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: –1.21% [–1.26 to –1.16]), similar progress was not observed for chewing tobacco (0.46% [0.13 to 0.79]). 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 (–0.94% [–1.72 to –0.14]), 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 smoking tobacco 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.

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beliefs about a variety of benefits (eg, for morning sickness), and local distribution and production. 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, and these products are usually cheaper than cigarettes. 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 and are associated with varying degrees and types of harm. This study focuses on chewing tobacco use, because the associated health risks are well documented. Many studies have found strong evidence for the increased risk of oral cancer due to chewing tobacco.

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. Studies have been done previously that estimated prevalence for a particular country, region, or source, or a restricted time period or age group, 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. 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.
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 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.13 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.11 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).
The proportion of unspecified smokeless tobacco that is chewing tobacco varies widely across countries. For example, in Sweden, snus (pulverised tobacco for sub-labial administration, which we classify as non-chewing tobacco)²⁶ is the predominant product used, while in India, most users of smokeless tobacco use chewing tobacco.⁶ 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.¹⁸ 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 (24·4% [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.
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 for females until age 80–84 years, after which it much more. Globally in 2019, prevalence increased with these 12 countries, prevalence by age and sex differed during the study period.

### 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

| Location    | 1990 Prevalence | 2019 Prevalence | Annualised rate of change 1990–2019 | Annualised rate of change 1990–2005 | Annualised rate of change 2005–19 |
|-------------|-----------------|-----------------|-------------------------------------|-------------------------------------|-----------------------------------|
| Females     |                 |                 |                                     |                                     |                                   |
| Global      | 2.41%           | 2.87%           | 0.73%                               | 0.64%                               | 0.06%                             |
| Cambodia    | 14.57%          | 12.84%          | 0.45%                               | -0.43%                              | 0.69%                             |
| Myanmar     | 6.63%           | 6.53%           | 0.60%                               | -0.05%                              | 1.24%                             |
| Sri Lanka   | 5.78%           | 5.45%           | -0.05%                              | 0.66%                               | 0.06%                             |
| Marshall Islands | 2.97% | 4.06% | 0.59%                               | 0.36%                               | 0.33%                             |
| Yemen       | 9.4%            | 4.35%           | 0.55%                               | -0.88%                              | -0.30%                            |
| Bangladesh  | 27.8%           | 25.39%          | 0.36%                               | -0.32%                              | 0.32%                             |
| Bhutan      | 13.76%          | 14.22%          | 0.10%                               | 0.12%                               | 0.13%                             |
| India       | 17.26%          | 11.13%          | 0.09%                               | -0.04%                              | 0.23%                             |
| Nepal       | 6.63%           | 8.21%           | 0.11%                               | -0.32%                              | -0.26%                            |
| Pakistan    | 5.4%            | 4.91%           | -0.12%                              | -0.19%                              | -0.05%                            |
| Madagascar  | 6.29%           | 6.38%           | 0.73%                               | -0.66%                              | -0.79%                            |
| Palau       | 18.28%          | 24.42%          | 0.70%                               | 1.03%                               | 0.43%                             |

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.
Figure 1: Age-standardised prevalence of chewing tobacco use in females (A) and males (B) aged 15 years and older, in 2019.
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% [19·63–44·24]), 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 males and seven had significant decreases among females aged 15–19 years in each of the 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 males and seven had significant decreases among females aged 15–19 years in each of the 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 aged 15–19 years in each of the 12 countries (appendix pp 24–27, 46–61).
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.
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% [95% UI 0·39–3·94]; 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% [95% UI 3·11–8·03] vs 1·65% [95% UI 0·39–3·94]; 184995 [100912–310674] chewing tobacco users vs 24044 [14985–36351] 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, the prevalence of smoking. This trend in high-prevalence countries has been noted previously, 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 acceptance and beliefs about associated benefits, complex cultural reasons such as wider social acceptability and beliefs about associated benefits, and targeted advertising. 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. Because the prevalence of chewing tobacco use nears or surpasses the prevalence of smoking tobacco use in some countries, efforts must be intensified to explicitly address smokeless tobacco products.

