Tobacco consumption: Examining age and sex patterns across countries

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Abstract

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Background: Tobacco is an important risk factor, resulting in 6.3 million deaths annually. Prevalence estimates are often used to quantify the impact of tobacco but do not capture the intensity of smoking. Tobacco consumption estimates often draw on production data at the national level. There are currently no robust estimates of tobacco consumption by age or sex across countries.

Methods: Data from the Global Adult Tobacco Survey, World Health Organization STEPwise approach to Surveillance, and the World Health Survey were combined to estimate prevalence and consumption by age and sex in 103 countries. Survey-based consumption estimates were compared to national production-based consumption estimates from the US Department of Agriculture.

Results: For both men and women, consumption increases with age and peaks in ages 45-54 before declining in the oldest ages. The peak in consumption is more pronounced in men than in women and men generally have higher consumption levels than women. There is a significant positive relationship between consumption and prevalence that is strongest for males and in younger ages. Production-based national consumption estimates and survey-based national consumption estimates are a fairly good approximation.

Conclusions: Using the standard production-based national estimates of per capita tobacco consumption masks significant trends by age and sex which could be important to direct resource allocation, identify high risk populations, or inform public policy. Consumption estimates can supplement traditional prevalence measures to more thoroughly examine population exposure to tobacco.

Introduction

Tobacco is a known risk factor for many adult diseases and causes of death, including cancers, chronic respiratory disease, and cardiovascular diseases.[1–3] The 2010 Global Burden of Disease estimated that 6.3 million deaths and 157 million disability-adjusted life years (DALYs) are attributable to tobacco smoking, including second-hand smoke. This represents more than one in ten deaths globally that are attributable to tobacco smoking.[2] Moreover, these non-communicable diseases for which tobacco is an important risk factor represent an increasing share of the global disease burden, especially in developing countries.[4]

Tobacco use is positioned to continue as an important risk factor for health and development in the coming decades. The number of deaths attributable to tobacco is estimated to increase to 8.3 million by 2030. And although tobacco-attributable deaths are projected to decline in high-income countries between 2002 and 2030, they are expected to double in low and middle-income countries.[5] The first step to addressing tobacco as a risk factor is understanding exposure to tobacco in populations.

Prevalence estimates are often used to quantify the impact of tobacco because prevalence is a "simple, timely, and powerful indicator."[6] Prevalence is a straightforward metric that measures the fraction of a population that uses tobacco. However, the epidemiology of tobacco is complex and dependent on many factors: frequency of smoking, length of time an individual has smoked, type of tobacco, and level of inhalation. This is further complicated by the fact that major health effects often appear several decades after the peak in smoking prevalence and consumption. Prevalence estimates do not capture all the complexities of tobacco use, especially in terms of intensity of smoking.

Many studies have shown a dose-response relationship between the duration and level of exposure to tobacco and negative health outcomes.[1,3,7] Thun et al. (2013) pooled data across five large US cohort studies and calculated relative risks of smoking according to the number of cigarettes per day among current smokers. Relative risks of death from lung cancer, COPD, ischemic heart disease, and all-cause mortality increased with increased intensity of smoking for both men and women. For example, men who smoke fewer than 10 cigarettes per day have a relative risk of death from lung cancer of 15.83 compared to non-smokers, which increases to 23.61 for men who smoke 10-19 cigarettes per day, 32.42 for men who smoke 20-39 cigarettes per day, and 41.72 for those who smoke more than 40 cigarettes per day.[1] Thus, the quantity of cigarettes smoked is an important determinant of tobacco health burden that is not captured by prevalence alone.

Tobacco consumption measures the impact of tobacco in terms of the average number of cigarettes consumed. Existing tobacco consumption estimates often draw on data sources that measure production, imports, exports, or tobacco tax revenues within a country, producing estimates of per capita cigarette consumption at the national level. The United Nations Food and Agriculture Organization (FAO) and the United States Department of Agriculture (USDA) have released production-based tobacco consumption estimates. This data has the benefit of being in a comparable format for

many countries and over time, but using these data does not allow consumption patterns to be explored by subpopulations within countries, such as different age groups or sexes. There are currently no robust estimates of tobacco consumption by age or sex across countries.

Population-based surveys of youth and adults that include questions on tobacco use offer a data source to explore patterns and trends in tobacco consumption. Prevalence estimates could be supplemented with estimates of tobacco consumption to give a more thorough picture of a country's tobacco exposure. Adding consumption information may be especially important to analyzing tobacco-related health burden and projecting future trends. This information becomes more meaningful when it is age and sex specific. It is important to understand these trends in tobacco exposure in order to allocate sufficient resources, identify high risk populations, and create targeted program interventions and meaningful public policy.

The objectives of this study are to examine how tobacco consumption patterns vary by age and sex, compare consumption and prevalence patterns, and compare national consumption estimates from survey data with national consumption estimates from production-based sources.

Methods

Data sources

Three major survey families that include questions on tobacco consumption and have available microdata were included in the analysis. These are the Global Adult Tobacco Survey (GATS)[8], World Health Organization STEPwise approach to Surveillance (STEPS)[9], and the World Health Organization World Health Survey (WHS)[10]. Table 1 summarizes the number of observations included from each survey family.

These are household surveys that include an initial question on whether an individual is a daily smoker and follow-up questions on tobacco consumption. We calculated prevalence of daily smokers by age and sex. Those who report being daily smokers are asked about frequency of use and type of tobacco consumed. In some countries with very low smoking prevalence among women, there are few female responses to the tobacco consumption questions so some age-sex groups with insufficient sample sizes were not included in the final analysis.

Individual responses about different types of tobacco were combined in order to measure total cigarettes of any type (e.g. manufactured or hand-rolled) or cigarette equivalents (e.g. pipes full of tobacco or other tobacco) per day. Although manufactured cigarettes are the most common form of tobacco used worldwide,[11] tobacco can be smoked in many other forms including cigars, cigarillos, pipes, waterpipes, kreteks (clove cigarettes), or bidis (small cigarettes hand-rolled in a temburni or tendu leaf). Bidis are popular in India and other parts of South Asia and kreteks are the most common tobacco product consumed in Indonesia.[11,12] Waterpipes (also known as "shisha" or "hookah") are popular in North Africa, the Eastern Mediterranean region, and Southeast Asia.[12,13] Tobacco can also be

consumed in smokeless forms, mainly as chewing tobacco or snuff. Chewing tobacco is most prevalent in South and South East Asia.[12]

Responses within a survey were categorized by gender and the following age groups: 15-24, 25-34, 35-44, 45-54, 55-69, and 70+. Survey weights were used where available to calculate the average cigarette equivalents per smoker per day for each age-sex group within a survey, resulting in 1067 age-sex specific data points for 103 countries. The dataset includes observations within each of seven super regions, as defined in the Global Burden of Disease 2010[14], with the most data available for countries in East Asia/Pacific, Sub-Saharan Africa, and Eastern Europe/Central Asia.

To compare survey-based measures of consumption to national production-based measures of consumption we used data from the US Department of Agriculture (USDA). The USDA measures all tobacco (domestic and foreign) used by the domestic manufacturers, including discarded, destroyed, and unaccounted for tobacco. Consumption is estimated as production plus imports minus exports. USDA consumption data was available for 174 countries for 1960 through 2005. In order to create a complete time series for all countries for 1960 through 2011, we applied a spatial-temporal regression followed by a Gaussian process regression (GPR) following methods detailed by Hogan et al.[15] and Foreman et al.[16]

Consumption by age and sex

To explore trends in consumption by age and sex we ran separate linear regressions for males and females as follows:

$$\log(cigs_a) \sim \beta_0 + \beta_1\, age2 + \beta_2\, age3 + \beta_3\, age4 + \beta_4\, age5 + \beta_5\, age6 + \beta_6\, country$$

Where *log(cigs)* is the logged average cigarette equivalents per smoker per day for age group *a*. The a*ge* variables are dummies for each age group where *age1* is 15-24, *age2* is 25-34, *age3* is 35-44, *age4* is 45-54, *age5* is 55-69, and *age6* is 70+. Age dummies for each age group were used to avoid forcing a functional form over age and to allow for a non-linear relationship in consumption by age. The youngest age group is the absorbed category so all other age groups are analyzed in relation to *age1*. We included a random effect and random coefficients on *country* to examine different trends and levels of consumption by country and to account for correlation between repeated samples from a single country. Regressions were weighted by the inverse variance of each age-sex specific observation. Regression results were used to predict consumption for each age group, sex, and country within our sample.

Comparison with prevalence

We compared consumption results to the prevalence of daily smokers for each age and sex group within the same survey by scattering consumption estimates against prevalence estimates. We stratified results by age to avoid confounding. To explore the relationship between consumption and prevalence by age we ran separate linear regressions by sex and age group as follows:

$$\log(cigs) \sim \beta_0 + \beta_1\, prevalence + \beta_6\, country$$

Where *prevalence* is the fraction (0 to 1) of the population in that age and sex group who are daily smokers. We included a random effect and random coefficients on *country* as in the previous model. Regressions were weighted by the inverse variance of the consumption estimate for each age-sex specific observation.

We also calculated correlation coefficients between consumption and prevalence for each age-sex group.

National consumption comparison

Among the 136 surveys analyzed, 20 surveys representing 16 countries had sufficient sample sizes in each age-sex group to estimate consumption and prevalence across all six age groups for males and females in that country. The 20 surveys were nationally-representative and the consumption and prevalence estimates were combined with age and sex-specific population numbers from the Global Burden of Disease 2010 (GBD)[14] to calculate national cigarette equivalents per capita. There was at least one survey included from each of the seven GBD super regions.

These survey-based national consumption measures were compared to the national consumption estimates from the USDA. We calculated correlation coefficients between the survey-based and production-based (USDA) national consumption results.

All analyses were conducted in Stata 11.2 and R 3.0.1.

Results and Discussion

Consumption by age and sex

For men and women, there is a similar and significant age pattern for tobacco consumption. Consumption increases with age and peaks in middle age (45-54 years) before declining in the oldest age groups. This peak in consumption is more pronounced in men than in women. Across the sample of included countries, men aged 45-54 years have an average tobacco consumption that is 32.3% (95% CI 27.9 - 36.9%) higher than men aged 15-24, whereas women aged 45-54 have an average consumption 17.9% (8.4 – 28.2%) higher than women aged 15-24. After peaking in the middle ages, consumption in men declines in those over age 70 to a level that is not significantly different from ages 15-24. Women over age 70 have a significantly lower consumption level than women ages 15-24. We would expect to see declining consumption levels in the oldest ages as individuals who are heavier smokers die off after years of high consumption. Varying consumption levels by age may also reflect a cohort effect, where birth cohorts have different consumption patterns that are not obvious when viewing cross-sectional data. These age trends are illustrated in a summary of the model outputs for the regression of consumption on age in Table 2.

