

# Spatial, temporal, and demographic patterns in prevalence of chewing tobacco use in 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019

GBD 2019 Chewing Tobacco Collaborators\*



## Summary

**Background** Chewing tobacco and other types of smokeless tobacco use have had less attention from the global health community than smoked tobacco use. However, the practice is popular in many parts of the world and has been linked to several adverse health outcomes. Understanding trends in prevalence with age, over time, and by location and sex is important for policy setting and in relation to monitoring and assessing commitment to the WHO Framework Convention on Tobacco Control.

**Methods** We estimated prevalence of chewing tobacco use as part of the Global Burden of Diseases, Injuries, and Risk Factors Study 2019 using a modelling strategy that used information on multiple types of smokeless tobacco products. We generated a time series of prevalence of chewing tobacco use among individuals aged 15 years and older from 1990 to 2019 in 204 countries and territories, including age-sex specific estimates. We also compared these trends to those of smoked tobacco over the same time period.

**Findings** In 2019, 273·9 million (95% uncertainty interval 258·5 to 290·9) people aged 15 years and older used chewing tobacco, and the global age-standardised prevalence of chewing tobacco use was 4·72% (4·46 to 5·01). 228·2 million (213·6 to 244·7; 83·29% [82·15 to 84·42]) chewing tobacco users lived in the south Asia region. Prevalence among young people aged 15–19 years was over 10% in seven locations in 2019. Although global age-standardised prevalence of smoking tobacco use decreased significantly between 1990 and 2019 (annualised rate of change:  $-1\cdot21\%$  [ $-1\cdot26$  to  $-1\cdot16$ ]), similar progress was not observed for chewing tobacco ( $0\cdot46\%$  [ $0\cdot13$  to  $0\cdot79$ ]). Among the 12 highest prevalence countries (Bangladesh, Bhutan, Cambodia, India, Madagascar, Marshall Islands, Myanmar, Nepal, Pakistan, Palau, Sri Lanka, and Yemen), only Yemen had a significant decrease in the prevalence of chewing tobacco use, which was among males between 1990 and 2019 ( $-0\cdot94\%$  [ $-1\cdot72$  to  $-0\cdot14$ ]), compared with nine of 12 countries that had significant decreases in the prevalence of smoking tobacco. Among females, none of these 12 countries had significant decreases in prevalence of chewing tobacco use, whereas seven of 12 countries had a significant decrease in the prevalence of tobacco smoking use for the period.

**Interpretation** Chewing tobacco remains a substantial public health problem in several regions of the world, and predominantly in south Asia. We found little change in the prevalence of chewing tobacco use between 1990 and 2019, and that control efforts have had much larger effects on the prevalence of smoking tobacco use than on chewing tobacco use in some countries. Mitigating the health effects of chewing tobacco requires stronger regulations and policies that specifically target use of chewing tobacco, especially in countries with high prevalence.

**Funding** Bloomberg Philanthropies and the Bill & Melinda Gates Foundation.

**Copyright** © 2021 The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY 4.0 license.

## Introduction

Effective design of tobacco-control policies and appropriate allocation of resources requires understanding patterns and trends in all types of tobacco use.<sup>1</sup> Although 138 (77%) of the 180 countries committed to the aims of the WHO Framework Convention on Tobacco Control (FCTC) include smokeless tobacco in their statutes,<sup>2</sup> smokeless tobacco use has been monitored in far fewer countries than has smoking tobacco use, even in places with high prevalences of smokeless tobacco use.<sup>2</sup> Only 55 (31%) FCTC countries have data on adult smokeless

tobacco use from the past 10 years, and only 70 (39%) have data on smokeless tobacco use among young people.<sup>2</sup> Additionally, smoked and smokeless tobacco use patterns differ by demographic, socioeconomic, and cultural characteristics,<sup>3–6</sup> so detailed information on smokeless tobacco use patterns and trends are needed to tailor interventions that best meet the needs of these different subgroups.

Monitoring of smokeless tobacco use alongside smoked tobacco use should be done for a variety of reasons, including beliefs that it is a safe alternative to smoking,

*Lancet Public Health* 2021;  
6: e482–99

Published Online  
May 27, 2021  
[https://doi.org/10.1016/S2468-2667\(21\)00065-7](https://doi.org/10.1016/S2468-2667(21)00065-7)

This online publication has been corrected. The corrected version first appeared at [thelancet.com/public-health](https://www.thelancet.com/public-health) on June 2, 2021

\*Listed at the end of the Article

Correspondence to:  
Prof Emmanuela Gakidou,  
Institute for Health Metrics and  
Evaluation, University of  
Washington, Seattle, WA 98195,  
USA  
[gakidou@uw.edu](mailto:gakidou@uw.edu)

### Research in context

#### Evidence before this study

Previous studies of smokeless tobacco use have found that both prevalence and the type of product used vary widely across countries. Studies on the health effects of smokeless tobacco products have found differences in toxicity by type of product, with chewing tobacco products being the most harmful. Limitations of available survey data have posed a challenge to estimating internally consistent and comparable estimates of product-specific prevalence, disaggregated by location, age, sex, and time period. These limitations have made it difficult to form a comprehensive, global picture of where chewing tobacco is used most, among which age groups and sexes, and how this has changed over time.

#### Added value of this study

This study, based on results from the Global Burden of Diseases, Injuries, and Risk Factors Study 2019, is the first global analysis of prevalence of chewing tobacco use by age, sex, and time period that incorporates information from available nationally representative surveys with questions about smokeless tobacco use. To address the challenge of heterogeneous survey data, of which little were available, we developed and implemented a new approach to combining different definitions and sources of smokeless tobacco prevalence data across locations to mitigate the effects of compositional bias in the available data. These methods

improved estimates, particularly in locations that have less chewing tobacco-specific data but do have data on other smokeless tobacco products. This modelling approach allowed for the use of 752 data sources, integral to producing improved estimates by age, sex, and location, across which prevalence of chewing tobacco use varies widely. Finally, we compared trends in chewing tobacco with trends in smoking prevalence. The difference in trends over time between prevalences of chewing and smoking tobacco indicates that tobacco control efforts and policies have had a much larger effect on the prevalence of smoking tobacco use than on the prevalence of chewing tobacco use.

#### Implications of all the available evidence

Monitoring of prevalence of chewing tobacco use would benefit greatly from concerted efforts to add questions about its use in surveys that clearly distinguish the types of products, in a similar way to what is done for smoking tobacco. We found that the prevalence of chewing tobacco use has remained fairly stable over time and is high in many regions and demographic groups, including those with historically lower prevalence of smoking tobacco. Increased commitment to control of smokeless tobacco through both local interventions and expansion of the policies outlined in the WHO Framework Convention on Tobacco Control articles to smokeless tobacco products is urgently needed.

beliefs about a variety of benefits (eg, for morning sickness), and local distribution and production.<sup>6–8</sup> Moreover, smokeless tobacco is less regulated than smoked tobacco. Tobacco manufacturers can sell smokeless tobacco products that are sweeter or flavoured and aimed at new users,<sup>9</sup> and these products are usually cheaper than cigarettes.<sup>10</sup> A wide array of products is available in the market, but data on smokeless tobacco use are often not collected by specific products or subtypes, further complicating monitoring and regulation. Although all smokeless tobacco products are consumed through the mouth or nose without burning, the wide variety of products are used in different ways<sup>11</sup> and are associated with varying degrees and types of harm.<sup>12–14</sup> This study focuses on chewing tobacco use, because the associated health risks are well documented.<sup>12,15,16</sup> Many studies have found strong evidence for the increased risk of oral cancer due to chewing tobacco.<sup>11,14,17</sup>

In this context, we aimed to provide an improved understanding of chewing tobacco use, which is essential for targeted policy, assessment of the effectiveness of these policies, and, ultimately, mitigation of the associated harms.<sup>1</sup> Studies have been done previously that estimated prevalence for a particular country,<sup>18–20</sup> region,<sup>3,4,21</sup> or source,<sup>3,18–21</sup> or a restricted time period<sup>11,20,21</sup> or age group,<sup>5,22</sup> but to our knowledge no attempt has been made to synthesise multiple data sources to understand these trends

globally over time and across age groups. For the first time, as part of the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2019, we comprehensively estimated the prevalence of chewing tobacco use using all available data sources to estimate age-sex-specific prevalence of chewing tobacco use from 1990 to 2019 in 204 countries and territories. We also compared these trends with those of smoked tobacco over the same time period.<sup>23</sup> This manuscript was produced as part of the GBD Collaborator Network and in accordance with the GBD Protocol.

## Methods

### Overview and definitions

We modelled prevalence of current chewing tobacco use by using data on multiple types of smokeless tobacco use. We defined current chewing tobacco use as use of chewing tobacco products within the past 30 days on either a daily or occasional basis, or current use as defined by the survey. We produced estimates for males and females separately, and for each 5-year age group between the ages of 15 and 94 years with a terminal age group of individuals aged 95 years and older. We produced estimates for every year between 1990 and 2019 and for 204 countries and territories included in GBD 2019. This study adheres to the Guidelines for Accurate and Transparent Health Estimates Reporting.<sup>24</sup>

Because data on chewing tobacco alone are sparse, we systematically reviewed, extracted, and included in our estimations data on all types of smokeless tobacco. We classified data into three categories: chewing tobacco products only, non-chewing tobacco products only, and general smokeless tobacco with products not specified; we refer to this third category as unspecified smokeless tobacco. The first and second categories are distinct and do not overlap. Available data in these two categories were used to adjust data reported as general smokeless tobacco, which comprises the majority of data sources. As a result, in our modelling process we used information from all three categories to produce our final estimates of prevalence of chewing tobacco use for all countries.

#### Data sources

We searched the Global Health Data Exchange for representative surveys with data on use of any smokeless tobacco product among individuals aged 10 years and older collected between 1980 and 2019. Although we report data for individuals aged 15 years and older and from 1990 onwards, we included this additional age group and decade to inform time trends and age patterns of the model. We included individual-level survey data, tabulated survey report data, and data from scientific literature. We identified and extracted data from 752 surveys that were location and year specific that met our inclusion criteria. Of 204 countries and territories, 185 (91%) had at least one data source and 58 (28%) had at least five data sources. 57 countries (28%) had their most recent data source from either 2017 or 2018. Full details on inclusion criteria, search strings, and extraction methods are included in the appendix (pp 12–15). A list of all included surveys can be accessed through the GBD 2019 Data Input Sources Tool.

#### Modelling strategy and overview of spatiotemporal Gaussian process regression

A key challenge in modelling the prevalence of chewing tobacco use is that 562 (75%) of 752 sources with information on smokeless tobacco did not distinguish between specific smokeless tobacco products. Because this large proportion of sources reported on unspecified smokeless tobacco use, we used a modelling strategy that maximised the use of available information, rather than constraining our analysis to only focus on sources reporting the prevalence of chewing tobacco use alone. An overview of the modelling strategy, from data processing to final prevalence estimates, is shown in the appendix (p 23).

In three different parts of the estimation process, we used spatiotemporal Gaussian process regression (ST-GPR) to model location-age-sex-specific trends over time. Details on ST-GPR are described in full elsewhere.<sup>25</sup> Briefly, the model is implemented in three steps: first, linear regression; second, spatiotemporal smoothing, which adjusts the linear regression estimate on the basis

of residuals weighted by distance in time, age, and location; and finally, Gaussian process regression, which incorporates uncertainty in the data and quantifies the uncertainty of the estimates. For all ST-GPR models, we used an agnostic first-stage linear model that only includes a global intercept and age fixed effects. As a result, variations in final estimates by time, location, and age were entirely data driven and were incorporated in the second and third stages of the model. The information sharing across similar locations in ST-GPR is particularly useful in this context because the proportion of chewing tobacco use versus non-chewing tobacco use appears to be very similar within geographical regions.<sup>11</sup> Additionally, we do not believe that these trends over age and time are substantially affected by different survey methods (appendix p 20). The end result of ST-GPR is 1000 draws from the posterior distribution of the Gaussian process, from which we calculated the mean and 2·5th and 97·5th percentiles to characterise the 95% uncertainty interval (UI).

#### Smokeless tobacco product mapping and generation of the prevalence model

Case definitions varied substantially across data sources. Surveys reported on 262 unique combinations of smokeless tobacco products, which we mapped to one of two mutually exclusive and collectively exhaustive categories: either chewing tobacco products or non-chewing tobacco products. Non-chewing tobacco products refers to smokeless tobacco products that are not chewing tobacco. In some cases, surveys did not specify a product, or specified a wide array of products that spanned both categories. We mapped these sources to a third category of unspecified smokeless tobacco. The product map is in the appendix (p 15). After product mapping, 170 sources reported on the prevalence of chewing tobacco use, 137 reported on the prevalence of non-chewing tobacco use, and 690 reported on the prevalence of unspecified smokeless tobacco use.

After product mapping, 141 (19%) of 752 sources reported data only in aggregated age groups or as both sexes combined. We split these data into our standard 5-year age groups by sex. To do so, we ran separate ST-GPR models for each of the product categories (chewing tobacco, non-chewing tobacco, and unspecified smokeless tobacco), using only data originally available in our standard 5-year age groups and separately by sex. In these models, we purposefully tuned the parameter controlling the decay function for age weights in the spatiotemporal smoothing step to ensure that age patterns were data driven rather than model driven. We then used the modelled estimates to generate age and sex ratios that included uncertainty and varied by location and year. We applied these ratios to the data originally reported in aggregated age groups or as both sexes combined to split the aggregated data into our target demographic groups. Additional details on these methods are in the appendix (pp 16–17).

For the Global Health Data Exchange see <http://ghdx.healthdata.org/>

See Online for appendix

For the GBD 2019 Data Input Sources Tool see <http://ghdx.healthdata.org/gbd-2019/data-input-sources>

The proportion of unspecified smokeless tobacco that is chewing tobacco varies widely across countries. For example, in Sweden, snus (pulverised tobacco for sublabial administration, which we classify as non-chewing tobacco)<sup>26</sup> is the predominant product used, while in India, most users of smokeless tobacco use chewing tobacco.<sup>6</sup> To include data sources that report the prevalence of unspecified smokeless tobacco use, we needed an estimate of the proportion of unspecified smokeless tobacco that is chewing tobacco in each country.

To arrive at that proportion, first we ran separate models for chewing tobacco and non-chewing tobacco, using all available data for each indicator. Then, based on the results of these models, we estimated an age-sex-location-year-specific ratio of chewing tobacco as a proportion of chewing and non-chewing tobacco. Finally, we used this estimated ratio to adjust data reported as prevalence of unspecified smokeless tobacco use. We added the variance of the estimated ratio to the original variance of the data to reflect the uncertainty in this adjustment.

The final step in our modelling process was a ST-GPR model that included all data reported as prevalence of chewing tobacco use, and data reported as unspecified smokeless tobacco that have been adjusted on the basis of the estimated product type ratio. Because data variance is an input to ST-GPR, datapoints with higher variance had a lower influence on final estimates than did datapoints with a lower variance. As a result, the adjusted datapoints added information to the final model, but were weighted less in the final estimation than datapoints that were reported directly as prevalence of chewing tobacco use. Additional details of these methods are in the appendix (pp 18–20).

