakia, Slovenia, Spain, Sweden, Switzerland, Trinidad and Tobago, the United Kingdom, and the United States of America) belong to high-income countries (HIC) according to the World

Bank classification, and 13 countries (Armenia, Brazil, Cuba, Grenada, Guatemala, Kyrgyzstan, Mauritius, Mexico, Republic of Moldova, Romania, Saint Vincent and the Grenadines, The Former Yugoslav Republic of Macedonia [North Macedonia], and Uzbekistan) belong to middle-income countries (MIC).<sup>[18]</sup>

### Statistical analysis

Continuous data were expressed as mean  $\pm$  standard deviation and analyzed by Student's *t* test. The SPSS software package 2015 (SPSS Inc., Chicago, IL, USA) was used to perform all statistical analyses. A two-sided *P* < 0.05 was considered statistically significant.

### Results

Baseline (year 2000) age-standardized mortality rate was  $25.4 \pm 10.0$  per 100,000 population (*n* = 49). On average, by the year 2016, total lung cancer mortality declined by 10% in 49 countries, 13% in HIC, and 3% in MIC. Total lung cancer mortality declined by 14% in 42 countries (Armenia, Australia, Austria, Bahamas, Belgium, Brazil, Canada, Croatia, Cuba, Czechia, Denmark, Estonia, Finland, France, Germany, Guatemala, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, New Zealand, Norway, Republic of Korea, Saint Vincent and the Grenadines, Slovakia, Slovenia, Spain, Sweden, Switzerland, The Former Yugoslav Republic of Macedonia [North Macedonia], the United Kingdom, the United States of America, and Uzbekistan), did not change in one (Chile), and increased by 18% on average in six countries (Brunei Darussalam, Grenada, Mauritius, Republic of Moldova, Romania, and Trinidad and Tobago).

Mortality trends in countries with the highest, more than 30% decline (Guatemala 46%, Mexico 36%, Czechia 32%, and the United States 32%) are presented in Table 1. Guatemala belongs to lower MIC, and Mexico to upper MIC, while United States and Czechia to HIC. Reviewing tobacco prevalence trends from 2000 to 2015,<sup>[1]</sup> we found no data for Guatemala, no change in Czechia and visible decline in USA and Mexico both for males and females. We have noticed that in all these countries public education and awareness campaigns in lower physical activity have been fully achieved.

In countries with the highest increase of lung cancer mortality [Table 2], only Brunei-Darussalam belongs to HIC. Grenada and Mauritius belong to upper MIC and Republic of Moldova to lower MIC. By the year 2015,

**Table 1: Age-standardized lung cancer mortalities from countries with the highest decline from 2000 to 2016.**

Country	Mortality (/100,000 persons)			
	2000	2010	2015	2016
Guatemala	7.2	5.3	3.9	3.9
Mexico	10.2	7.7	6.6	6.5
Czechia	37.7	30.4	25.8	25.6
USA	40.6	33.3	28.9	27.8

mortality dramatically increased in Grenada and gradually increased in Brunei Darussalam; after 2010 it began stabilizing or slightly declining in Mauritius and Republic of Moldova. Regarding tobacco trends, no data were reported for Grenada and an increasing prevalence for males in Brunei Darussalam and Republic of Moldova. Tobacco prevalence for females in these countries did not change. Only Mauritius had a declining prevalence in males and slight decline in females. Public education and awareness campaigns on physical activity have been fully achieved only in Brunei Darussalam and Mauritius, and not achieved in Grenada and Republic of Moldova.

Before 2010, lung cancer mortality gradually declined in some countries (as shown in Table 1) or increased (as shown in Table 2) in other countries. After 2010, and implementation of WHO “best buy,” the lung cancer mortality trend continued to decline in countries as shown in Table 1 or increased in some countries as shown in Table 2. In view of this, we have analyzed 37 countries where lung cancer mortality declined in the period from 2010 after implementation of WHO “best buy” to 2016 and 12 countries where lung cancer mortality increased during the same period [Table 3].

Based on the WHO Progress monitor in 2017,<sup>[19]</sup> we analyzed the following “best buy” lifestyle modification measures on tobacco, alcohol, diet, and physical activity. The quantification of interventions was based on the level of the achieved measures [Table 3]. No difference was found between the groups. However, physical activity measures had a strong tendency to be better implemented in countries with declining lung cancer mortality ( $t = 1.79, P > 0.05$ ).