We used the model outputs to predict the level of consumption for men and women within each age group for all countries included in our analysis (in-sample prediction), as shown in Figures 1 and 2. These figures illustrate the age pattern, with consumption increasing in most countries for ages 15-54 and then decreasing after age 55. These figures also illustrate that in nearly all included countries women tend to have lower levels of consumption than men, with the exception of Ecuador, Bhutan, Nauru, and Vanuatu. However, included countries are predominantly developing and this trend may not hold in developed countries that are not included in this analysis. In terms of smoking prevalence, there is less than a twofold difference between men and women in developed countries, but a sevenfold difference in developing countries.[17]

The gender differential in tobacco consumption is especially pronounced in countries in North Africa / Middle East where men tend to have much higher consumption levels than women. For example, among ages 45-54, the largest absolute differences are seen in Tunisia, Occupied Palestinian Territory, and Kuwait where cigarette equivalents per smoker per day are 18.7 for males and 4.7 for females, 21.6 for males and 11.1 for females, and 21.1 for males and 11.4 for females, respectively. This is consistent with other studies that have shown much higher smoking prevalence in men as compared to women in this region.[17] Tobacco smoking is socially acceptable among men in the Middle East, where cigarettes are commonly offered to guests and are smoked in markets and cafes. However, female smoking is stigmatized, and in some countries women have restricted access to these public spaces where tobacco is commonly used.[17,18]

Figures 1 and 2 illustrate strong regional patterns in tobacco consumption. Consumption levels are highest in Eastern Europe and Central Asia and lowest in Sub-Saharan Africa. And, as stated, North Africa/Middle East has high consumption among males but low to moderate consumption among women. Although the data is not representative to be aggregated to the regional level, country findings are consistent with regional consumption patterns that other studies have shown.[19,20] The 2012 *Tobacco Atlas* estimates that 48% of all cigarettes are consumed in the Western Pacific region, stretching from Mongolia and China in the north down to Australia and New Zealand. Another 24% of the world's cigarettes are consumed in Europe, 11% in the Americas, 8% in South-East Asia, 6% in the Eastern Mediterranean, and only 3% are consumed in Africa.[19]

Among the countries included in the analysis, Table 3 lists the 10 countries with the lowest tobacco consumption by age and sex and Table 4 lists the 10 countries with the highest tobacco consumption by age and sex. The majority of countries with the lowest levels of consumption for both men and women are in Sub-Saharan Africa, with Mauritania, Congo, Mali, and Malawi among the lowest. The countries with the highest levels of consumption are predominantly in Eastern Europe/Central Asia for men and women, as well as in North Africa/Middle East for men. Many countries in sub-Saharan Africa have low consumption because they are not completely drawn into the global tobacco economy, although this is changing and consumption is increasing in many African countries.[21] High consumption in Eastern Europe may be due to social norms around adult smoking, limited tobacco control and enforcement in many countries, and generally low tobacco taxes and cigarette prices.[22]

Nauru, the world's smallest island nation with a population of 10,000[23] in Micronesia in the South Pacific, has the highest consumption across all age groups for females and the third highest consumption across all age groups for males, although there are large uncertainty intervals especially in the oldest ages for women. The data for Nauru is from a 2004 STEPS survey and the very high levels of consumption are consistent with the Nauru NCD Risk Factors STEPS report based on this same data.[24] In addition to high consumption, there are very high levels of prevalence with male prevalence upwards of 40% in ages 15-54 and female prevalence upwards of 50% in ages 25-54. The prevalence results are consistent with the *WHO Report on the Global Tobacco Epidemic, 2013* that reported 45.5% prevalence for adult men and 50.8% for adult women in Nauru.[25]

Including a random effect and random coefficients on country in our model allowed the average age trends to vary by country. Figure 3 includes maps of the country-level random coefficient for each age group for men and Figure 4 includes maps of the country-level random coefficient for each age group for women (excluding ages 15-24 which is the absorbed category in the regression). Examining the country random coefficients reveals whether the observed age pattern is different by country when we control for overall mean consumption differences between countries. Countries that have a random coefficient close to one follow the average age pattern, those with a random coefficient closer to zero have a flatter age pattern, and those with a random coefficient greater than one have a more dramatic age pattern.

Figures 3 and 4 illustrate that there is more country-level variation in the oldest ages and there is more country-level variation for women than for men. This country-level variation is also shown in the regression output in Table 5 where the standard deviations for the country random coefficients on age are higher in women than men and higher at older ages.

Comparison with prevalence

This is the first multi-country demonstration of how prevalence and consumption interact. This analysis reveals that there is a positive relationship between consumption and prevalence as shown in the age-specific graphs for men in Figure 5 and women in Figure 6. In the age-specific regressions of prevalence on consumption, prevalence is positively associated with consumption in all age groups except the oldest (ages 70+) for men and women (Table 6). The correlation coefficients between prevalence and consumption are shown in Table 7. There is a stronger relationship between prevalence and consumption for males and in younger ages. This may be because at the oldest ages the heaviest smokers are not captured by surveys because they are dying off which decreases prevalence and consumption measures.

In the comparison with prevalence we see similar regional trends to those that were seen in consumption alone. Sub-Saharan Africa has low consumption and low prevalence across countries, Eastern Europe has high prevalence and high consumption, and North Africa/Middle East has high prevalence and high consumption among men but low prevalence and moderate consumption among women. A recent systematic review of 55 published articles on smoking prevalence in sub-Saharan adult populations confirmed that prevalence is relatively low compared to developed and other

developing countries. The analysis also showed a similar male age pattern to our findings; male prevalence peaks between ages 30-49, and then declines, but this age pattern was not as consistent across studies for females.[26] In a separate study, Hosseinpoor and Parker used WHS data to examine age patterns in the prevalence of tobacco use and found a similar age pattern to what we found for consumption. They looked across all types of smoking tobacco and found that for both men and women prevalence increases with age until age 50, and then decreases in the oldest ages. This pattern was consistent for men and women in middle-income countries and for men in low-income countries, however they did not find a decline in prevalence of smoking for women at the oldest ages in low-income countries.[27] This similar age pattern would explain the strong correlation we find between measures of prevalence and consumption.

National consumption comparison with USDA

Among the 20 surveys that could be used to calculate national consumption, there is a fairly consistent relationship between the per capita consumption calculated from survey measures and the per capita consumption reported by the USDA. This relationship is illustrated in Figure 7 and is moderately strong with a correlation coefficient of 0.7175 (p=.0004).

Turkey, Poland, and Spain are notable outliers where the production-based estimates are significantly higher than the survey-based estimates. Since the survey estimates are based on self-reported tobacco use, this may be due to smokers underestimating how much they smoke. Studies have shown that survey data underestimates prevalence of smoking and consumption among smokers, especially at the youngest ages.[6] In this analysis tobacco consumption was calculated among daily smokers with the assumption that all other individuals over age 15 in a population consume zero cigarette equivalents. Countries with a high prevalence of occasional smokers would cause the survey-based measure to underestimate true national consumption per capita. And although we analyzed consumption across types of tobacco, these tobacco use questions are only asked to daily smokers and may miss individuals who are regular users of other forms of tobacco.

Bangladesh and Laos are notable outliers where the survey-based estimates are significantly higher than the USDA estimates. The Laos estimate is based on a nationally-representative 2003 World Health Survey which shows consumption numbers that are consistent with a 2008 subnational STEPS survey in Vientiane, the capital city. However, prevalence calculated from the 2003 WHS for men is very high, upwards of 60 percent in all age groups over 35, which is much higher than the 42.6 percent all-age prevalence of daily smokers as reported by the WHO[29] and may be responsible for driving up national consumption estimates.

The Bangladesh estimate is also based on a nationally-representative 2003 World Health Survey which shows very high prevalence for men and women. Male prevalence is upwards of 50% in ages 25-69, reaching nearly 70% in ages 35-54, and female prevalence increases with age to over 45% after age 45. These results are much higher than those from a 2009 Global Adult Tobacco Survey in Bangladesh that was also included in the analysis, especially for women where prevalence was less than 6% in all age

groups. However, the male prevalence estimates from the 2003 WHS are comparable to those from a 2007 Demographic and Health Survey (DHS) in Bangladesh that found that 69.3% (67.2 - 71.5%) of ever-married men aged 15-49 use tobacco. Tobacco questions were not included in the women's 2007 DHS questionnaire in Bangladesh.[12]

Non-manufactured cigarettes may not be captured in measures of production, imports, or exports and could lead to survey-based estimates that are significantly higher than production-based estimates. Survey-based estimates may also differ from production-based estimates if popular tobacco products contain less tobacco than a typical manufactured cigarette. For example, kreteks are produced with a mixture of tobacco (60-80%) and ground clove buds (20-40%)[30] and bidis contain a small amount of finely-ground tobacco. Kreteks and bidis have less tobacco than manufactured cigarettes so the aggregate amount of tobacco may underestimate the number of cigarettes.[31] Finally, home-grown tobacco would not be captured in production-based measures and could lead to underestimates.

Limitations

This analysis is based on all available data from three survey families: the WHS, GATS, and STEPS. While this has the benefit of using data based on fairly standardized and comparable questionnaires, it limits the amount of data we could include. A subset of surveys was not nationally representative and most surveys included survey weights, but where these were not available we presented un-weighted results. The survey families have data primarily from low and middle income countries, and 91 of the 103 countries included were classified as developing. Historically, cigarette consumption has been highest in high-income countries but now it is decreasing with new tobacco control policies in response to an increased understanding of the harmful effects of tobacco. At the same time, consumption is increasing in low and middle-income countries due to economic development, population increases, targeted marketing, and increased social acceptability.[19] Although there was limited data included for developed countries, examining trends in developing countries is important because the WHO projects that by 2030, more than 8 in 10 deaths attributable to tobacco will occur in low and middle-income countries.[32]

There were sufficient surveys included to explore trends across regions, with data available for each of the GBD super regions. However, the results are dependent on what countries had available surveys and are therefore not intended to be regionally representative. Despite this limitation, the country-level results within regions are consistent with other research on regional trends.

Using microdata, individual responses about different types of tobacco could be combined to measure tobacco usage across all types of tobacco. This creates a comparable framework and takes into account that different forms of tobacco are more popular in different regions. It will be increasingly important to capture the consumption of all types of tobacco, as types other than manufactured cigarettes gain popularity. Sales of smokeless tobacco increased by 59% worldwide between 2000 and 2010.[19] The waterpipe has always been popular in the Middle East, but is gaining popularity in many other regions of the world.[33] Other tobacco types are also becoming more popular in the younger generation. An analysis of Global Youth Tobacco Surveys (GYTS) among students ages 13-15 years in 131 countries between 1999 and 2005 showed that use of other tobacco products (such as chewing tobacco, snuff,

cigars, cigarillos, pipe, bidis, waterpipe, etc.) is as high as, or higher than, cigarette smoking in all regions of the world except the Americas and Europe.[34] However, analyzing consumption across all tobacco types does not address that different tobacco products may have different, more or less severe, health effects. For policymakers it may be helpful to understand the breakdown of different types of tobacco by age and sex within a country.