### Statistical analysis

We report the prevalence of chewing tobacco use and the number of people that currently use chewing tobacco, by location, year, age, and sex, as well as age-standardised estimates for individuals aged 15 years and older, all with their respective 95% UIs. Similarly we report prevalences by sex among individuals aged 15–19 years. We calculated annualised rates of change to assess time trends and compare changes across time with those observed for the prevalence of smoking tobacco use. We calculated all results (including annualised rates of change) that are reported as geographical aggregations using population-weighted aggregation. We determined annualised rates of change to be significant if the 95% UI did not include zero. We considered prevalence results to be significantly different if their 95% UIs did not intersect.

Details on modelling the prevalence of smoking tobacco use have been published separately.<sup>23</sup> Additionally, we did a sensitivity analysis comparing the results of this main method (using both chewing tobacco and adjusted unspecified smokeless tobacco data) versus the results of using only the data on chewing tobacco (appendix pp 28–29).

We did all analyses using R (version 3.6.3).

### Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

### Results

Globally, 273·9 million (95% UI 258·5–290·9) people used chewing tobacco in 2019 (appendix pp 62–69). The global age-standardised prevalence of chewing tobacco use in 2019 among people aged 15 years and older was 4·72% (4·46–5·01) and was 6·55% (6·10–7·03) among males and 2·87% (2·60–3·14) among females (table). Most people (228·2 million [213·6–244·7]; 83·29% [82·15–84·42]) who used chewing tobacco in 2019 resided in the south Asia region. The largest populations of people who use chewing tobacco are in India (185·8 million [171·3–202·5] users; 67·83% [65·77–69·75] of global users) and Bangladesh (25·7 million [23·7–27·6]; 9·37% [8·59–10·25] of global users). Nepal, Bhutan, and Palau also had very high prevalences of chewing tobacco use in 2019, with 4·4 million (4·1–4·8) users in Nepal, 113 040 (102 587–123 860) in Bhutan, and 3440 (3090–3819) in Palau. Among males aged 15 years and older in 2019, the age-standardised prevalence in south Asia was 24·65% (22·81–26·69), while the lowest prevalence globally was 0·17% (0·15–0·20) in southern Latin America (figure 1; appendix p 70). Similarly, the age-standardised prevalence for females in south Asia was 12·13% (10·91–13·45) in 2019, much greater than the lowest age-standardised prevalence globally, which was in western Europe (0·15% [0·14–0·17]; figure 1; appendix p 69). Outside of the south Asia region, the countries with the highest prevalence of chewing tobacco use in 2019 were, for males, Palau (25·76% [22·37–29·75]), Madagascar (16·98% [14·66–19·30]), Myanmar (14·18% [11·94–16·53]), and Sri Lanka (13·57% [11·39–15·77]; figure 1; appendix pp 30–37). For females, the highest prevalence of use was observed in Palau (24·42% [20·04–29·17]), Cambodia (12·84% [11·05–14·70]), Laos (6·73% [5·31–8·24]), and Botswana (6·54% [5·32–7·92]; figure 1; appendix pp 30–37).

Globally, prevalence of chewing tobacco use has increased slightly over time. The annualised rate of change between 1990 and 2019 for both sexes combined was 0·46% (95% UI 0·13 to 0·79), and was 0·39% (–0·01 to 0·83) for males and 0·60% (0·04 to 1·11) for females (appendix p 23). We identified high-prevalence locations by ranking the age-standardised prevalence of both sexes in 1990 and 2019. Here we concentrate on the 12 countries with the highest prevalence in either 1990 or 2019, or both. Within these countries, males in Yemen and females in Palau were the only demographic groups that had significant changes in prevalence between 1990 and 2019, with a significant decrease among males in Yemen (annualised rate of change –0·94% [–1·72 to –0·14]) and a significant increase among females in Palau (1·00% [0·03 to 1·98]; table). However, for these data on males in Yemen, further investigation is needed

	Females					Males				
	Prevalence		Annualised rate of change			Prevalence		Annualised rate of change		
	1990	2019	1990–2005	2005–19	1990–2019	1990	2019	1990–2005	2005–19	1990–2019
Global	2.41% (2.14 to 2.74)	2.87% (2.60 to 3.14)	0.73% (-0.23 to 1.60)	0.46% (-0.36 to 1.27)	0.60% (0.04 to 1.11)	5.84% (5.31 to 6.40)	6.55% (6.10 to 7.03)	0.65% (-0.04 to 1.31)	0.12% (-0.48 to 0.76)	0.39% (-0.01 to 0.83)
Cambodia	14.57% (12.45 to 16.95)	12.84% (11.05 to 14.70)	0.45% (-0.58 to 1.48)	-1.38% (-2.49 to -0.33)	-0.43% (-1.22 to 0.30)	1.62% (1.34 to 1.96)	1.70% (1.39 to 2.07)	0.69% (-0.62 to 2.04)	-0.42% (-1.93 to 1.08)	0.15% (-0.73 to 1.10)
Myanmar	6.63% (5.23 to 8.43)	6.53% (5.14 to 8.20)	0.60% (-0.99 to 2.13)	-0.75% (-2.35 to 1.08)	-0.05% (-1.15 to 1.02)	13.51% (11.19 to 16.07)	14.18% (11.94 to 16.53)	1.24% (0.03 to 2.43)	-0.97% (-2.30 to 0.33)	0.17% (-0.62 to 1.06)
Sri Lanka	5.78% (4.53 to 7.25)	5.15% (4.05 to 6.39)	-0.05% (-1.62 to 1.52)	-0.78% (-2.51 to 0.85)	-0.40% (-1.51 to 0.66)	12.43% (10.39 to 14.73)	13.57% (11.39 to 15.77)	0.65% (-0.45 to 1.82)	-0.06% (-1.27 to 1.15)	0.30% (-0.45 to 1.10)
Marshall Islands	2.97% (2.06 to 4.28)	4.06% (2.98 to 5.40)	0.69% (-1.97 to 3.20)	1.55% (-1.23 to 4.17)	1.10% (-0.56 to 2.76)	9.14% (7.14 to 11.51)	10.36% (8.25 to 12.63)	0.52% (-1.14 to 2.25)	0.35% (-1.19 to 1.94)	0.44% (-0.66 to 1.55)
Yemen	5.94% (4.78 to 7.28)	4.35% (3.37 to 5.43)	0.55% (-0.95 to 2.24)	-2.83% (-4.44 to -1.19)	-1.08% (-2.17 to 0.03)	14.09% (11.85 to 16.60)	10.73% (9.02 to 12.83)	0.32% (-0.83 to 1.51)	-2.30% (-3.47 to -1.13)	-0.94% (-1.72 to -0.14)
Bangladesh	27.88% (24.37 to 31.73)	25.39% (23.11 to 27.78)	0.36% (-0.57 to 1.29)	-1.04% (-1.81 to -0.25)	-0.32% (-0.92 to 0.29)	21.86% (19.04 to 24.69)	21.98% (19.91 to 24.15)	0.32% (-0.59 to 1.23)	-0.30% (-1.14 to 0.53)	0.02% (-0.53 to 0.60)
Bhutan	13.76% (11.23 to 16.58)	14.22% (11.83 to 16.67)	0.10% (-1.23 to 1.40)	0.14% (-1.23 to 1.58)	0.12% (-0.75 to 0.99)	25.87% (22.11 to 29.77)	27.15% (24.12 to 30.09)	0.13% (-0.82 to 1.15)	0.21% (-0.81 to 1.21)	0.17% (-0.45 to 0.79)
India	11.79% (9.75 to 14.18)	11.53% (10.03 to 13.14)	0.09% (-1.26 to 1.39)	-0.24% (-1.47 to 1.00)	-0.07% (-0.87 to 0.74)	27.68% (24.33 to 31.24)	25.98% (23.64 to 28.52)	0.23% (-0.70 to 1.12)	-0.69% (-1.49 to 0.14)	-0.21% (-0.76 to 0.37)
Nepal	8.63% (6.88 to 10.43)	8.21% (6.64 to 9.86)	0.11% (-1.27 to 1.54)	-0.47% (-2.00 to 0.98)	-0.17% (-1.10 to 0.79)	37.05% (32.86 to 41.48)	39.16% (36.12 to 42.41)	0.29% (-0.48 to 1.06)	0.09% (-0.63 to 0.82)	0.19% (-0.27 to 0.71)
Pakistan	5.14% (4.07 to 6.56)	4.91% (3.94 to 6.01)	-0.12% (-1.69 to 1.33)	-0.19% (-1.81 to 1.40)	-0.15% (-1.18 to 0.86)	14.35% (11.96 to 16.96)	14.03% (12.11 to 16.22)	0.10% (-0.95 to 1.25)	-0.26% (-1.55 to 1.08)	-0.07% (-0.82 to 0.70)
Madagascar	6.29% (4.72 to 8.08)	6.38% (4.91 to 7.97)	0.73% (-0.99 to 2.48)	-0.66% (-2.49 to 1.42)	0.06% (-1.21 to 1.35)	16.19% (13.58 to 19.01)	16.98% (14.66 to 19.30)	1.06% (0.04 to 2.17)	-0.79% (-1.88 to 0.37)	0.17% (-0.59 to 0.94)
Palau	18.28% (14.60 to 22.43)	24.42% (20.04 to 29.17)	0.70% (-0.97 to 2.25)	1.33% (-0.24 to 2.79)	1.00% (0.03 to 1.98)	21.32% (17.86 to 25.14)	25.76% (22.37 to 29.75)	0.43% (-0.64 to 1.54)	0.90% (-0.25 to 2.15)	0.66% (-0.05 to 1.39)

Data are given to two decimal places. Data in parentheses are 95% uncertainty intervals. Countries are ordered according to GBD super-region and region. GBD=Global Burden of Diseases, Injuries, and Risk Factors Study.

**Table: Prevalence and annualised rate of change between 1990 and 2019 of current chewing tobacco use in the 12 locations with the highest age-standardised prevalence of chewing tobacco use in either 1990 or 2019, by sex**

into the quality of the data due to conflict in this country during the study period.

Although temporal trends varied only slightly across these 12 countries, prevalence by age and sex differed much more. Globally in 2019, prevalence increased with age for females until age 80–84 years, after which it decreased, whereas for males prevalence increased up to age 35–39 years and then decreased in older age groups (appendix p 23). However, this global trend was not always reflected in the high-prevalence locations. In 2019, prevalence among males in the top 12 countries tended to decrease or flatten out in older age groups, with some countries observing peaks in prevalence in either young or

middle-aged adults—eg, prevalence peaked at 52.73% (95% UI 42.13–63.31) in males aged 40–44 years in Nepal and at 42.29% (27.90–58.09) in males aged 25–29 years in Palau (figure 2). However, some countries had a more constant prevalence across age groups—eg, in Bangladesh, prevalence among males aged 20–24 years was 15.95% (10.88–22.62) and among males aged 80–84 years was 27.23% (19.80–35.93; figure 2). Among females, prevalence often increased into older age groups. In Cambodia and Sri Lanka, prevalence of chewing tobacco use increased in each age group, with prevalences of 0.83% (0.31–1.86) in those aged 20–24 years and 35.71% (23.57–49.63) in those aged 70–74 years in Cambodia, and

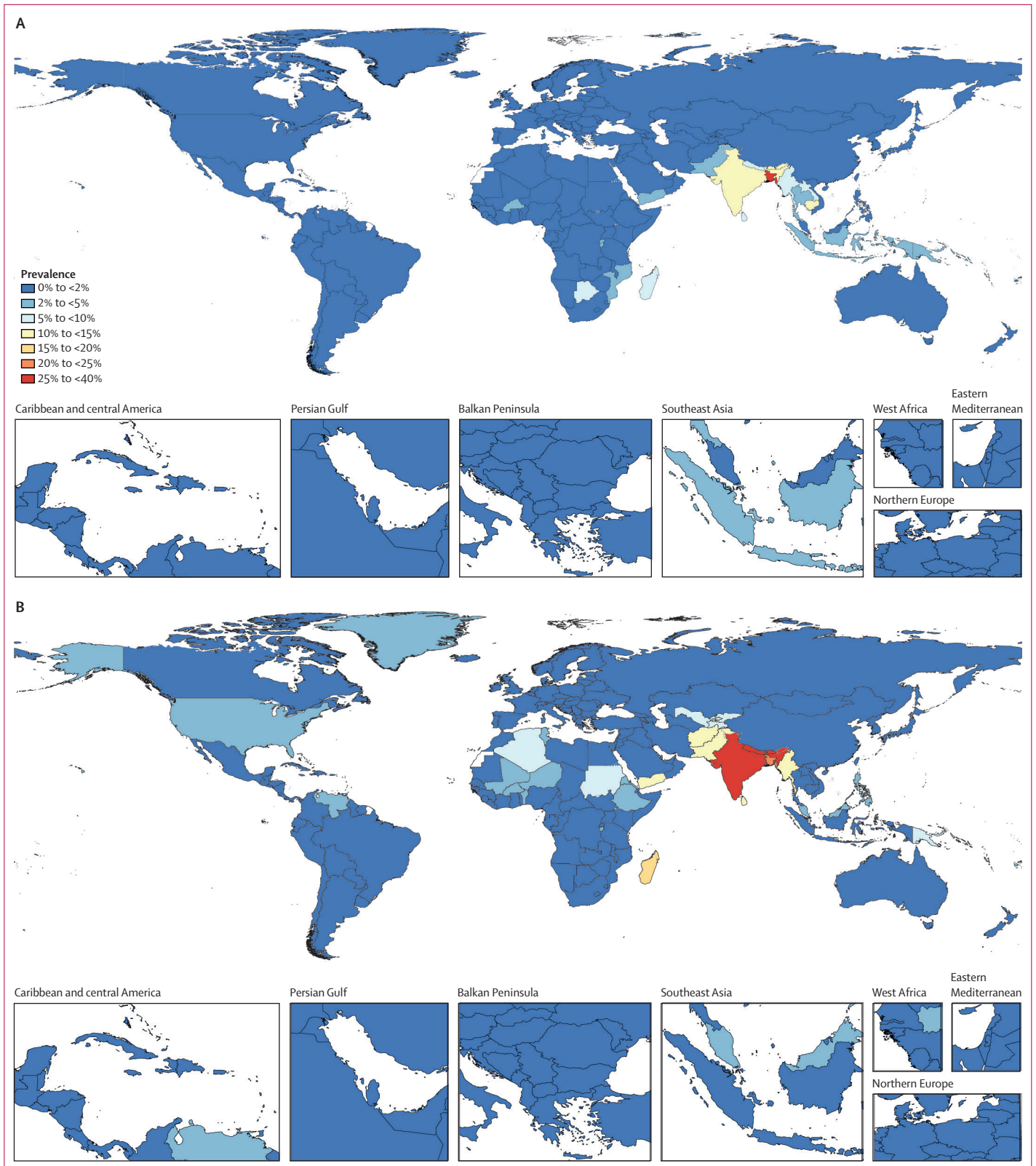
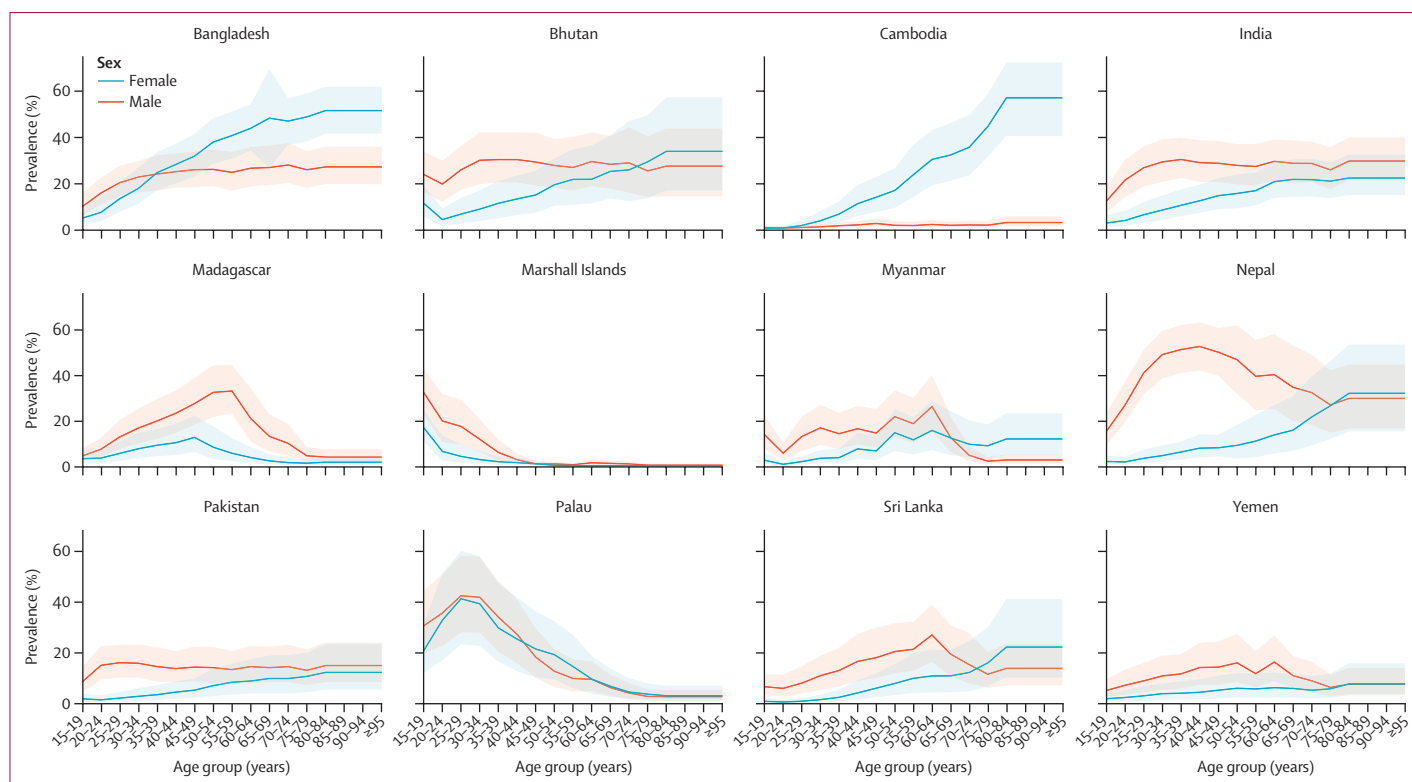