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, 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, complex cultural reasons such as wider social acceptability and beliefs about associated benefits, and targeted advertising. 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. 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.11,12 Tracking and understanding dual use might be important to uncover potential issues with targeted advertising, differential cessation success, or particularly problematic adolescent use.11,12 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.11,12 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 gutka (chewing tobacco preparation including betel nut) in 2013, which some studies have shown might have led people to purchase other types of smokeless tobacco,8,36 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.1 Additionally, subnational analysis will be important for future studies, because local evidence is crucial to local policy setting, and previous studies11,12 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.11,12

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.

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

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References
1 Giovino GA, Bierer L, Hartman AM, et al. Monitoring the tobacco use epidemic I: Overview: optimizing measurement to facilitate change. Prev Med 2009; 48 (suppl): 54–60.
2 Mehrzad 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.
3 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): 52–59.
4 Sinha DN, Rizwan SA, Ayal SK, 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.
5 Sinha DN, Kumar A, Bhattiya D, et al. Smokeless tobacco use among adolescents in global perspective. Nicotine Tob Res 2017; 19: 1395–96.
6 Kakde S, Bhoop 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: 633–45.
7 Sighaleh SS, Charkazi A. Factors contributing to mass consumption among Iranian Turkmen: a qualitative study. Tob Indu Dis 2018; 16: 37.
8 Kumar G, Pednekar MS, Narake S, Dhumal G, Gupta PC. Feedback from vendors on gutka ban in two states of India. Indian J Med Res 2018; 148: 109–102.
9 Kostygina G, Ling PM. Tobacco industry use of flavourings to promote smokeless tobacco products. Tob Control 2016; 25 (suppl 2): i40–49.
10 Thakur JS, Paika R. Determinants of smokeless tobacco use in India. Indian J Med Res 2018; 148: 41–45.
11 Siddiqi K, Husain S, Vidyasagar A, Readshaw A, Mishu MP, Shekiri 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.
12 Boffetta P, Agnus B, Weiderpass E, Andersson A. Smokeless tobacco use and risk of cancer of the pancreas and other organs. Int J Cancer 2005; 114: 992–95.
13 Stepanov I, Yershova K, Carmella S, Upadhyaya P, Hecht SS. Levels of (S)-N-nitrosornicotine in U.S. tobacco products. Nicotine Tob Res 2013; 15: 1305–10.
14 Asthana S, Lahani 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.
15 Sinha DN, Suliskatchy 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; 31–42.
16 Teo KK, Oonpui 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.
17 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: e113185.
18 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.
19 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: 2317–37.
20 Al-Tayy A, Yin-Oh MM, Sinor MZ, Al-Akhlais 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: 3.
21 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.
22 Chui 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.
23 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.
24 Stevens GA, Alkema L, Black RE, et al. Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER statement. Lancet 2016; 388: e19–23.
25 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.
26 Leon ME, Ivers A, Boffetta P, et al. Smokeless tobacco use in Sweden and other 17 European countries. Eur J Public Health 2016; 26: 817–21.
27 National Cancer Institute, Division of Cancer Control & Population Sciences. Smokeless tobacco and public health: a global perspective. https://cancercontrolcancer.gov/lp/tech/global-perspective/ (accessed April 8, 2021).
28 Zaatari GS, Bazzi A. Impact of the WHO FCTC on non-cigarette tobacco products. Tob Control 2019; 28 (suppl 2): i104–12.
29 Meija AB, Ling PM. Tobacco industry consumer research on smokeless tobacco users and product development. Am J Public Health 2010; 100: 78–87.
30 Pickwell SM, Schimmelprung S, Palirnasas LA. ‘Betelmania’. Betel quid chewing by Cambodian women in the United States and its potential health effects. West J Med 1994; 160: 326–30.
31 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: 1996–2012.
32 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.
33 Roth MA, Atits-Selmie A, Wardle H, Mindell J. Under-reporting of tobacco use among Bangladeshi women in England. J Public Health (Oxf) 2009; 31: 326–34.
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.
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.