Although we analyzed consumption across types of tobacco, most surveys are designed to only ask frequency and type of tobacco use questions to daily tobacco smokers and may miss individuals who are regular users of other forms of tobacco. This may not be an issue in most countries, as a separate analysis of the GATS data by Giovino and colleagues (2012) found that in most countries prevalence of any current tobacco use was similar to prevalence of current smoking. However, India and Bangladesh were notable exceptions where many non-smokers use smokeless tobacco.[11] Indeed, South Asia has the highest use of smokeless tobacco worldwide.[35]

The data included in the analysis spanned the years 2002 through 2012, however we did not control for year of the source data. We examined patterns by year (data not shown) and found that there was not a strong year effect. Future research should examine consumption data by age and sex over a much longer time period to explore cohort trends in consumption. And although we used the most recent data available, prevalence and consumption patterns can change rapidly with targeted tobacco interventions. For example, between the 2008 GATS and a follow-up 2012 GATS in Turkey, there was a relative decline in smoking prevalence of 13.5% among men and 13.7% among women. The WHO has attributed this to Turkey's comprehensive tobacco control efforts which include raising taxes on tobacco, enforcing bans on tobacco advertising, and anti-tobacco mass media campaigns.[25]

Finally, the results of this study show that there is a significant consumption age pattern and a strong association between consumption and prevalence, but this analysis does not attempt to explain these findings. From the available data it is impossible to determine whether the relationship between consumption and prevalence is causal or what may be driving this trend.

Conclusions

Monitoring and evaluation of tobacco use is essential to understand the tobacco epidemic and to determine how to best address it. Despite the recognition that tobacco use is an important risk factor for health, global tobacco surveillance has regressed. There are 96 countries that have not collected any tobacco data in the last five years, or have not collected representative data, and another 45 countries that conducted recent surveys but have not done so regularly so that trends can be examined. This represents 4.2 billion people, or roughly 60% of the world's population, that are inadequately covered by effective tobacco surveillance.[25] Fewer than one third of countries have recent, representative, and periodic tobacco data for adults and youth in order to adequately monitor the tobacco epidemic.[25] The *WHO Report on the Global Tobacco Epidemic, 2013* emphasized the importance of monitoring tobacco use to understand the tobacco epidemic, how to best address it, and what impact tobacco control measures have had on consumption.[25]

Not only do we need more countries participating in tobacco monitoring, but we need smarter tobacco monitoring. To understand the public health toll of tobacco use, it is important to examine the quantity of cigarette smoking within countries. Large survey families should consistently ask questions about tobacco consumption, taking into account different types of tobacco. Even a single additional question about total cigarette equivalents consumed could add important new data to our understanding of consumption patterns.

There are significant age and sex patterns for tobacco consumption within countries. Using the standard production-based national estimates of per capita tobacco consumption masks these trends which could be important to direct resource allocation, identify high risk populations, or inform public policy. Understanding whether the bulk of a country's consumption is in the youngest age groups versus the oldest is essential to plan for future strain on the health system since the effects manifest several decades later. There are additional data sources about tobacco consumption that could be added to this analysis to include a wider breadth of countries and determine if the same global age patterns hold.

We have shown that production-based national consumption estimates and survey-based national consumption estimates are a fairly good approximation. This is a new and important finding that is contrary to the conventional wisdom that production-based estimates are roughly twice as high as survey-based estimates. In the absence of survey data on consumption for all countries, regional age and sex patterns could be applied to production-based national consumption numbers to estimate consumption by age and sex. Future research should determine whether consumption is a good predictor of health burden at the individual level. Then consumption and prevalence could be combined into a single metric to more thoroughly examine population exposure to tobacco.

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Figures

Figure 1. Tobacco consumption (average cigarettes per smoker per day) in males, by age group: (A) 15-24, (B) 25-34, (C) 35-44, (D) 45-54, (E) 55-69, (F) 70+

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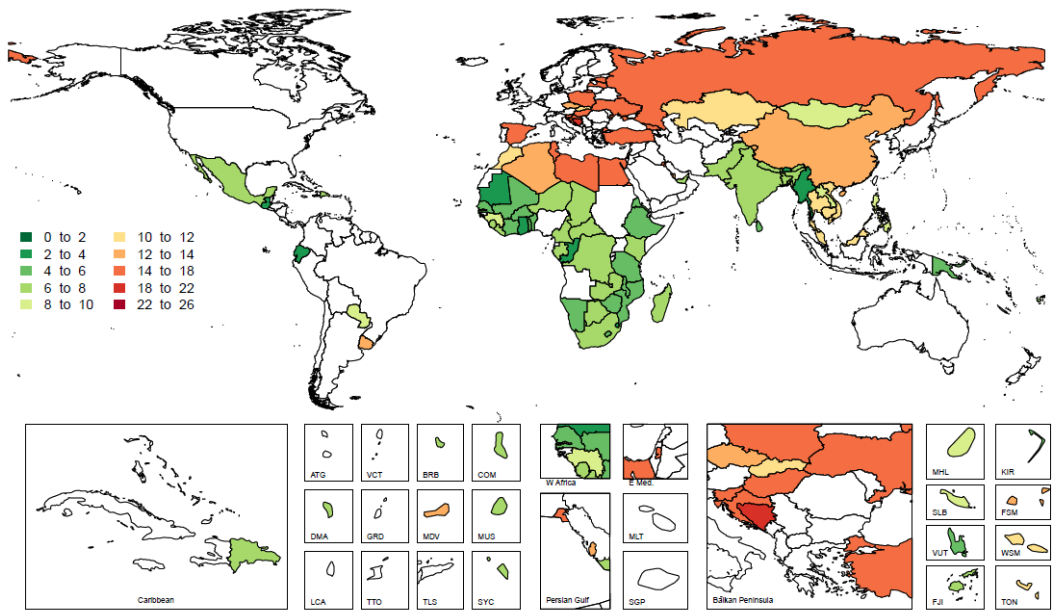

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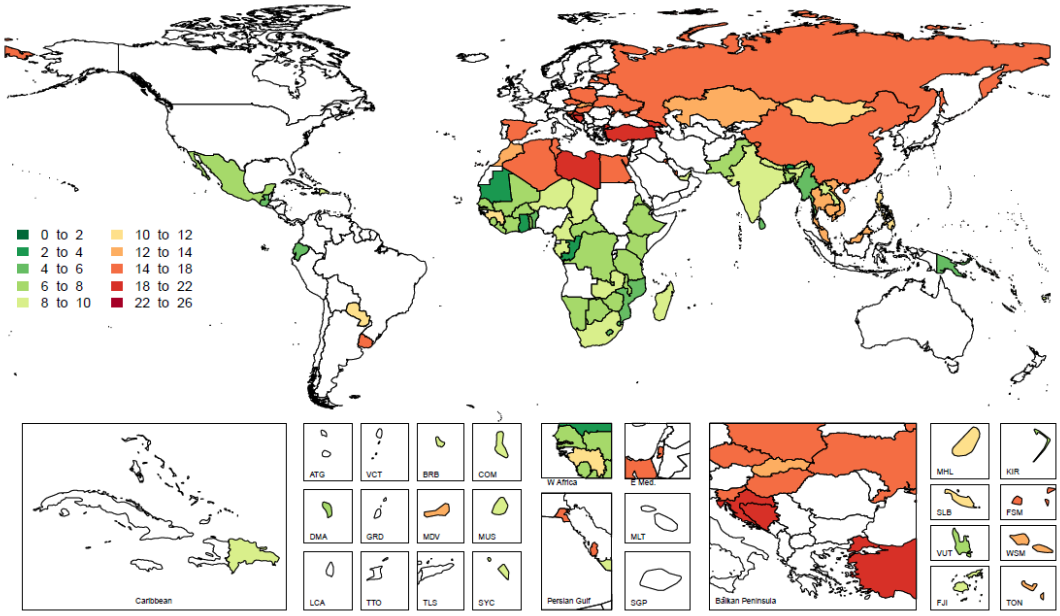