Figure 1: Age-standardised prevalence of chewing tobacco use in females (A) and males (B) aged 15 years and older, in 2019



**Figure 2:** Age-sex pattern of prevalence of chewing tobacco use in 2019 among the 12 locations with the highest age-standardised prevalence of chewing tobacco use in either 1990 or 2019, or both

The bold lines are prevalence estimates, with shaded areas indicating 95% uncertainty intervals.

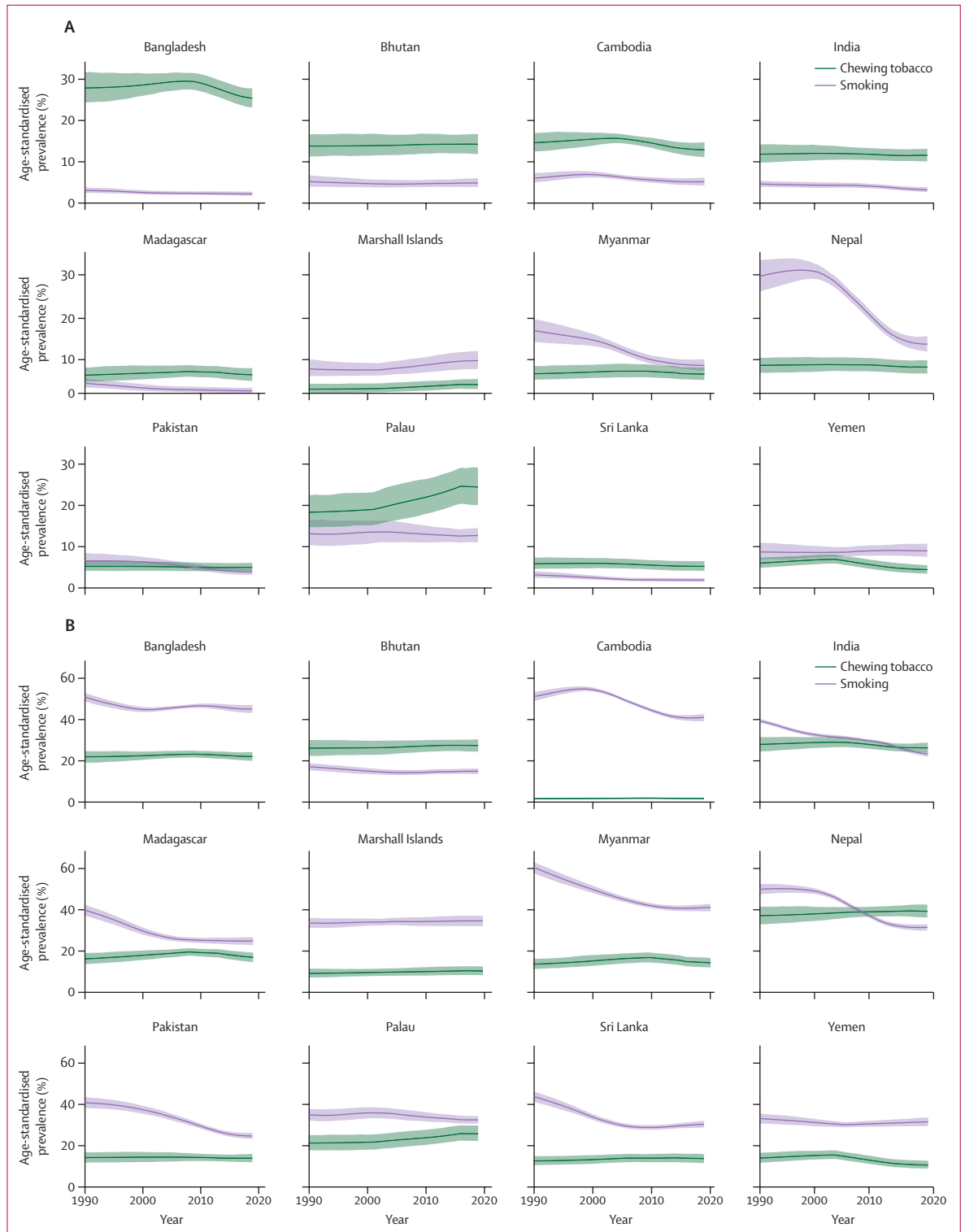
0.76% (0.29–1.66) in those aged 20–24 years, and 12.29% (4.89–24.71) in those aged 70–74 years in Sri Lanka (figure 2). Pakistan and Yemen had similar prevalences across age groups, whereas Madagascar and Palau had peaks in prevalence in females, among those aged 45–49 years in Madagascar (12.79% [6.40–22.50]) and among those aged 25–29 years in Palau (41.12% [23.31–59.80]; figure 2).

Prevalence of chewing tobacco use was often quite high at young ages. In 2019, 126 (62%) of 204 locations had higher prevalence among males aged 15–19 years than the age-standardised prevalence for males older than 19 years; among females, 135 (66%) locations had a higher prevalence among those aged 15–19 years than the age-standardised prevalence for females older than 19 years. For both sexes combined, seven locations—Marshall Islands, Federated States of Micronesia, Papua New Guinea, Bhutan, Guam, Northern Mariana Islands, and Palau—had prevalences of more than 10% in this age group (appendix pp 46–61). In 2019, south Asia and Oceania were the regions with the highest prevalence among people aged 15–19 years (figure 3; appendix p 29). Among males aged 15–19 years, the Marshall Islands had the highest prevalence of chewing tobacco use in 2019, at 32.50% (95% UI 22.82–42.74). Palau (30.55% [19.63–44.26]), Federated States of Micronesia (28.91% [19.52–39.75]),

Northern Mariana Islands (27.78% [18.02–40.14]), and Bhutan (23.97% [16.34–33.82]) comprise the other top five countries for males in this age group (appendix pp 29, 43–58). The list is similar among females; the Federated States of Micronesia had the highest prevalence (22.55% [13.68–33.76]), with Northern Mariana Islands (21.62% [12.36–34.12]), Palau (20.85% [12.24–31.53]), Marshall Islands (17.04% [10.97–24.66]), and Papua New Guinea (13.24% [7.45–20.57]) comprising the rest of the top five countries among females in this age group (appendix pp 29, 43–58).

Unlike the prevalence of chewing tobacco use, the global age-standardised prevalence of smoking decreased significantly between 1990 and 2019 (annualised rate of change: –1.21% [95% UI –1.26 to –1.16]). Among females in 2019, chewing tobacco use was more common than smoking tobacco use in eight of 12 countries, and in individuals aged 15–19 years in six of 12 countries. Similarly, among males in 2019, prevalence of chewing tobacco use was higher than smoking tobacco use in three of 12 countries and in individuals aged 15–19 years in four of 12 countries (appendix pp 24–27, 46–61).

Between 1990 and 2019, among the 12 countries with the highest prevalence of chewing tobacco use, nine had significant decreases in prevalence of smoking among males and seven had significant decreases among females



**Figure 3:** Age-standardised prevalence of chewing tobacco use versus prevalence of smoking among the 12 locations with the highest age-standardised prevalence of both-sex chewing tobacco use, in females (A) and males (B), in 1990–2019. Bold lines are prevalence estimates, with shaded areas showing the 95% uncertainty intervals.



(appendix pp 38–45). Among males in Nepal and India, the prevalence of chewing tobacco use surpassed the prevalence of smoking tobacco use in the past 5–10 years (figure 3). Among females, the difference in prevalence of chewing tobacco use versus prevalence of smoking tobacco use varied substantially by country (figure 3). For example, for females in Nepal and Myanmar, smoking prevalence decreased significantly over 1990–2019, whereas the prevalence of chewing tobacco use was stable over this period. In Madagascar and Palau, the prevalence of chewing tobacco use among females surpassed the prevalence of smoking tobacco in the past decade (figure 3).

Two countries in 2019 had a higher prevalence of chewing tobacco use than of smoking tobacco use among people aged 15–19 years. Among males in 2019, Uzbekistan had a significantly higher prevalence of chewing tobacco use than of smoking tobacco use (12.68% [95% UI 6.92–21.30] vs 1.65% [1.03–2.49]; 184995 [100912–310674] chewing tobacco users vs 24044 [14985–36351] smokers; appendix pp 46–61). Among females, Bangladesh had significantly higher prevalence of chewing tobacco use than smoking tobacco use (5.08% [2.24–10.01] vs 1.06% [0.42–2.15]; 402545 [177719–793059] chewing tobacco users vs 83927 [33649–162605] smokers; appendix pp 46–61).

We did a sensitivity analysis to compare our final model to a model that only used chewing tobacco data (no adjusted unspecified smokeless tobacco data). Overall, the correlation of the two estimates was 0.821, and on average our final model was 0.83 percentage points lower globally than when just using the chewing tobacco data. Additional comparisons are provided in the appendix (pp 28–29).

## Discussion

In 2019, 273.9 million (95% UI 258.5–290.9) people used chewing tobacco, and age-standardised prevalence for people aged 15 and older was 4.72% (4.46–5.01). 83.29% of chewing tobacco users live in south Asia, with 185.8 million chewing tobacco users residing in India. Other countries with high prevalence of chewing tobacco use include Palau, Bangladesh, and Nepal, which together had 30.1 million chewing tobacco users in 2019. A major concern emerging from our analyses is that the prevalence of chewing tobacco use has remained constant and high. Of the 12 countries with the highest prevalences of chewing tobacco use, 11 had no significant decreases in prevalence of chewing tobacco use among males, whereas nine had significant decreases in prevalence of smoking tobacco use among males, and no countries had a significant decrease in prevalence of chewing tobacco use among females, whereas seven had significant decreases in prevalence of smoking tobacco use among females. Among females in 2019, we found that use of chewing tobacco was more common than smoking in eight of the 12 highest prevalence countries for people aged 15 years and older, and among just those aged 15–19 years in six of 12 countries. Among

males, prevalence of chewing tobacco use was higher than smoking in three of 12 countries and in individuals aged 15–19 years in four of 12 countries. The serious adverse health effects resulting from chewing tobacco use<sup>11,12,15–17</sup> necessitate stronger regulations and policies than are currently in place, particularly in countries with persistently high prevalence.

Much of the previous research on the prevalence of chewing tobacco use has focused on a particular country,<sup>18–20</sup> region,<sup>3,4,21</sup> source,<sup>3,18–21</sup> time period,<sup>11,20,21</sup> or age group,<sup>5,22</sup> making formation of a comprehensive global picture of where chewing tobacco is used most, among which age groups and sexes, and how these trends have changed over time very difficult. Our study is a step towards understanding this full picture so that policy makers, public health officials, and advocacy organisations have access to a full set of comparable estimates for use in addressing this harmful substance. Additionally, our aim to combine multiple sources and definitions of smokeless tobacco use across 204 locations has highlighted data synthesis issues due to definition variations and differences in data granularity that should be addressed in future surveillance of smokeless tobacco use.

Underscoring the importance of strengthening control on use of chewing tobacco, we found that countries with high use of chewing tobacco had almost no change in prevalence between 1990 and 2019, whereas several of these locations had significant decreases in smoking prevalence during the same period. This finding is especially true among females, in whom the prevalence of chewing tobacco use was often close to, if not larger than, the prevalence of smoking. This trend in high-prevalence countries has been noted previously,<sup>27</sup> but our findings highlight this association over an extended time period and across the sexes. These findings might be due to a combination of factors, including less widespread application of the WHO FCTC articles on chewing tobacco,<sup>2,28</sup> complex cultural reasons such as wider social acceptability and beliefs about associated benefits,<sup>6–8</sup> and targeted advertising.<sup>29</sup> Cambodia stands out as a place where the prevalence of chewing tobacco use is very high among females, particularly in comparison with among males, perhaps due to a variety of different environmental and cultural reasons.<sup>30</sup> Because the prevalence of chewing tobacco use nears or surpasses the prevalence of smoking tobacco use in some countries, efforts must be intensified and the scope of tobacco control be expanded to explicitly address smokeless tobacco products.

Our findings also call attention to chewing tobacco use among adolescents, because seven countries had prevalences of more than 10% among people aged 15–19 years in 2019. Additionally, as observed among females, some locations with high chewing tobacco use among young people also had significantly higher prevalences of chewing tobacco use than of smoking tobacco use in 2019. These locations might be emerging markets for chewing tobacco, which should be reflected in how these countries enact the

FCTC articles. Initiation of use during youth, consumption, and patterns of use should also continue to be studied.