In view of this, we reviewed physical activities achievements in countries with declining mortality, where the

above-mentioned country-wide lifestyle modification measures have not been achieved. Surprisingly, we found out that Lithuania and Sweden were among these countries. Keeping in mind that Lithuania is one of the leading countries involved in the WHO non-communicable diseases intervention programs<sup>[20]</sup> and has had multiple health promoting campaigns, we assumed that public education and awareness campaign on physical activity has been fully achieved before the current assessment in 2016. Adjustment was also made for Sweden where WHO Global Health inter-country comparable physical activity estimates before 2010 showed high proportion of Swedish population meeting the WHO physical activity recommendations. The reported estimates were 68.9% for the total adult population, with 73.7% for men and 64.2% for women.<sup>[21]</sup> In view of this, we assumed that this measure could be at least partially achieved and gave 1 point to this country. After these adjustments, the difference between groups has become statistically significant ( $t = 2.09, P < 0.05$ ). In the WHO NCDs progress monitor 2017,<sup>[19]</sup> this indicator was considered fully achieved if the country responded “Yes” to the following question: “Has your country implemented any national public awareness program on physical activity within the past 5 years” and provided the needed supporting documentation. In understanding that during the last 5 years, Lithuania and Sweden have not implemented awareness programs, but we assumed the national awareness level remained high in these countries, as mentioned before. WHO NCD Progress Monitor 2020 has demonstrated that Lithuania and Sweden have fully achieved public education and awareness campaign on physical activity.<sup>[22]</sup>

We found no significant difference between groups in the level of NCD risk factors [Table 4]. However, we saw a tendency towards a higher level of ambient air pollution in countries with increasing lung cancer mortality. Obesity status was nearly the same in both groups of countries.

Although we did not find significant difference in the current prevalence of smoking between countries, the smoking prevalence trends from 2000 to 2015 demonstrated that in countries with declining lung cancer mortality, 91% of countries had decreasing tobacco prevalence in males and 82% in females, while 9% of countries had increasing or stable tobacco prevalence in males and 18% in females. In countries with increasing lung cancer mortality, 60% of countries had decreasing

**Table 2: Age-standardized lung cancer mortalities in countries with the highest increase from 2000 to 2016.**

Country	Mortality (/100,000 persons)			
	2000	2010	2015	2016
Grenada	8.6	9.8	14.3	13.1
Brunei Darussalam	21.9	24.3	26.0	25.9
Mauritius	8.3	10.8	10.9	9.6
Republic of Moldova	17.9	21.1	20.9	20.5

**Table 3: Lifestyle modification measures in countries with different lung cancer mortality trends in 2010–2016.**

Scores of lifestyle modifications	Countries with declining lung cancer mortality (n = 37)	Countries with increasing lung cancer mortality (n = 12)	t	P
Tobacco demand reduction measures	5.5 ± 1.9	4.5 ± 3.1	1.06	>0.05
Measures for harmful use of alcohol reduction	2.6 ± 1.1	3.0 ± 1.2	0.92	>0.05
Unhealthy diet reduction measures	2.6 ± 1.6*	1.5 ± 1.6	0.84	>0.05
Measures of public education and awareness campaign on physical activity				
Before adjustment	1.7 ± 0.7	1.2 ± 1.0	1.79	>0.05
After adjustment <sup>†</sup>	1.8 ± 0.6	1.2 ± 1.0	2.09	<0.05

Data were presented as mean ± standard deviation. \* Only the data of 36 countries are available; † Adjusted for Lithuania as fully achieved and Sweden as partially achieved.