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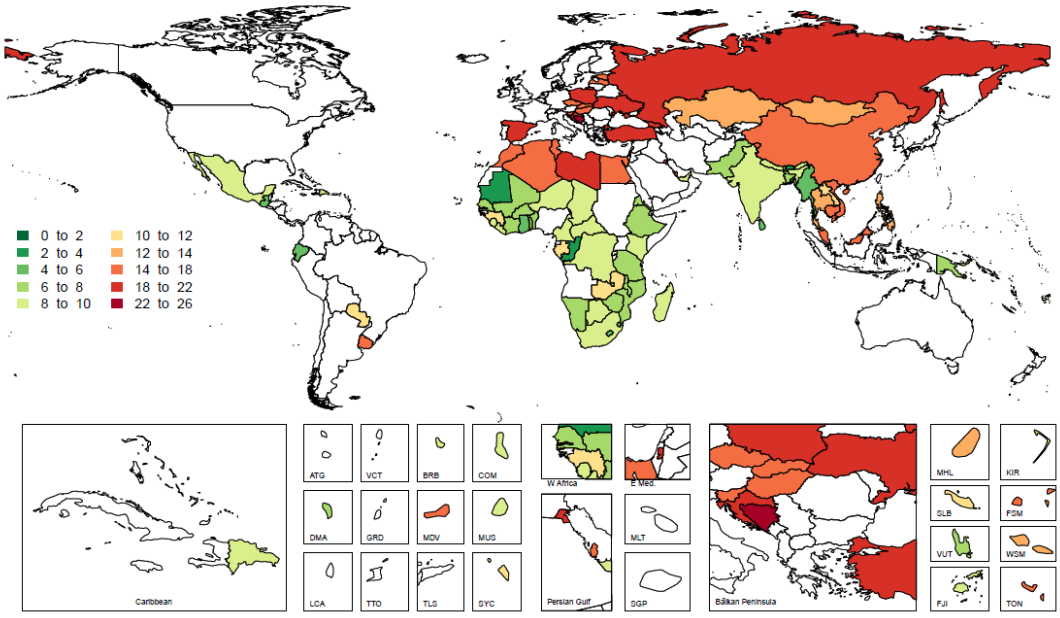
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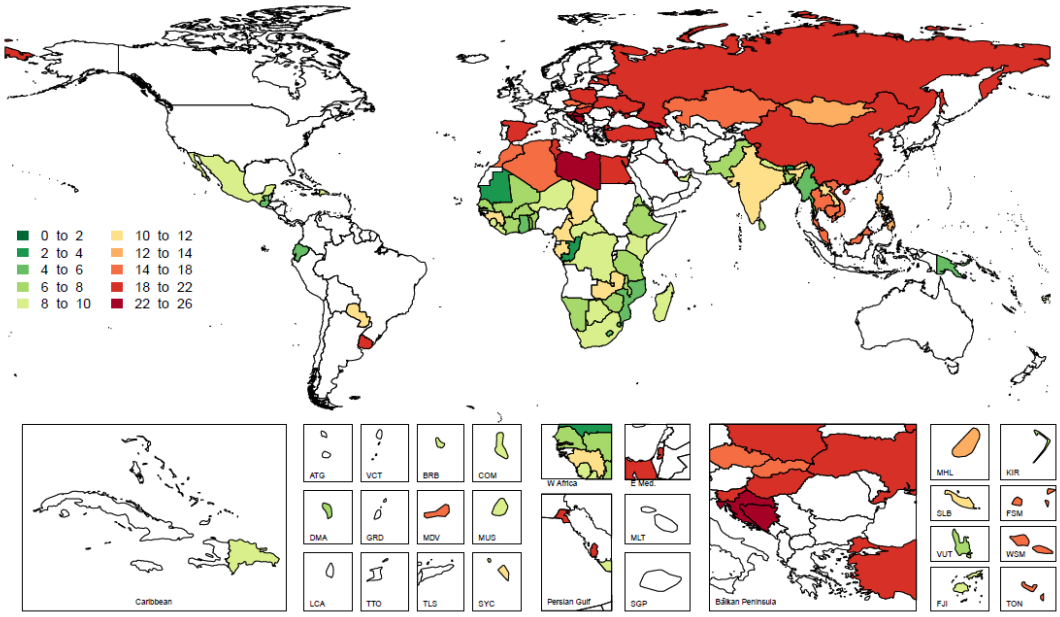
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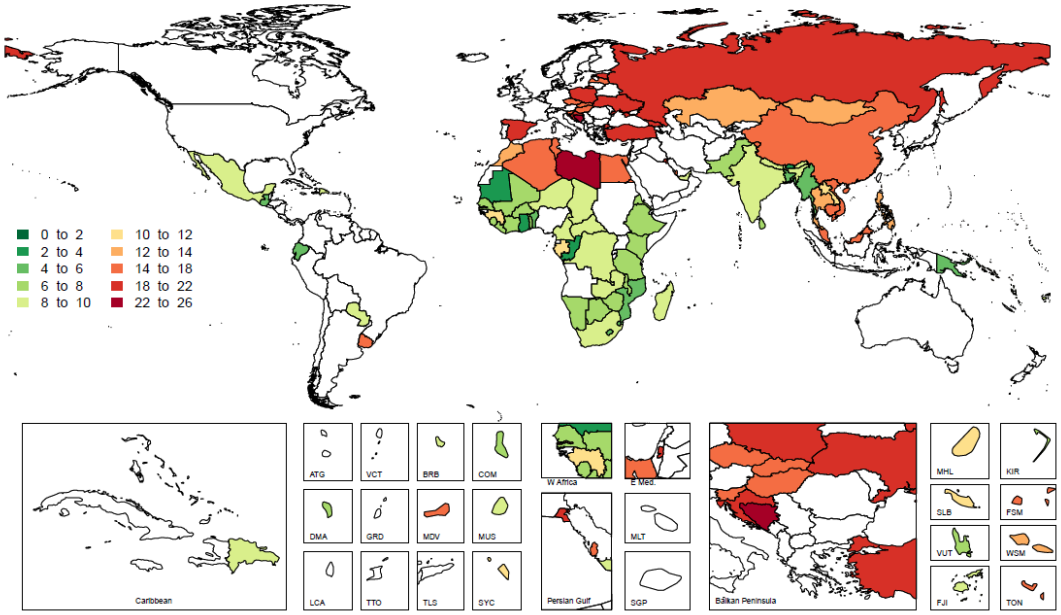
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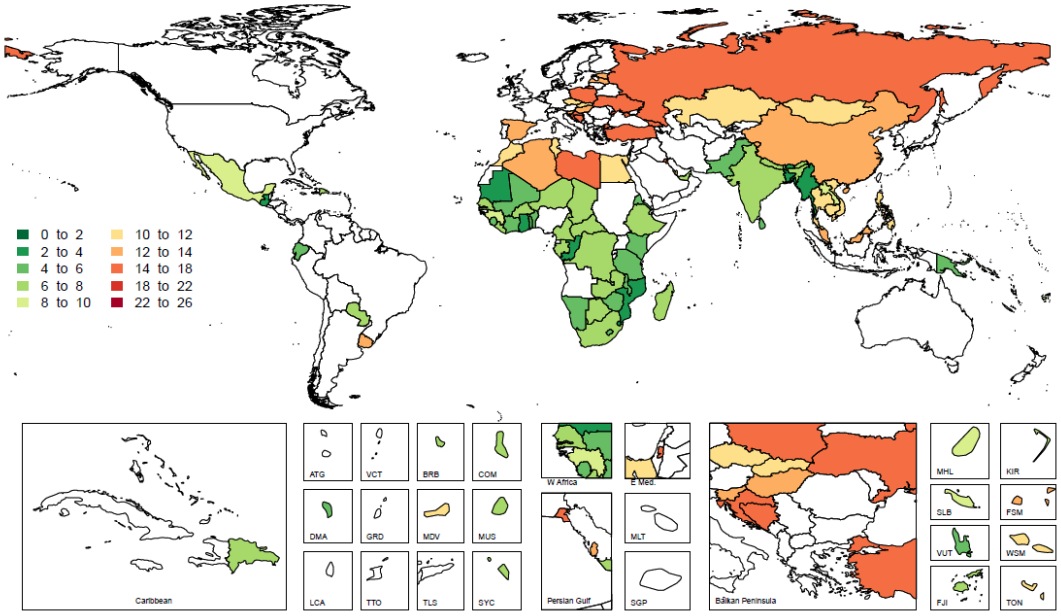
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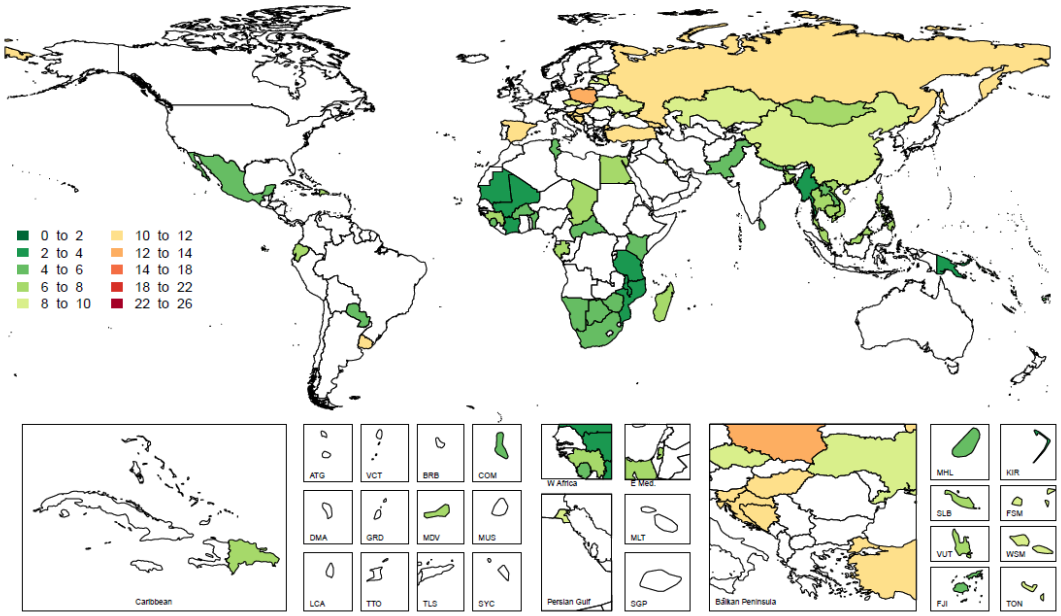
Figure 2. Tobacco consumption (average cigarettes per smoker per day) in females, by age group: (A) 15-24, (B) 25-34, (C) 35-44, (D) 45-54, (E) 55-69, (F) 70+

(A)



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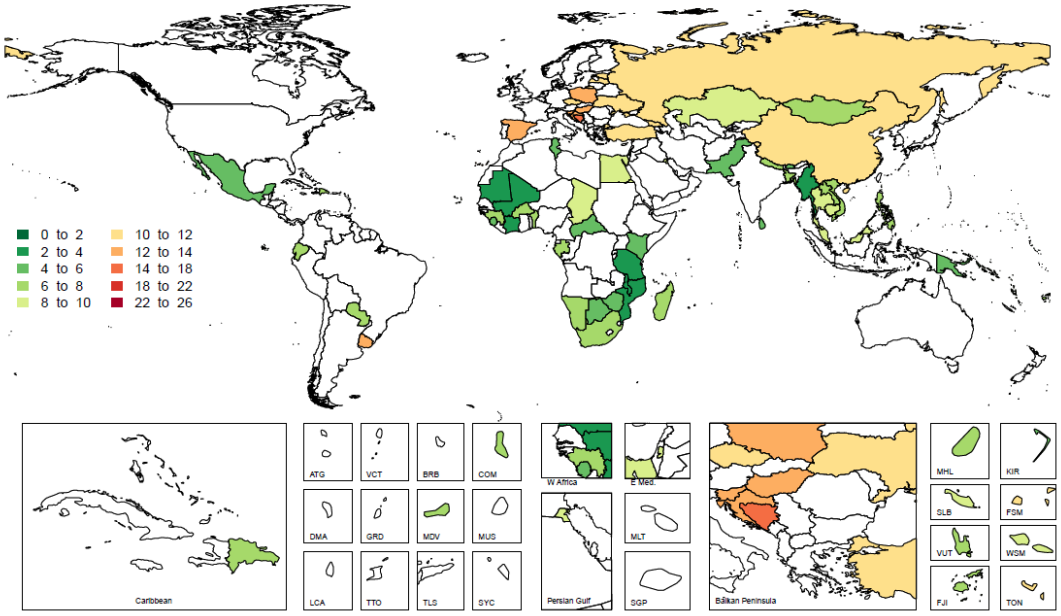