Our findings should be considered in the context of the limitations of the study. First, we did not quantify dual use of chewing tobacco and smoking, which is important to understand for both policy setting and burden implications.<sup>31</sup> Tracking and understanding dual use might be important to uncover potential issues with targeted advertising, differential cessation success, or particularly problematic adolescent use.<sup>31,32</sup> Second, our study relies on self-reported data and reporting biases might be present that vary across age groups, sexes, geographical regions, and socioeconomic statuses. The nature of these biases is not yet known, and previous studies indicate mixed scale and scope.<sup>33–35</sup> However, because we measured prevalence and not amount of chewing tobacco used, under-reporting of smokeless tobacco use is unlikely to affect these results to a large degree. Third, although we aimed to better address the main limitation of modelling the prevalence of chewing tobacco use—a combination of data sparsity and compositional bias in survey questions across locations—higher quality data would improve our estimates and ensure that the location-year-age-sex ratios we used to adjust the unspecified smokeless tobacco data are accurate. Surveys that ask about locally relevant products would aid in providing estimates that are more precise and rely less on smoothing across age, time, and location. Improved questionnaires could also allow for analyses further differentiated by smokeless tobacco subtype or local products, or both, which would be beneficial for policy making. For example, a handful of Indian states banned gutkha (chewing tobacco preparation including betel nut) in 2013, which some studies have shown might have led people to purchase other types of smokeless tobacco,<sup>8,36</sup> which cannot be captured in the current study. Additionally, both more granular data and additional data sources can help to avoid any instances where trends across age groups and over time are caused by different survey methods, although we do not believe that this limitation would substantially change our findings of this study. Future work should explore disaggregation by other subgroups beyond age and sex. For example, previous studies have shown that socioeconomic status, educational attainment, and urbanicity might affect smokeless tobacco use.<sup>3</sup> Additionally, subnational analysis will be important for future studies, because local evidence is crucial to local policy setting, and previous studies<sup>18,37</sup> have shown wide variation in the prevalence of chewing tobacco use within some countries. Specifically, an analysis of chewing tobacco use across subnational units in India should be prioritised.<sup>38,39</sup>

Chewing tobacco use continues to persist even with many countries' commitment to the WHO FCTC articles, and there is a large opportunity for policies and programmes to better target the use of these products. In the absence of stronger policies that are effectively implemented, these trends might stay the same as they

have in the past. Additionally, the popularity of these products among adolescents, especially in places where prevalence of smoking has not historically been high, indicates the potential for these products to gain users in locations that do not currently have high use of chewing tobacco. Even as countries face competing political priorities and challenges from the tobacco industry, increased expansion, implementation, and enforcement of the WHO FCTC articles for smokeless tobacco in addition to locally targeted policies is integral to stemming the chewing tobacco epidemic.

#### Contributors

Please see appendix (pp 71–75) for more detailed information about individual authors' contributions to the research, divided into the following categories: managing the estimation or publication process; writing the first draft of the manuscript; Primary responsibility for applying analytical methods to produce estimates; primary responsibility for seeking, cataloguing, extracting, or cleaning data, designing or coding figure and tables; providing data or critical feedback on data sources; developing methods or computational machinery; providing critical feedback on methods or results; drafting the work or revising it critically for important intellectual content; extracting, cleaning, or cataloguing data; designing or coding figures and tables; and managing the overall research enterprise. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication. PK and MR accessed and verified the underlying study data.

#### GBD 2019 Chewing Tobacco Collaborators

Parkes J Kendrick, Marissa B Reitsma, Mohsen Abbasi-Kangevari, Amir Abdoli, Mohammad Abdollahi, Aidin Abedi, E S Abhilash, Victor Aboyans, Oladimeji M Adebayo, Shailesh M Advani, Bright Opoku Ahinkorah, Sohail Ahmad, Keivan Ahmadi, Haroon Ahmed, Budi Aji, Yonas Akalu, Chisom Joyqueenet Akunna, Fares Alahdab, Ziyad Al-Aly, Fahad Mashhour Alanezi, Turki M Alanzi, Khalid F Alhabib, Tilahun Ali, Sheikh Mohammad Alif, Wahid Alipour, Syed Mohamed Aljunid, Mahmoud A Alomari, Tarek Tawfik Amin, Saeed Amini, Hubert Amu, Robert Ancuceanu, Jason A Anderson, Catalina Liliana Andrei, Tudorel Andrei, Alireza Ansari-Moghaddam, Benny Antony, Davood Anvari, Jalal Arabloo, Nicholas D Arrian, Monika Arora, Kurnia Dwi Artanti, Wondwossen Niguse Asmare, Desta Debalakie Atnafu, Marcel Ausloos, Asma Tahir Awan, Getinet Ayano, Getie Lake Aynalem, Samad Azari, Darshan B B, Ashish D Badiye, Atif Amin Baig, Maciej Banach, Srikanta K Banerjee, Suzanne Lyn Barker-Collo, Till Winfried Bärnighausen, Hiba Jawdat Barqawi, Sanjay Basu, Mohsen Bayati, Shahrzad Bazargan-Hejazi, Tariku Tesfaye Bekuma, Derrick A Bennett, Isabela M Bensenor, Habib Benzian, Catherine P Benziger, Adam E Berman, Akshaya Srikanth Bhagavathula, Neeraj Bhala, Nikha Bhardwaj, Pankaj Bhardwaj, Krittika Bhattacharyya, Sadia Bibi, Ali Bijani, Antonio Biondi, Dejana Braithwaite, Hermann Brenner, Andre R Brunoni, Katrin Burkart, Sharath Burugina Nagaraja, Zahid A Butt, Florentino Luciano Caetano dos Santos, Josip Car, Giulia Carreras, Joao Mauricio Castaldelli-Maia, Maria Sofia Sofia Cattaruzza, Jung-Chen Chang, Pankaj Chaturvedi, Simiao Chen, Onyema Greg Chido-Amajuoyi, Dinh-Toi Chu, Sheng-Chia Chung, Liliana G Ciobanu, Vera Marisa Costa, Rosa A S Couto, Baye Dagnew, Xiaochen Dai, Albertino Antonio Moura Damasceno, Giovanni Damiani, Lalit Dandona, Rakhi Dandona, Parnaz Daneshpajounejad, Jiregna Darega Gela, Meseret Derbew Molla, Abebaw Alemayehu Desta, Samath Dhamminda Dharmaratne, Meghnath Dhimal, Arielle Wilder Eagan, Mohammad Ebrahimi Kalan, Kristina Edvardsson, Andem Effiong, Maha El Tantawi, Iffat Elbarazi, Saman Esmailnejad, Ibtihal Fadhil, Emerito Jose A Faraon, Medhat Farwati, Farshad Farzadfar, Mehdi Fazlzadeh, Valery L Feigin, Rachel Feldman, Irina Filip, Filippos Filippidis, Florian Fischer, Luisa Sorio Flor, Nataliya A Foigt, Morenike Oluwatoyin Folayan, Masoud Foroutan, Mohamed M Gad, Silvano Gallus, Biniyam Sahiledengle Geberemariam,

Birhan Gebresillasse Gebregiorgis, Lemma Getacher, Abera Getachew Obsa, Mansour Ghafourifard, Reza Ghanei Gheshlagh, Ahmad Ghashghaee, Nermin Ghith, Gabriela Fernanda Gil, Paramjit Singh Gill, Ibrahim Abdelmageed Ginawi, Salime Goharinezhad, Mahaveer Golechha, Sameer Vali Gopalani, Giuseppe Gorini, Michal Grivna, Avirup Guha, Rafael Alves Guimarães, Yuming Guo, Rajat Das Gupta, Rajeev Gupta, Tarun Gupta, Vin Gupta, Nima Hafezi-Nejad, Mohammad Rifat Haider, Randah R Hamadeh, Graeme J Hankey, Arief Hargono, Simon I Hay, Golnaz Heidari, Claudiu Herteliu, Kamal Hezam, Thomas R Hird, Ramesh Holla, Mehdi Hosseinzadeh, Mihaela Hostiu, Sorin Hostiu, Mowafa Househ, Thomas Hsiao, Junjie Huang, Charles Ugochukwu Ibeneme, Segun Emmanuel Ibitoye, Irena M Ilic, Milena D Ilic, Leebek Raja Inbaraj, Seyed Sina Naghibi Irvani, Jessica Y Islam, Rakibul M Islam, Sheikh Mohammed Shariful Islam, Farhad Islami, Hiroyasu Iso, Ramaiah Itumalla, Jalil Jaafari, Vardhmaan Jain, Mihajlo Jakovljevic, Sung-In Jang, Shubha Jayaram, Panniyammakal Jeemon, Ravi Prakas Jha, Jost B Jonas, Mikko Jürisson, Ali Kabir, Zubair Kabir, Leila R Kalankesh, Tanuj Kanchan, Himal Kandel, Neeti Kapoor, André Karch, Salah Eddin Karimi, Kindie Mitiku Kebede, Bayew Kelkay, Ryan David Kennedy, Yousef Saleh Khader, Ejaz Ahmad Khan, Maryam Khayamzadeh, Gyu Ri Kim, Ruth W Kimokoti, Mika Kivimäki, Soewarta Kosen, Sindhura Lakshmi Koulmane Laxminarayana, Ai Koyanagi, Kewal Krishan, Nuworza Kugbey, G Anil Kumar, Nithin Kumar, Om P Kurmi, Dian Kusuma, Ben Lacey, Iván Landires, Savita Lasrado, Paolo Lauriola, Doo Woong Lee, Yo Han Lee, Janni Leung, Shanshan Li, Hualiang Lin, Wei Liu, Alessandra Lugo, Shilpashree Madhava Kunjathur, Azeem Majeed, Afshin Maleki, Reza Malekzadeh, Deborah Carvalho Malta, Abdullah A Mamun, Narayana Manjunatha, Borhan Mansouri, Mohammad Ali Mansournia, Santi Martini, Manu Raj Mathur, Prashant Mathur, Mohsen Mazidi, Martin McKee, Carlo Eduardo Medina-Solís, Suresh Mehata, Walter Mendoza, Ritesh G Menezes, Bartosz Miazgowski, Irmina Maria Michalek, Ted R Miller, GK Mini, Andreea Mirica, Erkin M Mirrakhimov, Hamed Mirzaei, Sanjeev Misra, Yousef Mohammad, Abdollah Mohammadian-Hafshejani, Shafiu Mohammed, Ali H Mokdad, Mariam Molokhia, Lorenzo Monasta, Mohammad Ali Moni, Rahmatollah Moradzadeh, Shane Douglas Morrison, Tilahun Belete Mossie, Sumaira Mubarik, Erin C Mullany, Christopher J L Murray, Shankar Prasad Nagaraju, Mohsen Naghavi, Nitish Naik, Mahdi Nalini, Vinay Nangia, Atta Abbas Naqvi, Sreenivas Narasimha Swamy, Muhammad Naveed, Javad Nazari, Sabina O Nduaguba, Ruxandra Irina Negoii, Sandhya Neupane Kandel, Huong Lan Thi Nguyen, Yeshambel T Nigatu, Molly R Nixon, Chukwudi A Nnaji, Jean Jacques Noubiap, Christoph Nowak, Virginia Nuñez-Samudio, Felix Akpojene Ogbo, Ayodipupo Sikiru Oguntade, In-Hwan Oh, Andrew T Olagunju, Mayowa O Owolabi, Mahesh P A, Keyvan Pakshir, Adrian Pana, Demosthenes Panagiotakos, Songhomitra Panda-Jonas, Ashok Pandey, Utsav Parekh, Eun-Cheol Park, Eun-Kee Park, Fatemeh Pashazadeh Kan, Mona Pathak, Shrikant Pawar, Richard G Pestell, Hai Quang Pham, Marina Pinheiro, Khem Narayan Pokhrel, Akram Pourshams, Akila Prashant, Amir Radfar, Vafa Rahimi-Movaghar, Mohammad Hifz Ur Rahman, Muhammad Aziz Rahman, Amir Masoud Rahmani, Pradhun Ram, Jewel Rana, Chhabi Lal Ranabhat, Priya Rathi, David Laith Rawaf, Salman Rawaf, Reza Rawassizadeh, Andre M N Renzaho, Aziz Rezapour, Mavra A Riaz, Leonardo Roever, Luca Ronfani, Gholamreza Roshandel, Ambuj Roy, Bedanta Roy, Basema Saddik, Amirhossein Sahebkar, Sana Salehi, Hamideh Salimzadeh, Abdallah M Samy, Juan Sanabria, Milena M Santric-Milicevic, Bruno Piassi Sao Jose, Brijesh Sathian, Monika Sawhney, Ganesh Kumar Saya, Falk Schwendicke, Abdul-Aziz Seidu, Nachimuthu Senthil Kumar, Sadaf G Sepanlou, Omid Shafaat, Syed Mahboob Shah, Masood Ali Shaikh, Mohammed Shannawaz, Kiomars Sharafi, Aziz Sheikh, Sara Sheikhhahaei, Mika Shigematsu, Rahman Shiri, Kawkab Shishani, K M Shivakumar, Siddharudha Shivalli, Roman Shrestha, Soraya Siabani, Negussie Boti Sidemo, Inga Dora Sigfusdottir, Rannveig Sigurvinisdottir, João Pedro Silva, Ambrish Singh, Jasvinder A Singh, Virendra Singh, Dharendra Narain Sinha, Valentin Yurievich Skryabin, Anna Aleksandrovna Skryabina, Ali Soroush, Ireneous N Soyiri, Chandrashekhar T Sreeramareddy, Dan J Stein, Paschalis Steiropoulos, Stefan Stortecky, Kurt Straif, Rizwan Suliankatchi Abdulkader, Gerhard Sulo, Johan Sundström, Takahiro Tabuchi, Eyayou Girma Tadesse, Anmut Tagele Tamiru, Minale Tareke, Md Ismail Tareque, Ingan Ukur Tarigan, Bhaskar Thakur, Kavumpurathu Raman Thankappan, Rekha Thapar, Musliu Adetola Tolani, Marcos Roberto Tovani-Palone, Bach Xuan Tran, Jaya Prasad Tripathy, Gebiyaw Wudie Tsegaye, Hayley D Tymeson, Saif Ullah, Brigid Unim, Rachel L Updike, Olalekan A Uthman, Marco Vacante, Constantine Vardavas, Narayanaswamy Venketasubramanian, Madhur Verma, Simone Vidale, Bay Vo, Giang Thu Vu, Yasir Waheed, Yanzhong Wang, Kevin Welding, Andrea Werdecker, Joanna L Whisnant, Nuwan Darshana Wickramasinghe, Befikadu Legesse Wubishet, Kazumasa Yamagishi, Yuichiro Yano, Vahid Yazdi-Feyzabadi, Yigizie Yeshaw, Mohammed Zewdu Yimmer, Naohiro Yonemoto, Zabihollah Yousefi, Chuanhua Yu, Ismael Yunusa, Hasan Yusefzadeh, Muhammed Shahriar Zaman, Mohammad Zamani, Maryam Zamanian, Mikhail Sergeevich Zastrozhin, Anastasia Zastrozhina, Jianrong Zhang, Zhi-Jiang Zhang, Chenwen Zhong, Yves Miel H Zuniga, Emmanuela Gakidou.