**Table 4: Mean population level of NCD risk factors in countries with different lung cancer mortalities by 2016.**

Risk factors	Countries with declining mortality (n = 37)	Countries with increasing mortality (n = 12)	t	P
Percentage of tobacco smoking in adults aged $\geq 15$ years (%)				
Males	29.6 $\pm$ 10.8	33.9 $\pm$ 7.7	1.51	>0.05
Females	16.4 $\pm$ 6.7	15.2 $\pm$ 11.4	0.35	>0.05
Total	22.6 $\pm$ 5.7*	24.5 $\pm$ 8.5 <sup>†</sup>	0.73	>0.05
Percentage of physical inactivity in adults aged $\geq 18$ years (%) <sup>‡</sup>				
Males	24.8 $\pm$ 8.4	25.4 $\pm$ 8.5	0.08	>0.05
Females	37.1 $\pm$ 8.8	36.0 $\pm$ 12.1	0.29	>0.05
Total	33.4 $\pm$ 7.5*	30.8 $\pm$ 9.9 <sup>‡</sup>	0.84	>0.05
Percentage of harmful use of alcohol in those aged $\geq 15$ years, liters of pure alcohol per person per year				
Males	15.6 $\pm$ 4.7	14.2 $\pm$ 6.8	0.67	>0.05
Females	3.9 $\pm$ 1.6	3.2 $\pm$ 1.8	0.21	>0.05
Total	9.6 $\pm$ 3.0	8.4 $\pm$ 4.3	0.90	>0.05
Percentage of obesity (%) <sup>  </sup>	23.7 $\pm$ 6.6	23.7 $\pm$ 5.6	–	–
Ambient air pollution <sup>¶</sup>	1.1 $\pm$ 0.9	1.6 $\pm$ 0.9	1.67	>0.05
Household air pollution (%) <sup>#</sup>	8.0 $\pm$ 9.8	6.8 $\pm$ 2.6	0.66	>0.05

Data were presented as mean  $\pm$  standard deviation. \* Only the data of 34 countries are available; <sup>†</sup> Only the data of ten countries are available; <sup>‡</sup> Percentage of the population not meeting the WHO recommendations on physical activity for health; <sup>§</sup> Only the data of 11 countries are available; <sup>||</sup> Obesity was defined in adults as the percentage of the population aged 18 years and older having a body mass index  $\geq 30$  kg/m<sup>2</sup> and in adolescents as the percentage of the population aged 10 to 19 years who are more than two standard deviations above the median of the WHO growth reference for children and adolescents; <sup>¶</sup> Exceedance of WHO guideline level for annual concentration of particles  $\leq 2.5$  micrometers in the air (by a multiple of); <sup>#</sup> Percentage of the population with primary reliance on polluting fuels and technologies. NCD: Non-communicable diseases; WHO: World Health Organization.

tobacco prevalence in males and 30% in females, while 40% of countries had increasing or stable tobacco prevalence in males and 70% in females.

## Discussion

As mentioned above, the mortality of lung cancer from 2000 to 2016 demonstrated a decline in 86% of countries (42 out of 49). Increasing lung cancer mortality was seen only in six countries (12%). It is well established that tobacco smoke causes most cases of lung cancer by damaging DNA and mutating protective genes. Lung cancer risks correlate with amount and duration of smoking. Since DNA-damaged genes accumulate over time, lung cancer may occur years after people begin or quit smoking.<sup>[10]</sup> There are now more former smokers than smokers worldwide, but former smokers are not free from cancer risk. This explains why we did not see a difference in the current prevalence of smoking between countries with different lung cancer mortalities. However, analysis of smoking trends from 2000 to 2015 has clearly demonstrated higher mortality rate in countries with less visible decline or no decline of tobacco usage. The most dramatic growth of lung cancer mortality was observed in Grenada (52%) where no measures to reduce tobacco demand, and improve physical activity and diet have been registered. Only measures for reduction of harmful alcohol use have been partially achieved in this country. Lung cancer is largely preventable through tobacco control. Public health programs that reduce smoking are effective, but more are urgently needed, especially in countries where smoking is increasing because the incidence of lung cancer follows the prevalence of smoking.

Lung cancer may also occur in people who have never smoked. Other risk factors such as passive exposure to tobacco smoke, biomass fuel, diesel exhaust, radon,

asbestos, and other environmental and workplace carcinogens may be responsible.<sup>[10]</sup> The International Agency for Research on Cancer classifies outdoor air pollution as a lung carcinogen in humans.<sup>[23]</sup> Indoor air pollution is a major risk factor for lung cancer, especially in never-smoking women living in several regions of Asia. Indoor air pollution caused by burning of wood, other solid fuels, and kerosene in poorly ventilated houses, as well as fumes from high-temperature cooking using unrefined vegetable oils, such as rapeseed oil, may cause lung cancer.<sup>[24,25]</sup> However, we did not find a significant difference in ambient and household air pollution between countries with declining and increasing lung cancer mortality.