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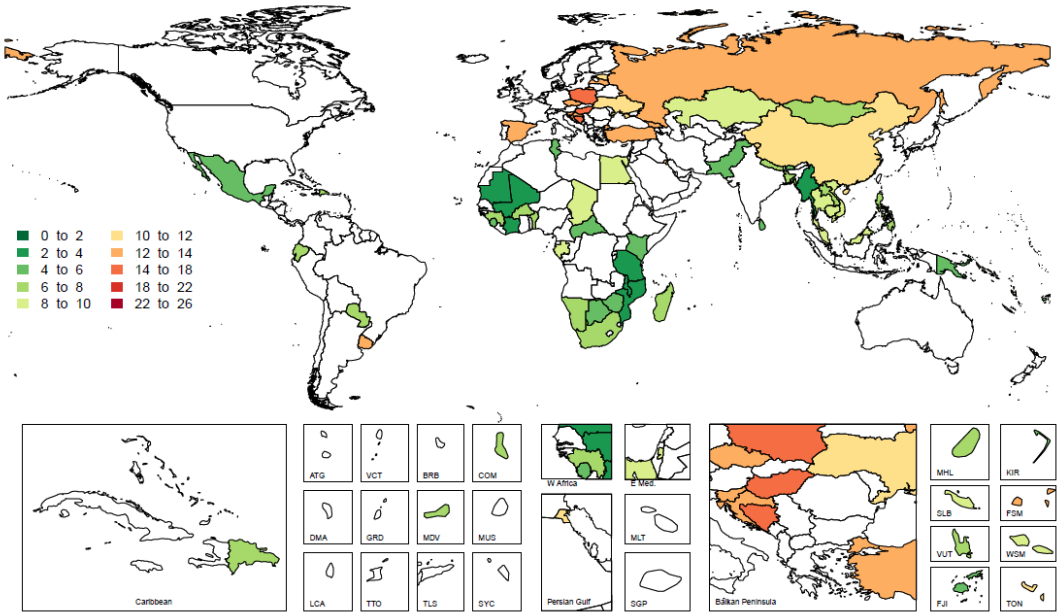
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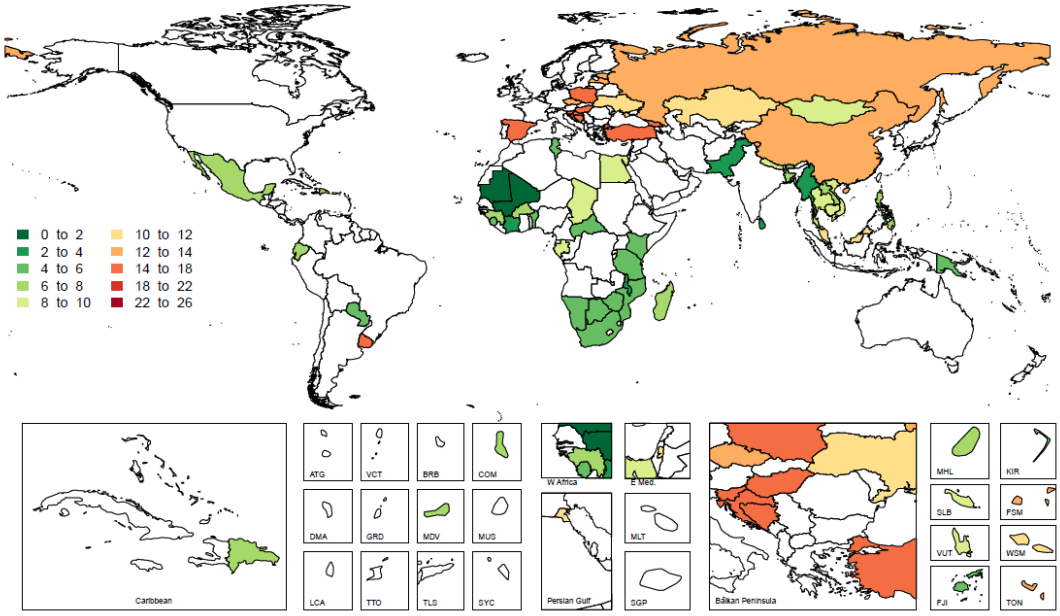
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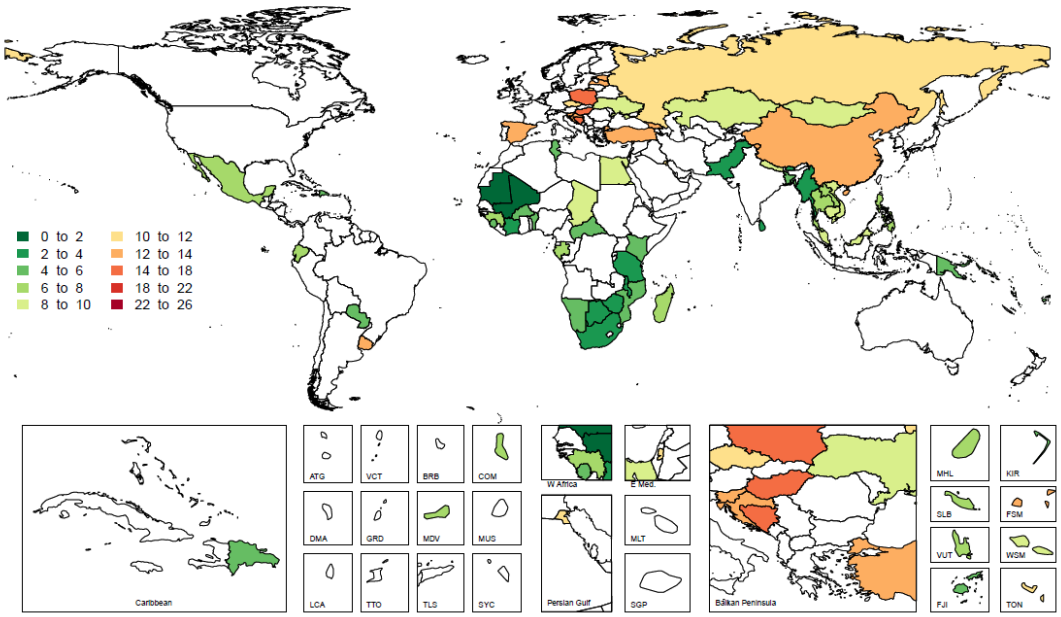
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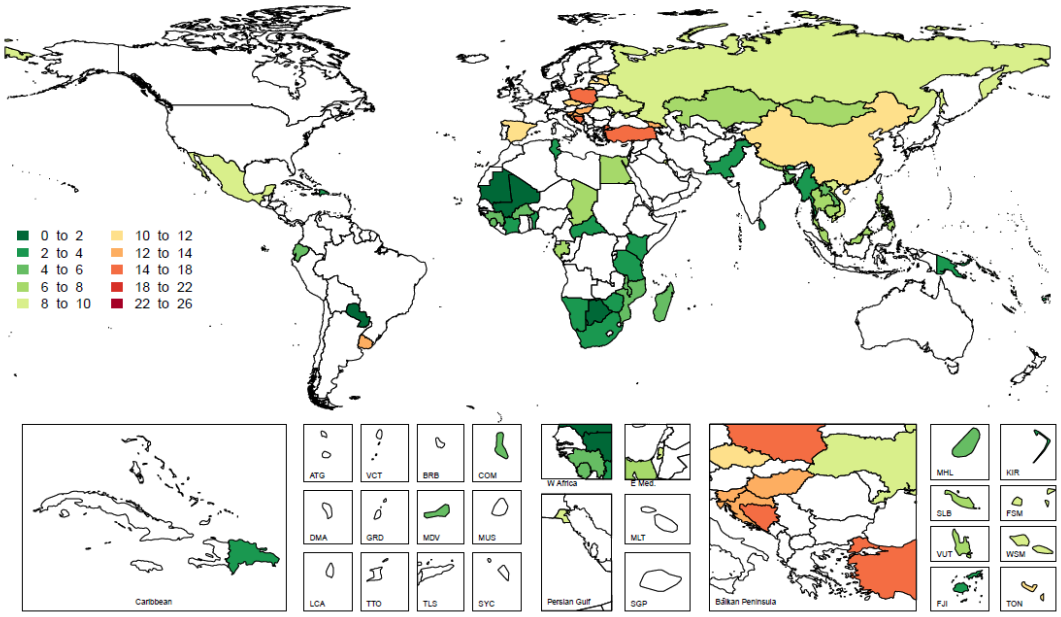
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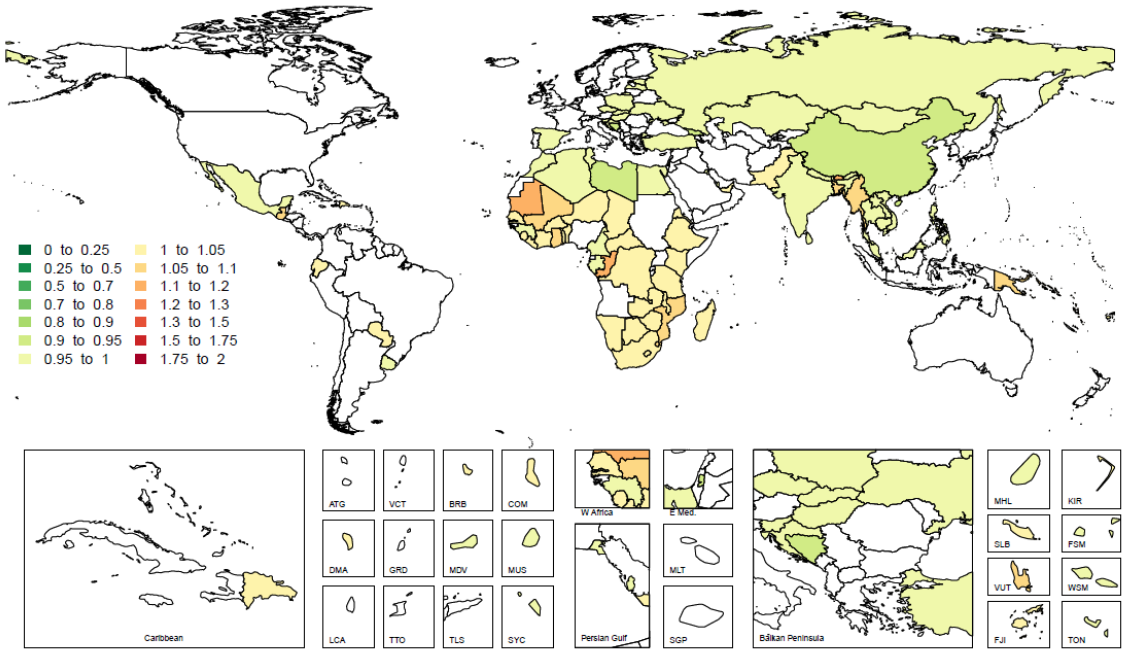
Figure 3. Map of country-level variation in the relative age pattern for males by age group: (A) 25-34, (B) 35-44, (C) 45-54, (D) 55-69, (E) 70+[1]