**Affiliations**  
 Institute for Health Metrics and Evaluation (P J Kendrick BS, M B Reitsma BS, J A Anderson BS, N D Arian BA, K Burkart PhD, X Dai PhD, Prof L Dandona MD, Prof R Dandona PhD, Prof S D Dharmaratne MD, Prof V L Feigin PhD, R Feldman BS, G F Gil BA, V Gupta MD, Prof S I Hay FMedSci, T Hsiao BS, Prof A H Mokdad PhD, E C Mullany BA, Prof C J L Murray DPhil, Prof M Naghavi MD, M R Nixon PhD, H D Tymeson BA, R L Updike MPH, J L Whisnant MPH, Prof E Gakidou PhD), Department of Health Metrics Sciences, School of Medicine (K Burkart PhD, Prof R Dandona PhD, Prof S D Dharmaratne MD, V Gupta MD, Prof S I Hay FMedSci, Prof A H Mokdad PhD, Prof C J L Murray DPhil, Prof M Naghavi MD, Prof E Gakidou PhD), University of Washington, Seattle, WA, USA; Social Determinants of Health Research Center (M Abbasi-Kangevari MD), Shahid Beheshti University of Medical Sciences, Tehran, Iran (M Khayamzadeh MD); Department of Parasitology and Mycology (A Abdoli PhD), Jahrom University of Medical Sciences, Jahrom, Iran; The Institute of Pharmaceutical Sciences (TIPS) (Prof M Abdollahi PhD), School of Pharmacy (Prof M Abdollahi PhD), Non-communicable Diseases Research Center (Prof F Farzadfar DSc), Department of Environmental Health Engineering (M Fazlzadeh PhD, Prof A Maleki PhD), School of Medicine (N Hafezi-Nejad MD), Digestive Diseases Research Institute (Prof R Malekzadeh MD, M Nalini MD, Prof A Pourshams MD, H Salimzadeh PhD, S G Sepanlou MD), Department of Epidemiology and Biostatistics (M Mansournia PhD), Sina Trauma and Surgery Research Center (Prof V Rahimi-Movaghar MD), Tehran University of Medical Sciences, Tehran, Iran; Department of Orthopaedic Surgery (A Abedi MD), Department of Radiology (S Salehi MD), University of Southern California, Los Angeles, CA, USA; Department of Botany (E S Abhilash PhD), Sree Narayana Guru College Chelannur, Kozhikode, India; Department of Cardiology (Prof V Aboyans MD), Dupuytren University Hospital, Limoges, France; University of Limoges, Limoges, France (Prof V Aboyans MD); College of Medicine (O M Adebayo MD), Department of Medicine (A S Oguntade MSc, Prof M O Owolabi DrM), University College Hospital, Ibadan, Ibadan, Nigeria; Social Behavioral Research Branch (S M Advani PhD), National Institute of Health, Bethesda, MD, USA; Department of Oncology (S M Advani PhD), Georgetown University, Washington, DC, USA; The Australian Centre for Public and Population Health Research (ACPPHR) (B O Ahinkorah MPH), School of Health (S Siabani PhD), University of Technology Sydney, Sydney, NSW, Australia; Faculty of Pharmacy (S Ahmad MSc), MAHSA University, Kuala Langat, Malaysia; Lincoln Medical School (K Ahmadi PhD), Universities of Nottingham & Lincoln, Lincoln, UK; Department of Biosciences (H Ahmed PhD), COMSATS Institute of Information Technology, Islamabad, Pakistan; Faculty of Medicine and Public Health (B Aji DrPH), Jenderal Soedirman University, Purwokerto, Indonesia; Department of Medical Physiology (Y Akalu MSc), Department of Clinical Midwifery (G L Aynalem MSc),

Department of Human Physiology (B Dagnew MSc), Department of Biochemistry (M Derbew Molla MSc), Department of Surgical Nursing (A A Desta MSc), Department of Midwifery (B Kelkay MSc, A T Tamiru MSc), Department of Epidemiology and Biostatistics (Y Yeshaw MPH), University of Gondar, Gondar, Ethiopia; Department of Public Health (C J Akunna DMD), The Intercountry Centre for Oral Health (ICOH) for Africa, Jos, Nigeria; Department of Public Health (C J Akunna DMD), Federal Ministry of Health, Garki, Nigeria; Mayo Evidence-based Practice Center (F Alahdab MSc), Mayo Clinic Foundation for Medical Education and Research, Rochester, MN, USA; John T Milliken Department of Internal Medicine (Z Al-Aly MD), Washington University in St Louis, St Louis, MO, USA; Clinical Epidemiology Center (Z Al-Aly MD), Department of Veterans Affairs, St Louis, MO, USA; Health Information Management and Technology Department (T M Alanzi PhD), Forensic Medicine Division (Prof R G Menezes MD), Pharmacy Practice Department (A Naqvi PhD), Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia (F M Alanezi PhD); Department of Cardiac Sciences (Prof K F Alhabib MD), Department of Internal Medicine (Y Mohammad MD), King Saud University, Riyadh, Saudi Arabia; Department of Psychiatry (T Ali MSc), Haramaya University, Harar, Ethiopia; Department of Epidemiology and Preventive Medicine (S M Alif PhD, Prof Y Guo PhD, R M Islam PhD), School of Public Health and Preventive Medicine (S Li PhD), Monash University, Melbourne, VIC, Australia; Health Management and Economics Research Center (V Alipour PhD, J Arabloo PhD, S Azari PhD, A Ghashghaee BSc, M Hosseinzadeh PhD, A Rezapour PhD), Department of Health Economics (V Alipour PhD), Student Research Committee (A Ghashghaee BSc), Preventive Medicine and Public Health Research Center (S Goharinezhad PhD), Minimally Invasive Surgery Research Center (A Kabir MD), Iran University of Medical Sciences, Tehran, Iran (F Pashazadeh Kan BSN); Department of Health Policy and Management (Prof S M Aljunid PhD), Kuwait University, Safat, Kuwait; International Centre for Casemix and Clinical Coding (Prof S M Aljunid PhD), National University of Malaysia, Bandar Tun Razak, Malaysia; Department of Physical Education (Prof M A Alomari PhD), Qatar University, Doha, Qatar; Department of Rehabilitation Sciences and Physical Therapy (Prof M A Alomari PhD), Department of Public Health (Prof Y S Khader PhD), Jordan University of Science and Technology, Irbid, Jordan; Public Health Department (Prof T T Amin MD), Cairo University, Cairo, Egypt; Department of Health Services Management (S Amini PhD), Department of Epidemiology (R Moradzadeh PhD, M Zamanian PhD), Department of Pediatrics (J Nazari MD), Arak University of Medical Sciences, Arak, Iran; Department of Population and Behavioural Sciences (H Amu PhD), University of Health and Allied Sciences, Ho, Ghana; Pharmacy Department (Prof R Ancuceanu PhD), Cardiology Department (C Andrei PhD), Internal Medicine Department (M Hostiu PhD), Department of Legal Medicine and Bioethics (S Hostiu PhD), Department of Anatomy and Embryology (R I Negoii PhD), Carol Davila University of Medicine and Pharmacy, Bucharest, Romania; Department of Statistics and Econometrics (Prof T Andrei PhD, Prof M Ausloos PhD, Prof C Herteliu PhD, A Mirica PhD, A Pana MD), Bucharest University of Economic Studies, Bucharest, Romania; Department of Epidemiology and Biostatistics (Prof A Ansari-Moghaddam PhD), Zahedan University of Medical Sciences, Zahedan, Iran; Menzies Institute for Medical Research (B Antony PhD, A Singh MTech), University of Tasmania, Hobart, TAS, Australia; Department of Parasitology (D Anvari PhD), Department of Environmental Health (Prof Z Yousefi PhD), Mazandaran University of Medical Sciences, Sari, Iran; Department of Parasitology (D Anvari PhD), Iranshahr University of Medical Sciences, Iranshahr, Iran; Health Promotion Division (M Arora PhD), Health Policy Research (M R Mathur PhD), Public Health Foundation of India, Gurugram, India (Prof L Dandona MD, Prof R Dandona PhD, G Kumar PhD); Research Department (M Arora PhD), Health Related Information Dissemination Amongst Youth, New Delhi, India; Department of Epidemiology (K D Artanti MSc, A Hargono Drg), Faculty of Public Health (S Martini PhD), Universitas Airlangga (Airlangga University), Surabaya, Indonesia; Department of Nursing (W N Asmare MSc), Department of Public Health (K M Kebede MPH), Mizan-Tepi University, Mizan Teferi, Ethiopia; Department of Health System and Health Economics (D D Atnafu MPH), Department of Psychiatry (T B Mossie MSc, M Tareke MSc), College of Medicine and Health Sciences (G W Tsegaye MPH), Bahir Dar University, Bahir Dar, Ethiopia; School of Business (Prof M Ausloos PhD), University of Leicester, Leicester, UK; School of Nursing and Health Sciences (A T Awan DrPH), Capella University, Minneapolis, MN, USA; Grant Writing Academy (A T Awan DrPH), University of Nevada, Las Vegas, NV, USA; School of Public Health (G Ayano MSc, T R Miller PhD), Curtin University, Perth, WA, Australia; Kasturba Medical College, Mangalore (D B B MD, R Holla MD, P Rathi MD), Department of Nephrology (Prof S Nagaraju DM), Manipal Academy of Higher Education, Manipal, India; Department of Forensic Science (A D Badiye MSc, N Kapoor MSc), Government Institute of Forensic Science, Nagpur, India; Unit of Biochemistry (A A Baig PhD), Faculty of Business and Management (M A Riaz MCom), Universiti Sultan Zainal Abidin (Sultan Zainal Abidin University), Kuala Terengganu, Malaysia; Department of Hypertension (Prof M Banach PhD), Medical University of Lodz, Lodz, Poland; Polish Mothers' Memorial Hospital Research Institute, Lodz, Poland (Prof M Banach PhD); School of Health Sciences (Prof S K Banerjee PhD), Walden University, Minneapolis, MN, USA; School of Psychology (Prof S L Barker-Collo PhD), University of Auckland, Auckland, New Zealand; Heidelberg Institute of Global Health (HIGH) (Prof T W Bärnighausen MD, S Chen DSc, S Mohammed PhD), Department of Ophthalmology (Prof J B Jonas MD, S Panda-Jonas MD), Heidelberg University, Heidelberg, Germany; Harvard T H Chan School of Public Health (Prof T W Bärnighausen MD, I Yunusa PhD), Center for Primary Care (S Basu PhD), Department of Global Health and Social Medicine (A W Eagan MSW), Division of General Internal Medicine (Prof A Sheikh MD), Harvard University, Boston, MA, USA; Department of Clinical Sciences (H J Barqawi MPhil), Department of Family and Community Medicine (B Saddik PhD), University of Sharjah, Sharjah, United Arab Emirates; School of Public Health (S Basu PhD, F Filipidis PhD), Department of Primary Care and Public Health (J Car Phd, Prof A Majeed MD, Prof S Rawaf MD), Imperial College Business School (D Kusuma DSc), WHO Collaborating Centre for Public Health Education and Training (D L Rawaf MD), Imperial College London, London, UK; Health Human Resources Research Center (M Bayati PhD), Non-communicable Disease Research Center (Prof R Malekzadeh MD, S G Sepanlou MD), Department of Parasitology and Mycology (Prof K Pakshir PhD), Shiraz University of Medical Sciences, Shiraz, Iran; Department of Psychiatry (Prof S Bazargan-Hejazi BEP), Charles R Drew University of Medicine and Science, Los Angeles, CA, USA; Department of Psychiatry and Biobehavioral Sciences (Prof S Bazargan-Hejazi BEP), University of California Los Angeles, Los Angeles, CA, USA; Department of Public Health (T T Bekuma MPH), Wollega University, Nekemte, Ethiopia; Nuffield Department of Population Health (D A Bennett PhD, B Lacey PhD), University of Oxford, Oxford, UK; Department of Internal Medicine (I M Bensenor PhD, Prof A R Brunoni PhD), Department of Psychiatry (Prof A R Brunoni PhD, Prof J Castaldelli-Maia PhD), University of São Paulo, São Paulo, Brazil; Department of Epidemiology and Health Promotion (Prof H Benzian PhD), New York University, New York, NY, USA; Heart and Vascular Center (C P Benziger MD), Essentia Health, Duluth, MN, USA; Department of Medicine (A E Berman MD), Medical College of Georgia at Augusta University, Augusta, GA, USA; Department of Social and Clinical Pharmacy (A S Bhagavathula PharmD), Charles University, Hradec Kralova, Czech Republic; Institute of Public Health (A S Bhagavathula PharmD, I Elbarazi DrPH, Prof M Grivna PhD, Prof S M Shah PhD), United Arab Emirates University, Al Ain, United Arab Emirates; Institute of Applied Health Research and Translational Medicine (N Bhala PhD), Queen Elizabeth Hospital Birmingham, Birmingham, UK; Institute of Applied Health Research (N Bhala PhD), University of Birmingham, Birmingham, UK; Department of Anatomy (Prof N Bhardwaj MD), Government Medical College Pali, Pali, India; Department of Community Medicine and Family Medicine (P Bhardwaj MD), School of Public Health (P Bhardwaj MD), Department of Forensic Medicine and Toxicology (T Kanchan MD), Department of Surgical Oncology (Prof S Misra MCh), All India Institute of Medical Sciences, Jodhpur, India; Department of Statistical and Computational Genomics