While analyzing the physical inactivity policy, we saw a tendency towards better achievements of public education and awareness campaign on physical activity in countries with declining lung cancer mortality. WHO recommends three levels of physical activity for health for age groups 5 to 17, 18 to 64, and 65 years and above. Since lung cancer usually appears in the older age, we have addressed recommendations for the two last age groups. They include recreational or leisure-time physical activity, transportation (e.g., walking or cycling), occupational (i.e., work) and household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities. Adults should do at least 150 min of moderate-intensity aerobic physical activity per week, or do at least 75 min of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate and vigorous-intensity activity. For additional health benefits, adults aged 65 years and above should increase their moderate-intensity aerobic physical activity to 300 min per week, or engage in 150 min of vigorous-intensity aerobic physical activity per week or an equivalent combination of moderate- and vigorous-intensity activity. Adults of this age group with poor mobility should perform physical

activity to enhance balance and prevent falls on 3 or more days per week. When adults of this age group cannot do the recommended amounts of physical activity due to health conditions, they should be as physically active as their abilities and conditions allow.<sup>[26]</sup>

There is evidence from case-control studies that a diet rich in vegetables and fruits,<sup>[27]</sup> especially cruciferous vegetables,<sup>[28,29]</sup> may exert some protective effect against lung cancer. Many studies have addressed the risk of lung cancer according to estimated intake of either  $\beta$ -carotene or total carotenoids (which in most cases correspond to the sum of  $\alpha$ - and  $\beta$ -carotene).<sup>[30]</sup> Animal studies have shown that polyunsaturated fatty acids (PUFAs) have anti-neoplastic and anti-inflammatory properties. The Shanghai Women's Health Study and Shanghai Men's Health Study with a total of 121,970 study participants prospectively evaluated the association of specific types of dietary PUFA intake and lung cancer risk. Total saturated and monounsaturated fatty acid intake was not significantly associated with lung cancer risk. Total PUFAs intake was inversely associated with lung cancer risk. However, docosahexaenoic acid, an omega-3 fatty acid intake was positively associated with lung cancer. The ratio of n-6 PUFAs to n-3 PUFAs (i.e., 7:1) was inversely associated with the risk, particularly among never-smokers and adenocarcinoma patients.<sup>[31]</sup> This study highlights the important public health role of PUFAs in the prevention of lung cancer and other NCDs. A pooled analysis of eight cohort studies provided no evidence of an increased risk of lung cancer with a high intake of either total fat or saturated fat.<sup>[32]</sup> There is also no evidence that salt (sodium) and trans fatty acids consumption has a link with lung cancer risk. Our study did not show any association between unhealthy diet reduction measures adopted at the country level and lung cancer mortality.

Given the strong correlation between alcohol consumption and tobacco smoking in many populations, it is difficult to elucidate the contribution of alcohol to lung carcinogenesis while properly controlling for the potential confounding effect of tobacco. Meta-analyses have indicated that the increased risk of lung cancer observed among alcoholics was mainly attributable to such residual confounding, since no consistent association was observed in never-smokers.<sup>[33]</sup> A smoking-adjusted association is suggested for high alcohol consumption,<sup>[34,35]</sup> a conclusion confirmed by a pooled analysis of seven cohort studies.<sup>[36]</sup> Here, we found no association between harmful use of alcohol reduction measures and lung cancer mortality.

In this study, there was no significant difference in the level of obesity between countries with declining and increasing lung cancer mortality.

## Conclusions

Tobacco cessation remains the overarching strategy for elimination of lung cancer by helping current smokers to stop, and by reducing the number of people who start smoking. Our analysis demonstrates that 15 years of declining tobacco usage is now associated with decreasing lung cancer mortality. WHO Global Recommendations on

Physical Activity for Health need to be adapted and translated into culturally appropriate forms at country level. The cost of endorsing these recommendations is minimal and essentially related to the translation into country settings, communication, and dissemination. This approach could improve physical conditions in the population.

Besides tobacco control and public education and awareness campaign on physical activity, lung cancer could be influenced by implementing measures against harmful use of alcohol and unhealthy diet. Although the correlation between diet and lung cancer is less obvious compared with tobacco, emphasis should be placed on diet as part of the lifestyle changes, since current evidence shows a protective role of fruits and vegetables in lung cancer etiology. More research is needed to determine other causes of lung cancer and how to translate this knowledge into effective health policy.

Strengthening the basic commitments WHO is calling for, namely tobacco restrictions and attention to physical activity, diet, alcohol, and air quality will help move nations towards the mortality reductions of the SDG target 3.4.

## Conflicts of interest

None.

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