(A)



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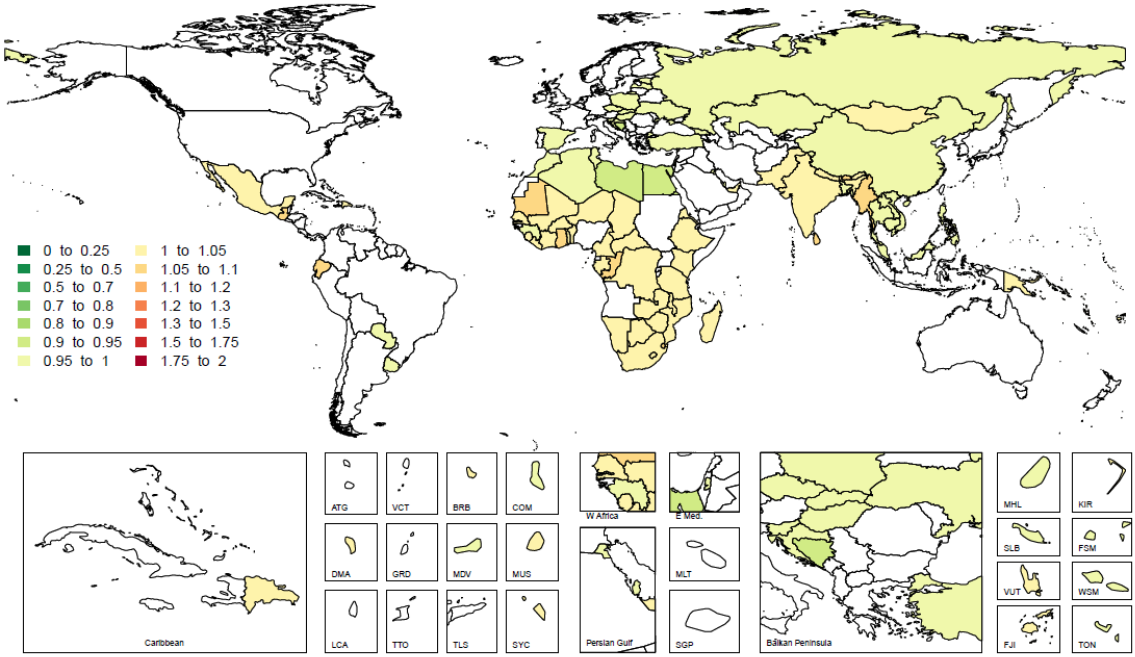
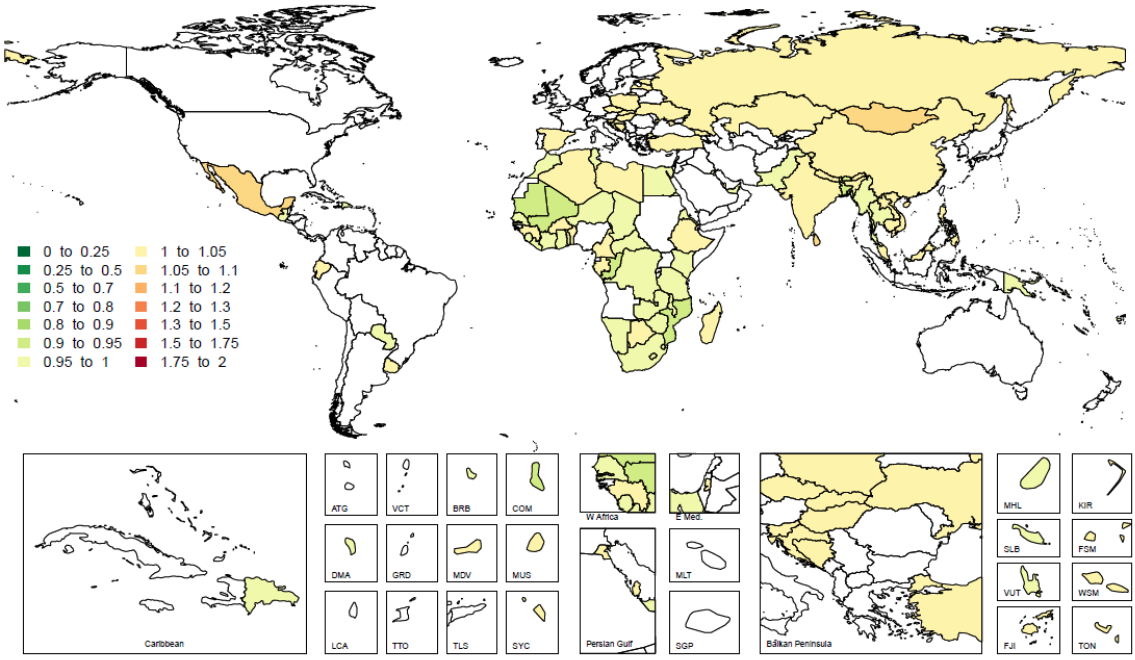


[1] Each country is colored according to the country random coefficient on age from the sex-specific regression of age group on consumption. Countries that have a random coefficient close to one follow the average age pattern, those with a random coefficient closer to zero have a flatter age pattern, and those with a random coefficient greater than one have a more dramatic age pattern.

(C)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1.2 to 1.3
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1.5 to 1.75
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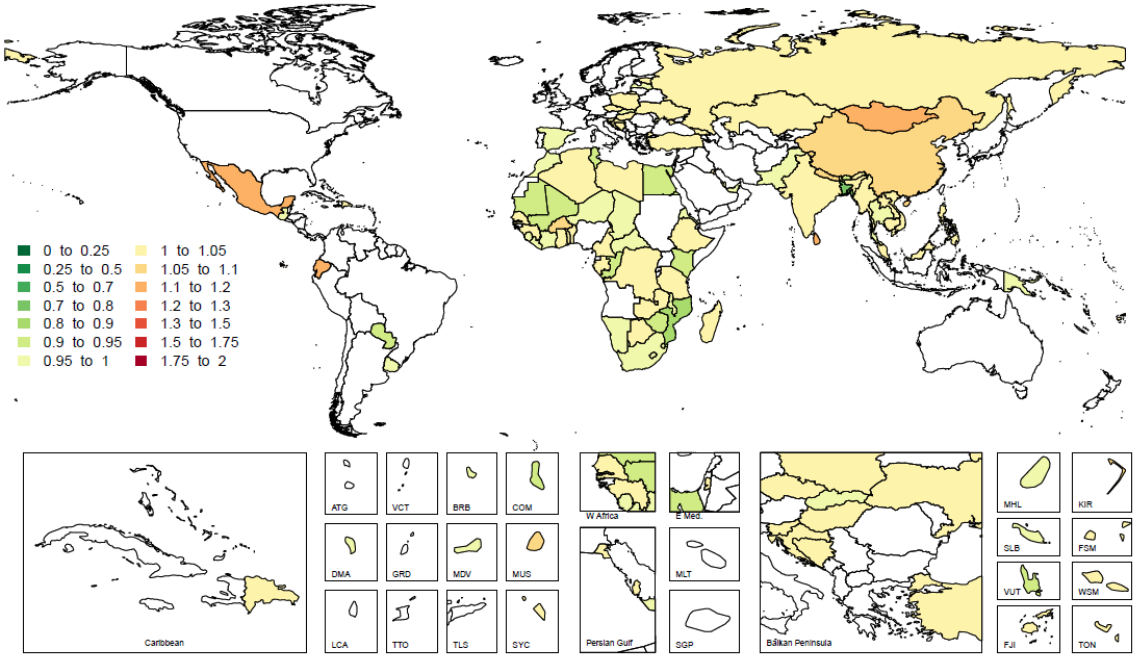
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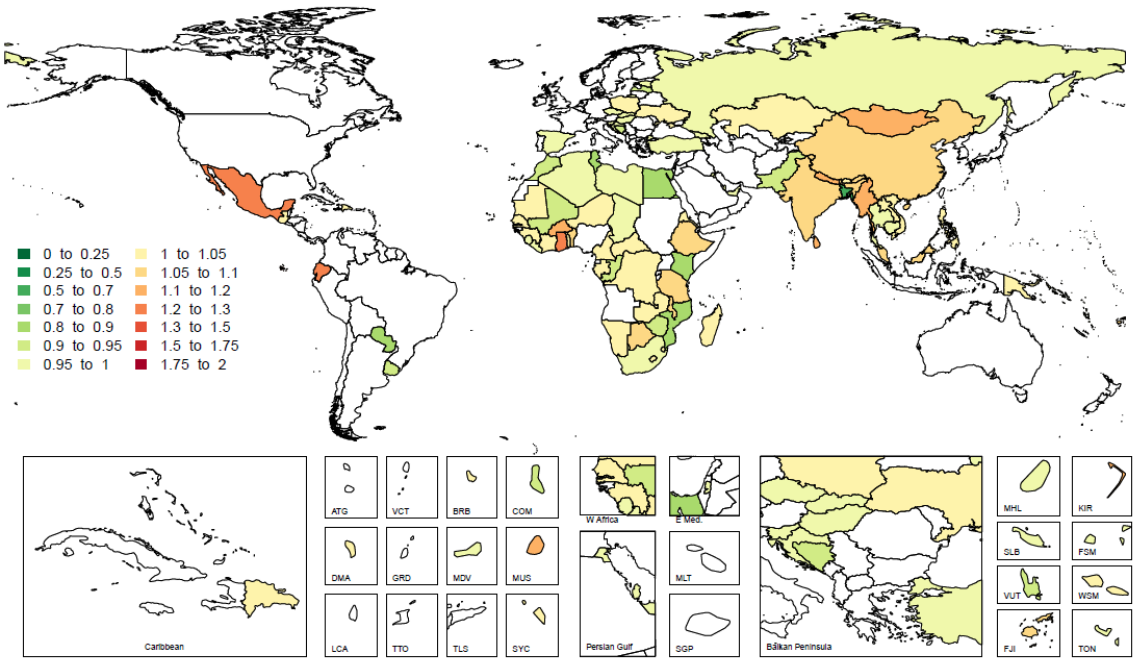
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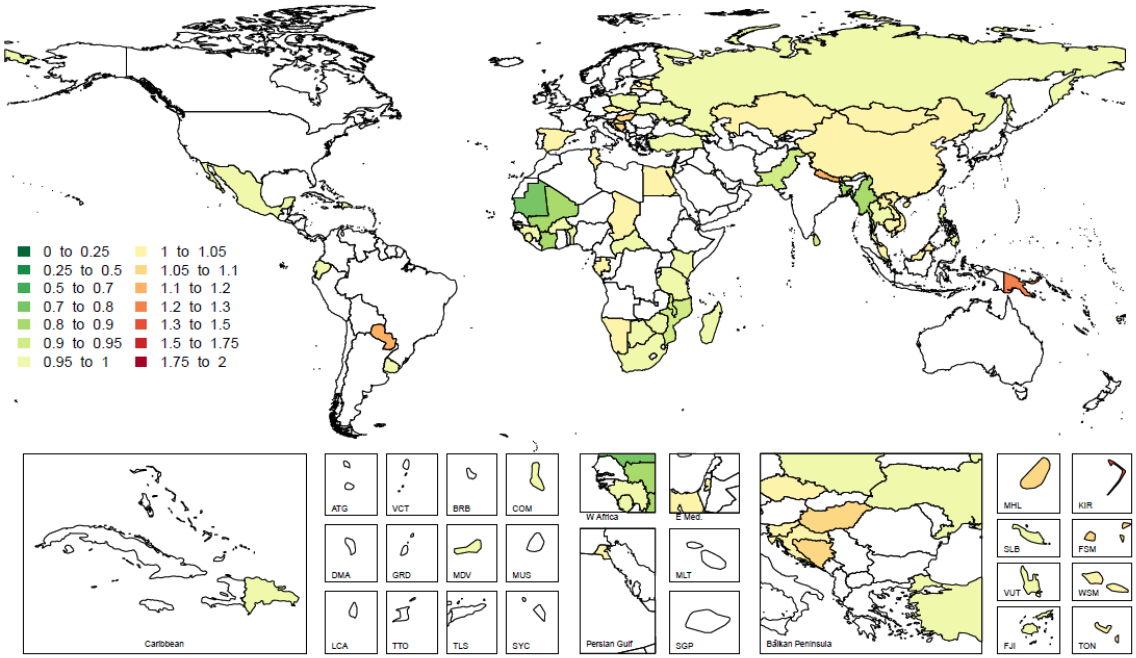
Figure 4. Map of country-level variation in the relative age pattern for females by age group: (A) 25-34, (B) 35-44, (C) 45-54, (D) 55-69, (E) 70+[2]