(K Bhattacharyya MSc), National Institute of Biomedical Genomics, Kalyani, India; Department of Statistics (K Bhattacharyya MSc), University of Calcutta, Kolkata, India; Institute of Soil and Environmental Sciences (S Bibi PhD, S Ullah PhD), University of Agriculture, Faisalabad, Faisalabad, Pakistan; Social Determinants of Health Research Center (A Bijani PhD), Student Research Committee (M Zamani MD), Babol University of Medical Sciences, Babol, Iran; Department of General Surgery and Medical-Surgical Specialties (Prof A Biondi PhD, M Vacante PhD), University of Catania, Catania, Italy; Department of Epidemiology (D Braithwaite PhD), Department of Pharmaceutical Outcomes and Policy (S O Nduaguba PhD), University of Florida, Gainesville, FL, USA; Cancer Population Sciences Program (D Braithwaite PhD), University of Florida Health Cancer Center, Gainesville, FL, USA; Division of Clinical Epidemiology and Aging Research (Prof H Brenner MD), German Cancer Research Center, Heidelberg, Germany; Department of Community Medicine (Prof S Burugina Nagaraja MD), Employee State Insurance Post Graduate Institute of Medical Sciences and Research, Bangalore, India; School of Public Health and Health Systems (Z A Butt PhD), University of Waterloo, Waterloo, ON, Canada; Al Shifa School of Public Health (Z A Butt PhD), Al Shifa Trust Eye Hospital, Rawalpindi, Pakistan; Institute of Microengineering (F Caetano dos Santos PhD), Federal Polytechnic School of Lausanne, Lausanne, Switzerland; Centre for Population Health Sciences (J Car PhD), Nanyang Technological University, Singapore, Singapore; Oncological Network, Prevention and Research Institute (G Gorini MD), Institute for Cancer Research, Prevention and Clinical Network, Florence, Italy (G Carreras PhD); Department of Public Health and Infectious Diseases (M S Cattaruzza PhD), La Sapienza University, Rome, Italy; College of Medicine (J Chang PhD), National Taiwan University, Taipei, Taiwan; Department of Nursing (J Chang PhD), National Taiwan University Hospital, Taipei, Taiwan; Center for Cancer Epidemiology (Prof P Chaturvedi MD), Department of Head & Neck Surgery (Prof P Chaturvedi MD), Tata Memorial Hospital, Mumbai, India; Department of Epidemiology (O G Chido-Amajuoyi MD), MD Anderson Cancer Center, Houston, TX, USA; Center for Biomedicine and Community Health (D Chu PhD), VNU-International School, Hanoi, Vietnam; Department of Health Informatics (S Chung PhD), Department of Epidemiology and Public Health (Prof M Kivimäki PhD), Institute of Cardiovascular Science (A S Oguntade MSc), University College London, London, UK; Health Data Research UK, London, UK (S Chung PhD); Adelaide Medical School (L G Ciobanu PhD), Centre for Heart Rhythm Disorders (J Noubiap MD), University of Adelaide, Adelaide, SA, Australia; School of Pharmacy and Medical Sciences (L G Ciobanu PhD), University of South Australia, Adelaide, SA, Australia; Research Unit on Applied Molecular Biosciences (UCIBIO) (V M Costa PhD, J P Silva PhD), Department of Chemical Sciences (R A S Couto MD), Department of Chemistry (M Pinheiro PhD), University of Porto, Porto, Portugal; Faculty of Medicine (Prof A A M Damasceno PhD), Eduardo Mondlane University, Maputo, Mozambique; IRCCS Istituto Ortopedico Galeazzi (Galeazzi Orthopedic Institute IRCCS) (G Damiani MD), University of Milan, Milan, Italy; Department of Dermatology (G Damiani MD), Harrington Heart and Vascular Institute (A Guha MD), Department of Nutrition and Preventive Medicine (Prof J Sanabria MD), Case Western Reserve University, Cleveland, OH, USA; Indian Council of Medical Research, New Delhi, India (Prof L Dandona MD); Department of Pathology (P Daneshpajouhnejad MD), Johns Hopkins University School of Medicine, Baltimore, MD, USA; Department of Pathology (P Daneshpajouhnejad MD), Department of Radiology and Interventional Neuroradiology (O Shafaat MD), Isfahan University of Medical Sciences, Isfahan, Iran; Department of Public Health (J Darga Gela MPH), Ambo University, Ambo, Ethiopia; Department of Community Medicine (Prof S D Dharmaratne MD), University of Peradeniya, Peradeniya, Sri Lanka; Health Research Section (M Dhimal PhD), Research Department (A Pandey MPH), Nepal Health Research Council, Kathmandu, Nepal; Department of Social Services (A W Eagan MSW), Tufts Medical Center, Boston, MA, USA; Department of Epidemiology (M Ebrahimi Kalan MSc), Florida International University, Miami, FL, USA; College of Science, Health and Engineering (K Edvardsson PhD), School of Nursing and Midwifery (M Rahman PhD), La Trobe University, Melbourne, VIC, Australia;

Centre for Clinical Epidemiology and Biostatistics (A Effiong MB), Research Centre for Generational Health and Ageing (B Wubishet MPH), University of Newcastle, Newcastle, NSW, Australia; Pediatric Dentistry and Dental Public Health Department (Prof M El Tantawi PhD), Alexandria University, Alexandria, Egypt; Department of Physiology (S Esmaeilnejad PhD), Tarbiat Modares University, Tehran, Iran; Tehran Medical Sciences Branch (S Esmaeilnejad PhD), Islamic Azad University, Tehran, Iran; Division of Non-Communicable Diseases (I Fadhil PhD), Ministry of Public Health and Population, Dubai, United Arab Emirates; Department of Health Policy and Administration (E A Faraon MD), University of the Philippines Manila, Manila, Philippines; Department of Internal Medicine (M Farwati MD, V Jain MD), Department of Cardiovascular Medicine (M M Gad MD), Cleveland Clinic, Cleveland, OH, USA; Department of Cardiovascular Medicine (M Farwati MD), Mayo Clinic, Rochester, MN, USA; Department of Environmental Health Engineering (M Fazlzadeh PhD), Ardabil University of Medical Science, Ardabil, Iran; National Institute for Stroke and Applied Neurosciences (Prof V L Feigin PhD), Auckland University of Technology, Auckland, New Zealand; Research Center of Neurology, Moscow, Russia (Prof V L Feigin PhD); Psychiatry Department (I Filip MD), Kaiser Permanente, Fontana, CA, USA; School of Health Sciences (I Filip MD), AT Still University, Mesa, AZ, USA; Institute of Gerontological Health Services and Nursing Research (F Fischer PhD), Ravensburg-Weingarten University of Applied Sciences, Weingarten, Germany; Sergio Arouca National School of Public Health, Rio de Janeiro, Brazil (L S Flor MPH); Federal University of Espirito Santo, Vitória, Brazil (L S Flor MPH); Institute of Gerontology (N A Foigt PhD), National Academy of Medical Sciences of Ukraine, Kyiv, Ukraine; Department of Child Dental Health (Prof M O Folayan FWACS), Obafemi Awolowo University, Ile-Ife, Nigeria; Department of Medical Parasitology (M Foroutan PhD), Abadan Faculty of Medical Sciences, Abadan, Iran; Gillings School of Global Public Health (M M Gad MD), Department of Epidemiology (J Y Islam PhD), University of North Carolina Chapel Hill, Chapel Hill, NC, USA; Department of Environmental Health Sciences (S Gallus DSc, A Lugo PhD), Mario Negri Institute for Pharmacological Research, Milan, Italy; Department of Public Health (B S Geberemariam MPH), Madda Walabu University, Bale Robe, Ethiopia; Department of Nursing (B G Gebregiorgis MSc), Department of Public Health (L Getacher MPH), Debre Berhan University, Debre Berhan, Ethiopia; School of Psychology (A Getachew Obsa MA), Addis Ababa University, Addis Ababa, Ethiopia; Department of Medical Surgical Nursing (M Ghafourifard PhD), School of Management and Medical Informatics (L R Kalankesh PhD), Social Determinants of Health Research Center (S Karimi PhD), Tabriz University of Medical Sciences, Tabriz, Iran; Faculty of Nursing and Midwifery (R Ghanei Gheshlagh PhD), Environmental Health Research Center (Prof A Maleki PhD), Kurdistan University of Medical Sciences, Sanandaj, Iran; Research Group for Genomic Epidemiology (N Ghith PhD), Technical University of Denmark, Copenhagen, Denmark; Medical School (Prof P S Gill DM), Division of Health Sciences (O A Uthman PhD), University of Warwick, Coventry, UK; Family Medicine Research Center (Prof I A Ginawi MD), Ministry of Health, Hail, Saudi Arabia; Health Systems and Policy Research (M Golechha PhD), Indian Institute of Public Health Gandhinagar, Gandhinagar, India; Hudson College of Public Health (S V Gopalani MPH), University of Oklahoma Health Sciences Center, Oklahoma City, OK, USA; Department of Health and Social Affairs (S V Gopalani MPH), Government of the Federated States of Micronesia, Palikir, Federated States of Micronesia; Department of Public Health and Preventive Medicine (Prof M Grivna PhD), Charles University, Prague, Czech Republic; Division of Cardiovascular Medicine (A Guha MD), Ohio State University, Columbus, OH, USA; Institute of Tropical Pathology and Public Health (IPTSP) (R A Guimarães MSc), Federal University of Goias, Goiânia, Brazil; Department of Epidemiology (Prof Y Guo PhD), Binzhou Medical University, Yantai City, China; Department of Epidemiology and Biostatistics (R Gupta MPH), Department of Clinical Pharmacy and Outcomes Sciences (I Yunusa PhD), University of South Carolina, Columbia, SC, USA; Centre for Noncommunicable Diseases and Nutrition (R Gupta MPH), BRAC University, Dhaka, Bangladesh;

Department of Preventive Cardiology (Prof R Gupta MD), Eternal Heart Care Centre & Research Institute, Jaipur, India; Department of Medicine (Prof R Gupta MD), Mahatma Gandhi University Medical Sciences, Jaipur, India; Department of Civil Engineering (Prof T Gupta DSc), Indian Institute of Technology Kanpur, Kanpur, India; Department of Radiology and Radiological Science (N Hafezi-Nejad MD, O Shafaat MD, S Sheikhabaehi MD), Institute for Global Tobacco Control (K Welding PhD), Johns Hopkins University, Baltimore, MD, USA; Department of Social and Public Health (M Haider PhD), Ohio University, Athens, OH, USA; Department of Family and Community Medicine (Prof R R Hamadeh PhD), Arabian Gulf University, Manama, Bahrain; Medical School (Prof G J Hankey MD), University of Western Australia, Perth, WA, Australia; Department of Neurology (Prof G J Hankey MD), Sir Charles Gairdner Hospital, Perth, WA, Australia; Independent Consultant, Santa Clara, CA, USA (G Heidari MD); School of Business (Prof C Herteliu PhD), London South Bank University, London, UK; Department of Applied Microbiology (K Hezam PhD), Taiz University, Taiz, Yemen; Department of Microbiology (K Hezam PhD), Nankai University, Tianjin, China; Department for Health (T R Hird PhD), University of Bath, Bath, UK; Clinical Legal Medicine Department (S Hostiu PhD), National Institute of Legal Medicine Mina Minovici, Bucharest, Romania; College of Science and Engineering (Prof M Househ PhD), Hamad Bin Khalifa University, Doha, Qatar; Jockey Club School of Public Health and Primary Care (J Huang MD, C Zhong MD), The Chinese University of Hong Kong, Hong Kong, China; Department of Public Health and Disease Control (C U Ibeneme MPH), Ministry of Health, Umuahia, Nigeria; Nigerian Field Epidemiology and Laboratory Training Program (C U Ibeneme MPH), African Field Epidemiology Network, Abuja, Nigeria; Department of Health Promotion and Education (S E Ibitoye MPH), Department of Medicine (Prof M O Owolabi DrM), University of Ibadan, Ibadan, Nigeria; Faculty of Medicine (I M Ilic PhD, Prof M M Santric-Milicevic PhD), School of Public Health and Health Management (Prof M M Santric-Milicevic PhD), University of Belgrade, Belgrade, Serbia; Department of Epidemiology (Prof M D Ilic PhD), Department of Global Health, Economics and Policy (Prof M Jakovljevic PhD), University of Kragujevac, Kragujevac, Serbia; Division of Community Health and Family Medicine (L R Inbaraj MD), Bangalore Baptist Hospital, Bangalore, India; Independent Consultant, Tabriz, Iran (S N Irvani MD); Institute for Physical Activity and Nutrition (S Islam PhD), Deakin University, Burwood, VIC, Australia; Sydney Medical School (S Islam PhD), Save Sight Institute (H Kandel PhD), University of Sydney, Sydney, NSW, Australia; Surveillance and Health Services Research (F Islami PhD), American Cancer Society, Atlanta, GA, USA; Public Health Department of Social Medicine (Prof H Iso MD), Graduate School of Medicine (Prof K Yamagishi MD), Osaka University, Suita, Japan; Department of Health Management (R Itumalla PhD), University of Hail, Hail, Saudi Arabia; Department of Environmental Health Engineering (J Jaafari PhD), Guilan University of Medical Sciences, Rasht, Iran; Institute of Comparative Economic Studies (Prof M Jakovljevic PhD), Hosei University, Tokyo, Japan; Department of Preventive Medicine (Prof S Jang PhD, G Kim PhD, Prof E Park PhD), Institute of Health Services Research (D Lee BS, Prof E Park PhD), Department of Public Health (D Lee BS), Yonsei University, Seoul, South Korea; Department of Biochemistry (Prof S Jayaram MD), Government Medical College, Mysuru, India; Achutha Menon Centre for Health Science Studies (P Jeemon PhD), Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, India; Department of Community Medicine (R P Jha MSc), Dr Baba Saheb Ambedkar Medical College & Hospital, Delhi, India; Department of Community Medicine (R P Jha MSc), Banaras Hindu University, Varanasi, India; Beijing Institute of Ophthalmology (Prof J B Jonas MD), Beijing Tongren Hospital, Beijing, China; Institute of Family Medicine and Public Health (M Jürisson PhD), University of Tartu, Tartu, Estonia; School of Public Health (Z Kabir PhD), University College Cork, Cork, Ireland; Sydney Eye Hospital (H Kandel PhD), South Eastern Sydney Local Health District, Sydney, NSW, Australia; Institute for Epidemiology and Social Medicine (A Karch MD), University of Münster, Münster, Germany; Institute for Global Tobacco Control, Baltimore, MD, USA (Prof R D Kennedy PhD); Department of Epidemiology and Biostatistics (E A Khan MPH), Health Services Academy, Islamabad, Pakistan; The Iranian Academy of Medical Sciences, Tehran, Iran (M Khayamzadeh MD); Department of Nutrition (R W Kimokoti MD), Simmons University, Boston, MA, USA; Department of Public Health (Prof M Kivimäki PhD), University of Helsinki, Helsinki, Finland; Independent Consultant, Jakarta, Indonesia (S Kosen MD); Kasturba Medical College, Udupi, India (S Koulmane Laxminarayana MD); Biomedical Research Networking Center for Mental Health Network (CIBERSAM) (A Koyanagi MD), San Juan de Dios Sanitary Park, Sant Boi de Llobregat, Spain; Catalan Institution for Research and Advanced Studies (ICREA), Barcelona, Spain (A Koyanagi MD); Department of Anthropology (K Krishan PhD), Panjab University, Chandigarh, India; University of Environment and Sustainable Development, Somanya, Ghana (N Kugbey PhD); Department of Community Medicine (N Kumar MD, R Thapar MD), Manipal Academy of Higher Education, Mangalore, India; Faculty of Health and Life Sciences (O P Kurmi PhD), Coventry University, Coventry, UK; Department of Medicine (O P Kurmi PhD), Department of Psychiatry and Behavioural Neurosciences (A T Olagunju MD), McMaster University, Hamilton, ON, Canada; Faculty of Public Health (D Kusuma DSc), University of Indonesia, Depok, Indonesia; National Institute for Health Research (NIHR) Oxford Biomedical Research Centre, Oxford, UK (B Lacey PhD); Unit of Genetics and Public Health (Prof I Landires MD), Unit of Microbiology and Public Health (V Nuñez-Samudio PhD), Institute of Medical Sciences, Las Tablas, Panama; Department of Public Health (V Nuñez-Samudio PhD), Ministry of Health, Herrera, Panama (Prof I Landires MD); Department of Otorhinolaryngology (S Lasrado MS), Father Muller Medical College, Mangalore, India; Institute of Clinical Physiology (P Lauriola MD), National Research Council, Pisa, Italy; Graduate School of Public Health (Y Lee PhD), Ajou University, Suwon-si, South Korea; Center for Youth Substance Abuse Research (J Leung PhD), The University of Queensland, St Lucia, QLD, Australia; School of Public Health (Prof H Lin PhD), Zhengzhou University, Zhengzhou, China; Institute for Health and Environment (W Liu PhD), Chongqing University of Science and Technology, Chongqing, China; Department of Biochemistry (S Madhava Kunjathur MD), BGS Global Institute of Medical Sciences, Bengaluru, India; Department of Maternal and Child Nursing and Public Health (Prof D C Malta PhD), Department of Infectious Diseases and Tropical Medicine (B P Sao Jose PhD), Federal University of Minas Gerais, Belo Horizonte, Brazil; Institute for Social Science Research (A A Mamun PhD), The University of Queensland, Indooroopilly, QLD, Australia; Department of Psychiatry (N Manjunatha MD), National Institute of Mental Health and Neurosciences, Bengaluru, India; Substance Abuse Prevention Research Center (B Mansouri PhD), Cardiovascular Research Center (M Nalini MD), Research Center for Environmental Determinants of Health (K Sharafi PhD), Department of Health Education and Health Promotion (S Siabani PhD), Department of Sports Medicine and Rehabilitation (A Soroush MD), Kermanshah University of Medical Sciences, Kermanshah, Iran; Indonesian Public Health Association, Surabaya, Indonesia (S Martini PhD); Institute of Population Health Sciences (M R Mathur PhD), University of Liverpool, Liverpool, UK; National Centre for Disease Informatics and Research (P Mathur PhD), Indian Council of Medical Research, Bengaluru, India; Department of Twin Research and Genetic Epidemiology (M Mazidi PhD), Faculty of Life Sciences and Medicine (M Molokhia PhD), School of Population Health and Environmental Sciences (Y Wang PhD), King's College London, London, UK; Department of Health Services Research and Policy (Prof M McKee DSc), Department of Medical Statistics (S Shivalli MD), London School of Hygiene & Tropical Medicine, London, UK; Department of Dentistry (C E Medina-Solis MSc), Autonomous University of Hidalgo State, Pachuca, Mexico; Ministry of Health, Kathmandu, Nepal (S Mehata PhD); Peru Country Office (W Mendoza MD), United Nations Population Fund (UNFPA), Lima, Peru; Center for Innovation in Medical Education (B Miazgowski MD), Pomeranian Medical University, Szczecin, Poland (B Miazgowski MD); Woman-Mother-Child Department (I Michalek PhD), Lausanne University Hospital, Lausanne, Switzerland; Pacific Institute for Research & Evaluation, Calverton, MD, USA (T R Miller PhD); Global Institute of Public Health (Prof G Mini PhD), Ananthapuri Hospitals and Research Institute, Trivandrum, India; Women's Social and Health

Studies Foundation, Trivandrum, India (Prof G Mini PhD); Internal Medicine Programme (Prof E M Mirrakhimov PhD), Kyrgyz State Medical Academy, Bishkek, Kyrgyzstan; Department of Atherosclerosis and Coronary Heart Disease (Prof E M Mirrakhimov PhD), National Center of Cardiology and Internal Disease, Bishkek, Kyrgyzstan; Research Center for Biochemistry and Nutrition in Metabolic Diseases (H Mirzaei PhD), Kashan University of Medical Sciences, Kashan, Iran; Department of Epidemiology and Biostatistics (A Mohammadian-Hafshejani PhD), Shahrekord University of Medical Sciences, Shahrekord, Iran; Health Systems and Policy Research Unit (S Mohammed PhD), Department of Surgery (M A Tolani FWACS), Ahmadu Bello University, Zaria, Nigeria; Clinical Epidemiology and Public Health Research Unit (L Monasta DSc, L Ronfani PhD), Burlo Garofolo Institute for Maternal and Child Health, Trieste, Italy; World Health Organization (WHO) Centre on eHealth (M Moni PhD), University of New South Wales, Sydney, NSW, Australia; Section of Plastic Surgery (S D Morrison MD), University of Michigan School of Medicine, Ann Arbor, MI, USA; Department of Epidemiology and Biostatistics (S Mubarak MS, Prof C Yu PhD), School of Medicine (Z Zhang PhD), Wuhan University, Wuhan, China; Department of Cardiology (Prof N Naik DM, Prof A Roy MD), All India Institute of Medical Sciences, New Delhi, India; Suraj Eye Institute, Nagpur, India (V Nangia MD); Discipline of Social & Administrative Pharmacy (A Naqvi PhD), University of Science, Malaysia, Penang, Malaysia; Mysore Medical College and Research Institute (Prof S Narasimha Swamy MD), Government Medical College, Mysore, India; Department of Biotechnology (M Naveed PhD), University of Central Punjab, Lahore, Pakistan; Cardio-Aid, Bucharest, Romania (R I Negoï PhD); Bupa Clemton Park (S Neupane Kandel BSN), Bupa, Sydney, NSW, Australia; Institute for Global Health Innovations (H L T Nguyen MPH, H Q Pham MD), Duy Tan University, Hanoi, Vietnam; Institute for Mental Health and Policy (Y T Nigatu PhD), Centre for Addiction and Mental Health, Toronto, ON, Canada; Department of Clinical Epidemiology (Y T Nigatu PhD), Institute for Clinical Evaluative Sciences, Ottawa, ON, Canada; Unit on Risk and Resilience in Mental Disorders (Prof D J Stein MD), South African Medical Research Council, Cape Town, South Africa (C A Nnaji MPH); School of Public Health and Family Medicine (C A Nnaji MPH), University of Cape Town, Cape Town, South Africa; Department of Neurobiology, Care Sciences and Society (C Nowak PhD), Karolinska Institute, Huddinge, Sweden; Translational Health Research Institute (F A Ogbo PhD, Prof A M N Renzaho PhD), School of Social Sciences and Psychology (Prof A M N Renzaho PhD), Western Sydney University, Penrith, NSW, Australia; Department of Preventive Medicine (I Oh PhD), Kyung Hee University, Dongdaemum-gu, South Korea; Department of Psychiatry (A T Olagunju MD), University of Lagos, Lagos, Nigeria; Department of Respiratory Medicine (Prof M P A DNB), Jagadguru Sri Shivarathreeswara Academy of Health Education and Research, Mysore, India; Department of Health Metrics (A Pana MD), Center for Health Outcomes & Evaluation, Bucharest, Romania; Department of Nutrition and Dietetics (Prof D Panagiotakos PhD), Harokopio University, Athens, Greece; Research Department (A Pandey MPH), Public Health Research Society Nepal, Kathmandu, Nepal; Department of Forensic Medicine & Toxicology (U Parekh MD), Pramukhswami Medical College, Anand, India; Department of Medical Humanities and Social Medicine (Prof E Park PhD), Kosin University, Busan, South Korea; Research & Development Department (M Pathak PhD), Kalinga Institute of Medical Sciences, Bhubaneswar, India; Department of Genetics (S Pawar PhD), Department of Internal Medicine (R Shrestha PhD), Yale University, New Haven, CT, USA; Pennsylvania Cancer and Regenerative Medicine Center (R G Pestell MD), Baruch S Blumberg Institute, Doylestown, PA, USA; Department of Medicine (R G Pestell MD), Xavier University School of Medicine, Woodbury, NY, USA; HIV and Mental Health Department (K N Pokhrel PhD), Integrated Development Foundation Nepal, Kathmandu, Nepal; Department of Biochemistry (Prof A Prashant PhD), Jagadguru Sri Shivarathreeswara University, Mysuru, India; College of Medicine (A Radfar MD), University of Central Florida, Orlando, FL, USA; Department of Community Medicine (M Rahman PhD), Maharishi Markandeshwar Medical College & Hospital, Solan, India; School of Nursing and Healthcare Professions (M Rahman PhD), Federation University Australia, Berwick, VIC, Australia; Future Technology Research Center (A Rahmani PhD), National Yunlin University of Science and Technology, Yunlin, Taiwan; Institute of Research and Development (A Rahmani PhD), Duy Tan University, Da Nang, Vietnam; Department of Cardiology (P Ram MD), Emory University, Atlanta, GA, USA; Department of Public Health (J Rana MPH), North South University, Dhaka, Bangladesh; Department of Biostatistics and Epidemiology (J Rana MPH), University of Massachusetts Amherst, Amherst, MA, USA; Research Department (C L Ranabhat PhD), Policy Research Institute, Kathmandu, Nepal; Health and Public Policy Department (C L Ranabhat PhD), Global Center for Research and Development, Kathmandu, Nepal; University College London Hospitals, London, UK (D L Rawaf MD); Academic Public Health England (Prof S Rawaf MD), Public Health England, London, UK; Department of Computer Science (R Rawassizadeh PhD), Boston University, Boston, MA, USA; Department of Clinical Research (L Roeber PhD), Federal University of Uberlândia, Uberlândia, Brazil; Golestan Research Center of Gastroenterology and Hepatology (GRCGH) (G Roshandel PhD), Golestan University of Medical Sciences, Gorgan, Iran; Faculty of Medicine (B Roy PhD), Quest International University Perak, Ipoh, Malaysia; Applied Biomedical Research Center (A Sahebkar PhD), Biotechnology Research Center (A Sahebkar PhD), Mashhad University of Medical Sciences, Mashhad, Iran; Department of Entomology (A M Samy PhD), Ain Shams University, Cairo, Egypt; Department of Surgery (Prof J Sanabria MD), Marshall University, Huntington, WV, USA; Department of Geriatrics and Long Term Care (B Sathian PhD), Hamad Medical Corporation, Doha, Qatar; Faculty of Health & Social Sciences (B Sathian PhD), Bournemouth University, Bournemouth, UK; Department of Public Health Sciences (M Sawhney PhD), University of North Carolina at Charlotte, Charlotte, NC, USA; Department of Preventive and Social Medicine (G Saya MD), Jawaharlal Institute of Postgraduate Medical Education and Research, Puducherry, India; Oral Diagnosis, Digital Health and Health Services Research (Prof F Schwendicke PhD), Charité University Medical Center Berlin, Berlin, Germany; Department of Population and Health (A Seidu MPhil), University of Cape Coast, Cape Coast, Ghana; College of Public Health, Medical and Veterinary Sciences (A Seidu MPhil), James Cook University, Townsville, QLD, Australia; Department of Biotechnology (Prof N Senthil Kumar PhD), Mizoram University, Aizawl, India; Department of Family Medicine (Prof S M Shah PhD), Aga Khan University, Karachi, Pakistan; Independent Consultant, Karachi, Pakistan (M A Shaikh MD); Department of Community Medicine (M Shannawaz PhD), BLDE University, Vijayapur, India; Centre for Medical Informatics (Prof A Sheikh MD), University of Edinburgh, Edinburgh, UK; National Institute of Infectious Diseases, Tokyo, Japan (M Shigematsu PhD); Finnish Institute of Occupational Health, Helsinki, Finland (R Shiri PhD); Washington State University, Pullman, WA, USA (K Shishani PhD); Public Health Dentistry Department (Prof K M Shivakumar PhD), Krishna Institute of Medical Sciences Deemed to be University, Karad, India; Department of Public Health (N B Sidemo MPH), Department of Biomedical Sciences (E G Tadesse MSc), Arba Minch University, Arba Minch, Ethiopia; Department of Psychology (Prof I D Sigfusdottir PhD, R Sigurvinsdottir PhD), Reykjavik University, Reykjavik, Iceland; Department of Health and Behavior Studies (Prof I D Sigfusdottir PhD), Columbia University, New York, NY, USA; School of Medicine (Prof J A Singh MD), University of Alabama at Birmingham, Birmingham, AL, USA; Medicine Service (Prof J A Singh MD), US Department of Veterans Affairs (VA), Birmingham, AL, USA; Department of Pulmonary Medicine (Prof V Singh MD), Asthma Bhawan, Jaipur, India; Department of Epidemiology (D N Sinha PhD), School of Preventive Oncology, Patna, India; Department of Epidemiology (D N Sinha PhD), Healis Sekhsaria Institute for Public Health, Mumbai, India; Department No.16 (V Y Skryabin MD), Laboratory of Genetics and Genomics (Prof M S Zastrozhin PhD), Moscow Research and Practical Centre on Addictions, Moscow, Russia; Therapeutic Department (A A Skryabina MD), Balashiha Central Hospital, Balashikha, Russia; Hull York Medical School (I N Soyiri PhD), University of Hull, Hull City, UK; Division of Community Medicine (C T Sreeramareddy MD), International Medical University, Kuala Lumpur, Malaysia; Department of Medicine (P Steiropoulos MD), Democritus University of Thrace, Alexandroupolis, Greece; Department of Cardiology (S Stortecky MD),

University of Bern, Bern, Switzerland; Schiller Institute (Prof K Straif PhD), Boston College, Boston, MA, USA; Barcelona Institute for Global Health, Barcelona, Spain (Prof K Straif PhD); Department of Statistics (R Suliankatchi Abdulkader MD), Manonmaniam Sundaranar University, Abishekapatti, India; National Institute of Epidemiology (R Suliankatchi Abdulkader MD), Indian Council of Medical Research, Chennai, India; Norwegian Institute of Public Health, Bergen, Norway (G Sulo PhD); Department of Medical Sciences (Prof J Sundström PhD), Uppsala University, Uppsala, Sweden; The George Institute for Global Health, Sydney, NSW, Australia (Prof J Sundström PhD); Cancer Control Center (T Tabuchi MD), Osaka International Cancer Institute, Osaka, Japan; Department of Population Science and Human Resource Development (Prof M I Tareque PhD), University of Rajshahi, Rajshahi, Bangladesh; Research and Development Center for Humanities and Health Management (I U Tarigan PhD), National Institute of Health Research & Development, Jakarta, Indonesia; Division of Biostatistics and Epidemiology (B Thakur PhD), Texas Tech University Health Sciences Center, El Paso, TX, USA; Department of Public Health and Community Medicine (Prof K R Thankappan MD), Central University of Kerala, Kasaragod, India; Department of Pathology and Legal Medicine (M R Tovani-Palone PhD), University of São Paulo, Ribeirão Preto, Brazil; Modestum LTD, London, UK (M R Tovani-Palone PhD); Department of Health Economics (B X Tran PhD), Hanoi Medical University, Hanoi, Vietnam; Department of Community Medicine (J P Tripathy MD), All India Institute of Medical Sciences, Nagpur, India; Department of Cardiovascular, Endocrine-metabolic Diseases and Aging (B Unim PhD), National Institute of Health, Rome, Italy; Laboratory of Toxicology (C Vardavas PhD), University of Crete, Heraklion, Greece; Raffles Neuroscience Centre (Prof N Venketasubramanian MBBS), Raffles Hospital, Singapore, Singapore; Yong Loo Lin School of Medicine (Prof N Venketasubramanian MBBS), National University of Singapore, Singapore, Singapore; Department of Community Medicine and Family Medicine (M Verma MD), All India Institute of Medical Sciences, Bathinda, India; Department of Neurology (S Vidale MD), Infermi Hospital, Rimini, Italy; Department of Neurology & Stroke Unit (S Vidale MD), Sant'Anna Hospital, Como, Italy; Faculty of Information Technology (B Vo PhD), Ho Chi Minh City University of Technology (HUTECH), Ho Chi Minh City, Vietnam; Center of Excellence in Behavioral Medicine (G T Vu BA), Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam; Foundation University Medical College (Prof Y Waheed PhD), Foundation University Islamabad, Islamabad, Pakistan; Demographic Change and Aging Research Area (A Werdecker PhD), Federal Institute for Population Research, Wiesbaden, Germany; Department of Community Medicine (N D Wickramasinghe MD), Rajarata University of Sri Lanka, Anuradhapura, Sri Lanka; School of Pharmacy (B Wubishet MPH), Mekelle University, Mekelle, Ethiopia; Research and Development Center for Health Services (Prof K Yamagishi MD), University of Tsukuba, Tsukuba, Japan; Department of Family Medicine and Community Health (Y Yano MD), Duke University, Durham, IL, USA; Health Services Management Research Center (V Yazdi-Feyzabadi PhD), Department of Health Management, Policy, and Economics (V Yazdi-Feyzabadi PhD), Kerman University of Medical Sciences, Kerman, Iran; Human Anatomy Unit (M Z Yimmer MSc), Wollo University, Dessie, Ethiopia; Department of Neuropsychopharmacology (N Yonemoto MPH), National Center of Neurology and Psychiatry, Kodaira, Japan; Department of Public Health (N Yonemoto MPH), Juntendo University, Tokyo, Japan; Department of Health care Management and Economics (H Yusefzadeh PhD), Urmia University of Medical Science, Urmia, Iran; School of Rehabilitation Therapy (M S Zaman MSc), Queen's University, Kingston, ON, Canada; Addictology Department (Prof M S Zastrozhin PhD), Pediatrics Department (A Zastrozhina PhD), Russian Medical Academy of Continuous Professional Education, Moscow, Russia; Department of General Practice (J Zhang MD), University of Melbourne, Melbourne, VIC, Australia; Victorian Comprehensive Cancer Centre, Melbourne, VIC, Australia (J Zhang MD); Health Technology Assessment Unit (Y H Zuniga BS), Department of Health Philippines, Manila, Philippines; #MentalHealthPH, Quezon City, Philippines (Y H Zuniga BS).