(A)



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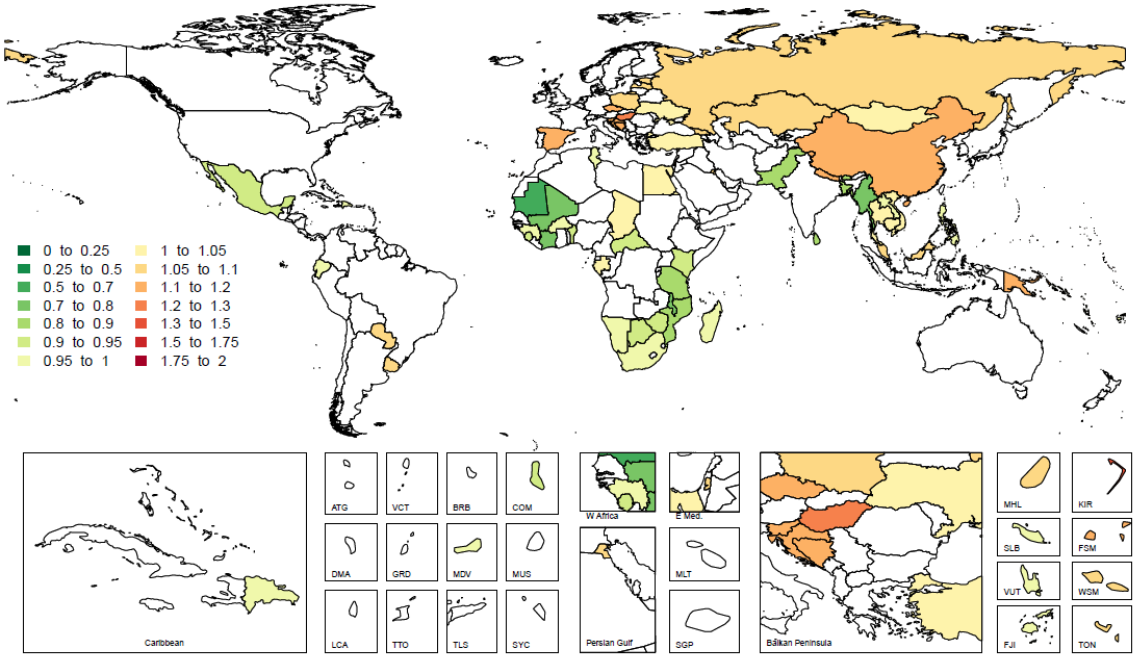
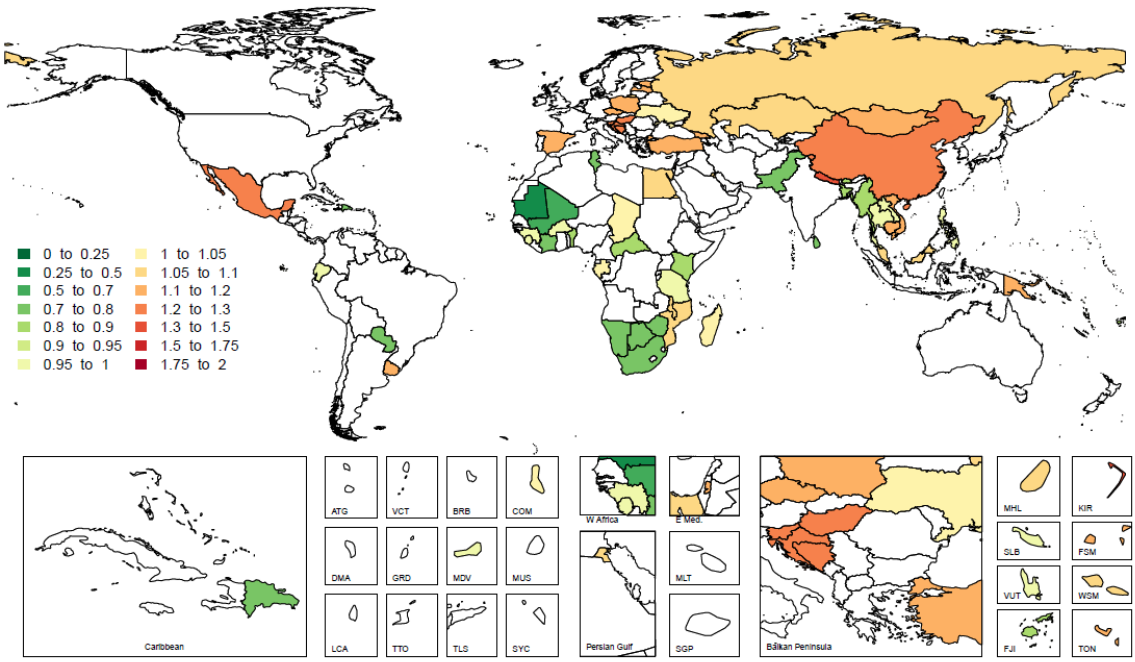


[2] Each country is colored according to the country random coefficient on age from the sex-specific regression of age group on consumption. Countries that have a random coefficient close to one follow the average age pattern, those with a random coefficient closer to zero have a flatter age pattern, and those with a random coefficient greater than one have a more dramatic age pattern.

(C)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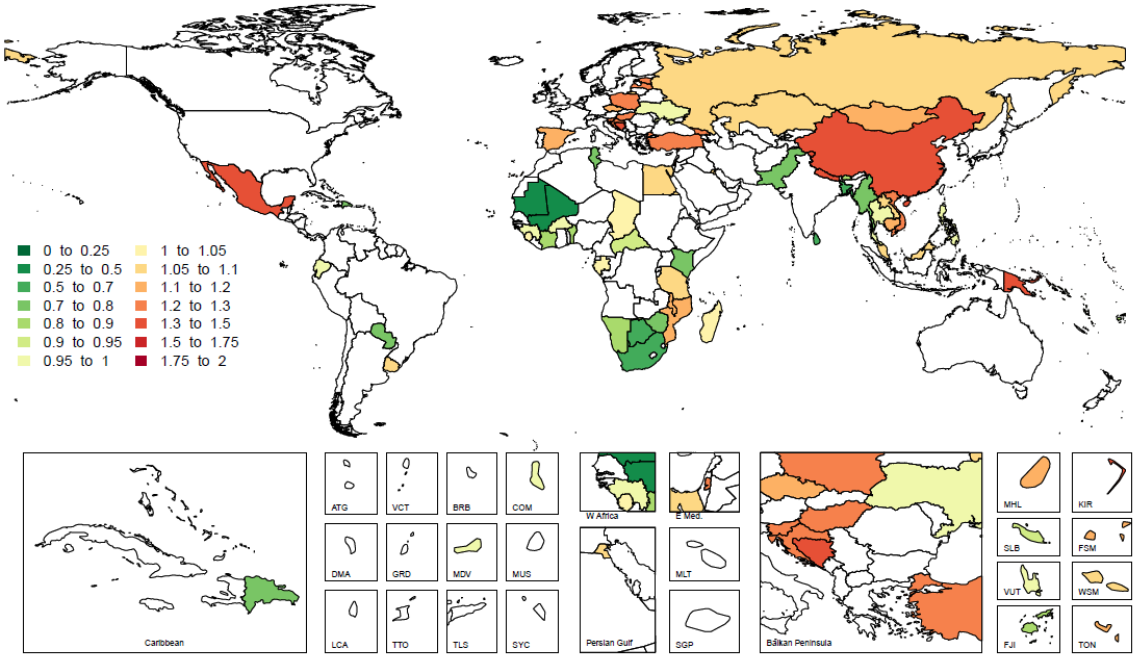
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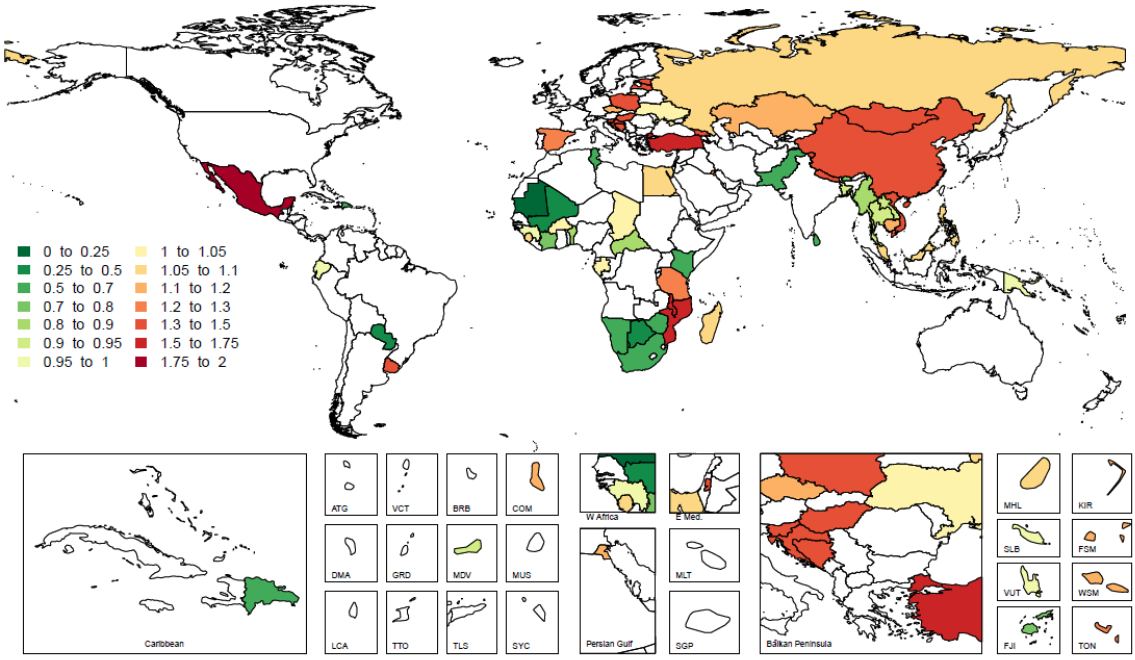
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Figure 5. Male consumption vs. prevalence by age group (15-24, 25-34, 35-44, 45-54, 55-69, 70+)