#### Declaration of interests

ViA reports personal fees from Bayer Healthcare, Boehringer Ingelheim/Lilly alliance, Bristol Myers Squibb/Pfizer alliance, and Novo Nordisk outside of the submitted work. RA reports consultancy and speakers' fees from UCB, Sandoz, AbbVie, Zentiva, Teva, Laropharm, Cegecim, Angelini, B Braun, Biessen Pharma, Hofigal, AstraZeneca, and Stada. BA reports personal fees from Australian Institute of Sports, grants and non-financial support from Natural Remedies, and non-financial support from Zydus Cadila outside of the submitted work. SI reports grants from National Heart Foundation of Australia, and Australian National Health and Medical Research Council outside the submitted work. KK reports non-financial support from UGC Centre of Advanced Study (CAS II), Department of Anthropology, Panjab University, Chandigarh, India, outside of the submitted work. TRM reports contracts from Gov't Plaintiff Lawyers, JUUL, outside of the submitted work. JAS reports consultancy fees from Crealta/Horizon, Medisys, Fidia, Two Labs Inc, Adept Field Solutions, Clinical Care Options, Clearview Healthcare Partners, Putnam Associates, Focus Forward, Navigant Consulting, Spherix, MedIQ, UBM LLC, Trio Health, Medscape, WebMD, Practice Point Communications, and the National Institutes of Health and the American College of Rheumatology; receives payment for lectures as a member on the speaker's bureau of Simply Speaking; owns stock options in TPT Global Tech, Vaxart pharmaceuticals, and Charlotte's Web Holdings; previously owned stock options in Amarin, Viking, and Moderna pharmaceuticals; held a placement on the steering committee of OMERACT, an international organisation that develops measures for clinical trials and receives arm's length funding from 12 pharmaceutical companies; serves on the US Food and Drug Administration Arthritis Advisory Committee; is a member of the Veterans Affairs Rheumatology Field Advisory Committee; is the editor and is the Director of the University of Alabama at Birmingham Cochrane Musculoskeletal Group Satellite Center on Network Meta-analysis, all outside of the submitted work. JS reports ownership of companies providing services to Itrim, Amgen, Janssen, Novo Nordisk, Eli Lilly, Boehringer Ingelheim, Bayer, Pfizer, and AstraZeneca outside of the submitted work. DJS reports personal fees from Lundbeck, Takeda, Johnson & Johnson, and Servier outside of the submitted work. SS reports grants from Edwards Lifesciences, Medtronic, Boston Scientific, and Abbott; and personal fees from Boston Scientific, Teleflex, and BTG outside of the submitted work. All other authors declare no competing interests.

#### Data sharing

To download the data used in these analyses, please visit the Global Health Data Exchange GBD 2019 website.

#### Acknowledgments

The authors alone are responsible for the views expressed in this Article and they do not necessarily represent the views, decisions, or policies of the institutions with which they are affiliated or their funders. SheMA thanks the International Centre for Casemix and Clinical Coding, Faculty of Medicine, National University of Malaysia and Department of Health Policy and Management, Faculty of Public Health, Kuwait University for the approval and support to participate in this research project. SKB received contributions from the Social Change Grant Program with Walden University. DAB receives support from the Oxford National Institute for Health Research (NIHR) Biomedical Research Centre (BRC). VMC acknowledges a grant (SFRH/BHD/110001/2015), through Portuguese national funds through Fundação para a Ciência e Tecnologia (FCT), IP, under the Norma Transitória DL57/2016/CP1334/CT0006. MEK was supported by University Graduate School Dissertation Year Fellowship at Florida International University. NG is employed as a postdoctoral researcher by the Technical University of Denmark and her salary is covered by a research grant from Novo Nordisk Foundation. CH, MarA, and AdP are partially supported by a grant from the Romanian National Authority for Scientific Research and Innovation (CNDS-UEFISCDI, project number PN-III-P4-ID-PCCF-2016-0084). CH and AdP are partially supported by a grant from the Romanian National Authority for Scientific Research and Innovation (CNDS-UEFISCDI, project number PN-III-P2-2.1-SOL-2020-2-0351). JYI is supported by UNC's Cancer Care Quality Training 2T32CA116339-11. SMSI received funding from Deakin University,



the National Heart Foundation of Australia, and the Australian National Health and Medical Research Council. Mih] has been co-funded through a grant from the Ministry of Science Education and Technological Development of the Republic of Serbia (O1 175 014). P] was supported by the Wellcome Trust/DBT India Alliance Intermediate Fellowship 2015–21 (1A/CPH1/14/1/501497). MK has received funding from the Wellcome Trust (221854/Z/20/Z), the UK Medical Research Council (MRC S011676), and Helsinki Institute of Life Science (H970). SLKL acknowledges institutional support by Manipal Academy of Higher Education. KK is supported by UGC Centre of Advanced Study (CAS II), awarded to the Department of Anthropology, Panjab University, Chandigarh, India. BL acknowledges support from UK Biobank, the NIHR Oxford BRC, and the BHF Oxford Centre of Research Excellence. IL is member of the Sistema Nacional de Investigación, which is supported by the Secretaría Nacional de Ciencia, Tecnología e Innovación, Panamá. MariM is supported by the NIHR BRC at Guy's and St Thomas' National Health Service Foundation Trust and King's College London. AMS acknowledges the support of the Egyptian Fulbright Mission Program. MMS-M acknowledges the support of the Ministry of Education, Science and Technological Development of the Republic of Serbia (contract number 175087). AzS acknowledges the support of the Health Data Research UK BREATHE Hub. JPS acknowledges support from the Applied Molecular Biosciences Unit (grant number UIDB/04378/2020), supported through Portuguese national funds via FCT/MCTES. AmbS is supported by the International Graduate Research Scholarship, University of Tasmania.

Editorial note: the *Lancet* Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

#### References

- Giovino GA, Biener L, Hartman AM, et al. Monitoring the tobacco use epidemic I. Overview: optimizing measurement to facilitate change. *Prev Med* 2009; **48** (suppl): S4–10.
- Mehrotra R, Yadav A, Sinha DN, et al. Smokeless tobacco control in 180 countries across the globe: call to action for full implementation of WHO FCTC measures. *Lancet Oncol* 2019; **20**: e208–17.
- Palipudi K, Rizwan SA, Sinha DN, et al. Prevalence and sociodemographic determinants of tobacco use in four countries of the World Health Organization: South-East Asia region: findings from the Global Adult Tobacco Survey. *Indian J Cancer* 2014; **51** (suppl 1): S24–32.
- Sinha DN, Rizwan SA, Aryal KK, Karki KB, Zaman MM, Gupta PC. Trends of smokeless tobacco use among adults (aged 15–49 years) in Bangladesh, India and Nepal. *Asian Pac J Cancer Prev* 2015; **16**: 6561–68.
- Sinha DN, Kumar A, Bhartiya D, et al. Smokeless tobacco use among adolescents in global perspective. *Nicotine Tob Res* 2017; **19**: 1395–96.
- Kakde S, Bhopal RS, Jones CM. A systematic review on the social context of smokeless tobacco use in the South Asian population: implications for public health. *Public Health* 2012; **126**: 635–45.
- Sighaldehy SS, Charkazi A. Factors contributing to nass consumption among Iranian Turkmen: a qualitative study. *Tob Induc Dis* 2018; **16**: 37.
- Kumar G, Pednekar MS, Narake S, Dhupal G, Gupta PC. Feedback from vendors on gutka ban in two states of India. *Indian J Med Res* 2018; **148**: 98–102.
- Kostygina G, Ling PM. Tobacco industry use of flavourings to promote smokeless tobacco products. *Tob Control* 2016; **25** (suppl 2): ii40–49.
- Thakur JS, Paika R. Determinants of smokeless tobacco use in India. *Indian J Med Res* 2018; **148**: 41–45.
- Siddiqi K, Husain S, Vidyasagaran A, Readshaw A, Mishu MP, Sheikh A. Global burden of disease due to smokeless tobacco consumption in adults: an updated analysis of data from 127 countries. *BMC Med* 2020; **18**: 222.
- Boffetta P, Aagnes B, Weiderpass E, Andersen A. Smokeless tobacco use and risk of cancer of the pancreas and other organs. *Int J Cancer* 2005; **114**: 992–95.
- Stepanov I, Yerushova K, Carmella S, Upadhyaya P, Hecht SS. Levels of (S)-N'-nitrososonornicotine in U.S. tobacco products. *Nicotine Tob Res* 2013; **15**: 1305–10.
- Asthana S, Labani S, Kailash U, Sinha DN, Mehrotra R. Association of smokeless tobacco use and oral cancer: a systematic global review and meta-analysis. *Nicotine Tob Res* 2019; **21**: 1162–71.
- Sinha DN, Suliankatchi RA, Gupta PC, et al. Global burden of all-cause and cause-specific mortality due to smokeless tobacco use: systematic review and meta-analysis. *Tob Control* 2018; **27**: 35–42.
- Teo KK, Ounpuu S, Hawken S, et al. Tobacco use and risk of myocardial infarction in 52 countries in the INTERHEART study: a case-control study. *Lancet* 2006; **368**: 647–58.
- Gupta B, Johnson NW. Systematic review and meta-analysis of association of smokeless tobacco and of betel quid without tobacco with incidence of oral cancer in South Asia and the Pacific. *PLoS One* 2014; **9**: e113385.
- Gupta V, Yadav K, Anand K. Patterns of tobacco use across rural, urban, and urban-slum populations in a north Indian community. *Indian J Community Med* 2010; **35**: 245–51.
- Krishnamoorthy Y, Ganesh K. Spatial pattern and determinants of tobacco use among females in India: evidence from a nationally representative survey. *Nicotine Tob Res* 2020; **22**: 2231–37.
- Al-Tayar B, Tin-Oo MM, Sinor MZ, Alakhali MS. Prevalence and association of smokeless tobacco use with the development of periodontal pocket among adult males in Dawan Valley, Yemen: a cross-sectional study. *Tob Induc Dis* 2015; **13**: 35.
- Sreeramareddy CT, Pradhan PM, Sin S. Prevalence, distribution, and social determinants of tobacco use in 30 sub-Saharan African countries. *BMC Med* 2014; **12**: 243.
- Choi S, Kim Y, Lee J, Kashiwabara M, Oh K. Tobacco use among students aged 13–15 years in South Korea: the 2013 Global Youth Tobacco Survey. *J Prev Med Public Health* 2017; **50**: 60–65.
- GBD 2019 Tobacco Collaborators. Spatial, temporal, and demographic patterns in prevalence of smoking tobacco use and attributable disease burden in 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. *Lancet* 2021; published online May 27. [https://doi.org/10.1016/S0140-6736\(21\)01169-7](https://doi.org/10.1016/S0140-6736(21)01169-7).
- Stevens GA, Alkema L, Black RE, et al. Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER statement. *Lancet* 2016; **388**: e19–23.
- GBD 2019 Risk Factor Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396**: 1223–49.
- Leon ME, Lugo A, Boffetta P, et al. Smokeless tobacco use in Sweden and other 17 European countries. *Eur J Public Health* 2016; **26**: 817–21.
- National Cancer Institute, Division of Cancer Control & Population Sciences. Smokeless tobacco and public health: a global perspective. <https://cancercontrol.cancer.gov/brp/tcrb/global-perspective/> (accessed April 8, 2021).
- Zaatari GS, Bazzi A. Impact of the WHO FCTC on non-cigarette tobacco products. *Tob Control* 2019; **28** (suppl 2): s104–12.
- Mejia AB, Ling PM. Tobacco industry consumer research on smokeless tobacco users and product development. *Am J Public Health* 2010; **100**: 78–87.
- Pickwell SM, Schimelpfening S, Palinkas LA. 'Betelmania'. Betel quid chewing by Cambodian women in the United States and its potential health effects. *West J Med* 1994; **160**: 326–30.
- Singh PK, Yadav A, Lal P, et al. Dual burden of smoked and smokeless tobacco use in India, 2009–17: a repeated cross-sectional analysis based on Global Adult Tobacco Survey. *Nicotine Tob Res* 2020; **22**: 2196–202.
- Tomar SL, Alpert HR, Connolly GN. Patterns of dual use of cigarettes and smokeless tobacco among US males: findings from national surveys. *Tob Control* 2010; **19**: 104–09.
- Roth MA, Aitsi-Selmi A, Wardle H, Mindell J. Under-reporting of tobacco use among Bangladeshi women in England. *J Public Health (Oxf)* 2009; **31**: 326–34.
- Jain R, Jhanjee S, Jain V, et al. Biochemical validation of self-reported smokeless tobacco abstinence among smokeless tobacco users: results from a clinical trial of varenicline in India. *J Psychoactive Drugs* 2015; **47**: 331–35.
- Agaku IT, King BA. Validation of self-reported smokeless tobacco use by measurement of serum cotinine concentration among US adults. *Am J Epidemiol* 2014; **180**: 749–54.

- 36 Reddy P, Anjum S, Monica M, Yadav Rao K, Akula S, Sai Pravallika T. Is there any impact of the gutkha ban on users and vendors in Rangareddy district? A cross sectional study. *Asian Pac J Cancer Prev* 2016; **17**: 5005–09.
- 37 Sreeramareddy CT, Pradhan PMS, Mir IA, Sin S. Smoking and smokeless tobacco use in nine South and Southeast Asian countries: prevalence estimates and social determinants from Demographic and Health Surveys. *Popul Health Metr* 2014; **12**: 22.
- 38 Singh A, Ladusingh L. Prevalence and determinants of tobacco use in India: evidence from recent Global Adult Tobacco Survey data. *PLoS One* 2014; **9**: e114073.
- 39 Ladusingh L, Dhillon P, Narzary PK. Why do the youths in northeast India use tobacco? *J Environ Public Health* 2017; **2017**: 1391253.