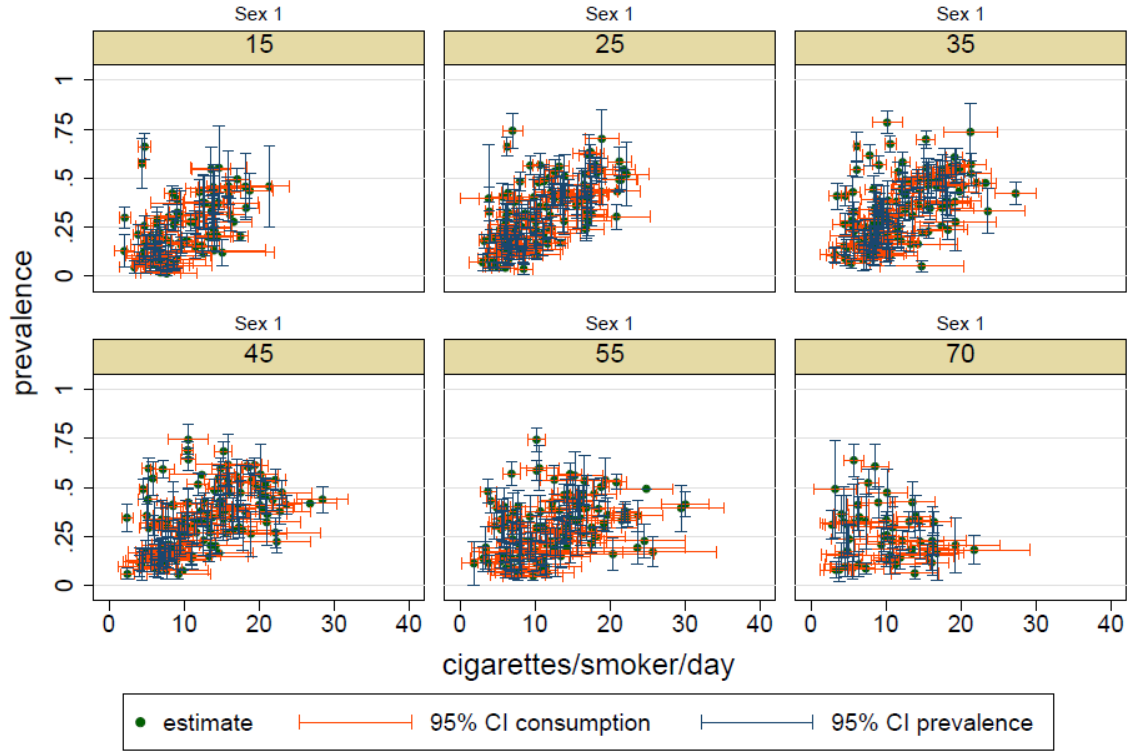


Figure 6. Female consumption vs. prevalence by age group (15-24, 25-34, 35-44, 45-54, 55-69, 70+)

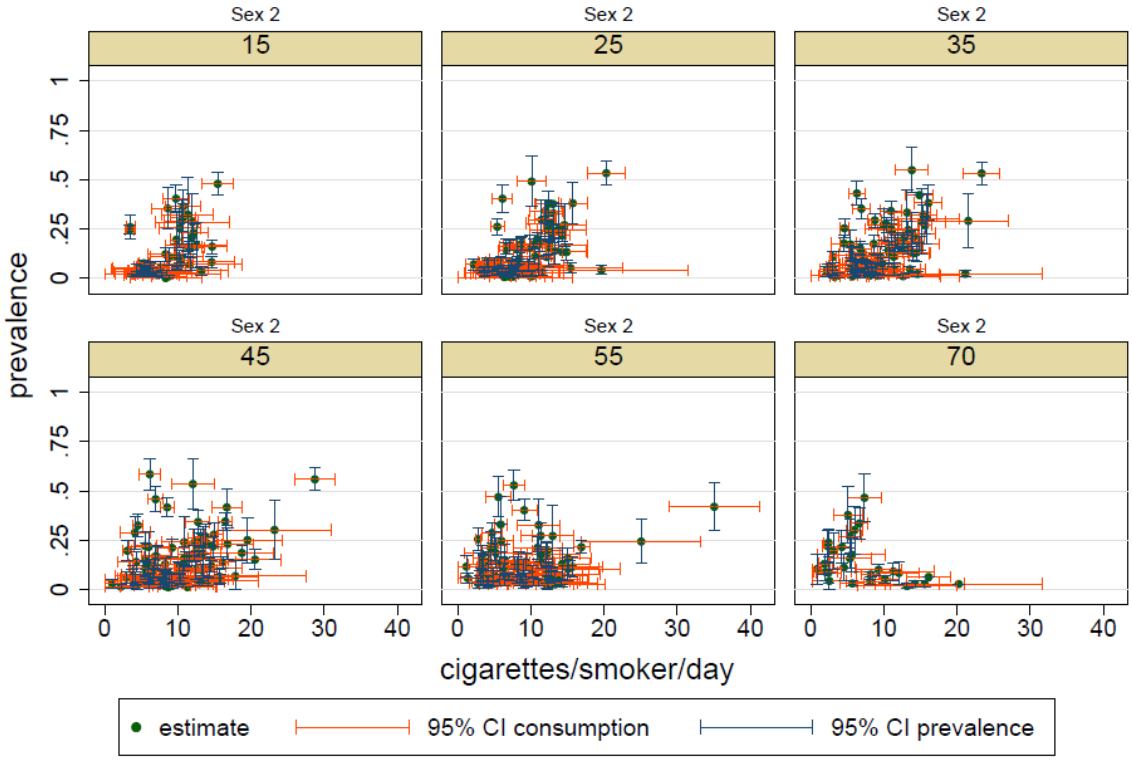
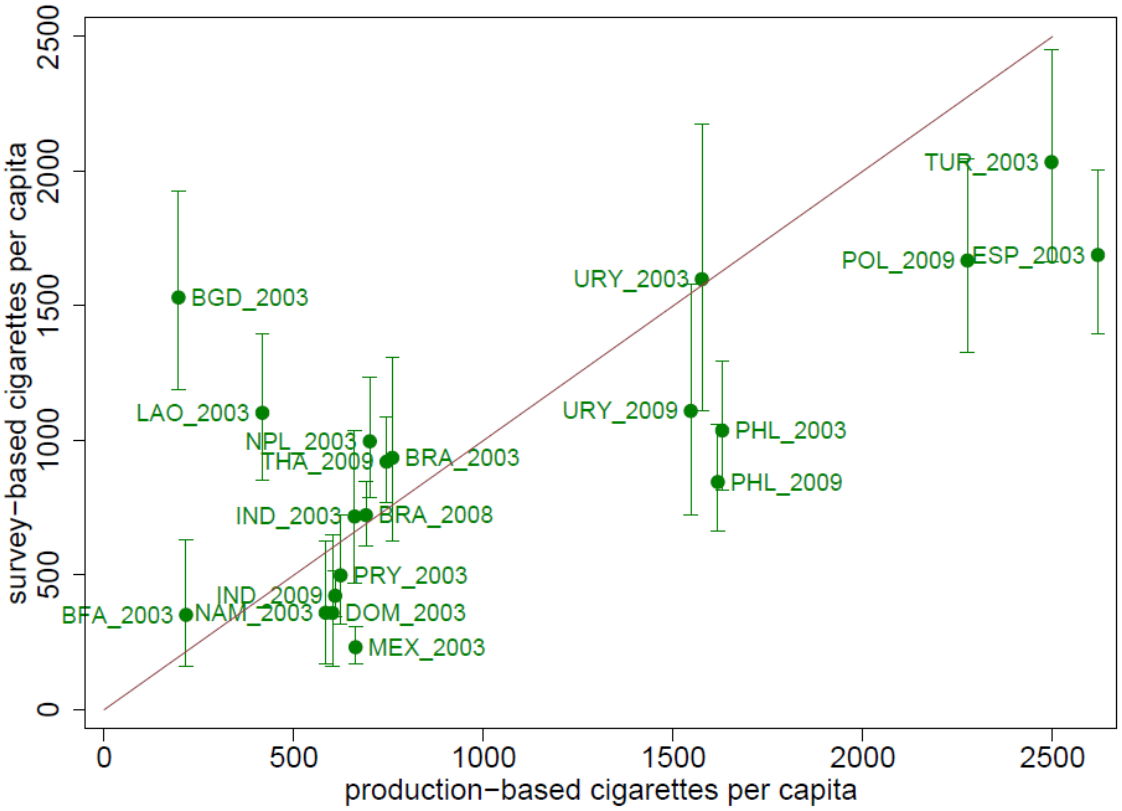


Figure 7. Comparison of national cigarettes per capita based on production data vs. survey data



Tables

Table 1. Data sources included in consumption estimates, by survey

	GATS	WHS	STEPS	Total
Number of surveys	14	52	70	136
Survey years	2008-2010	2002-2004	2002-2012	2002-2012
Number of countries included	14	52	62	103
Number of age-sex specific data points	152	476	439	1067

Table 2. Estimate of the mean relationship between age and consumption by sex[3]

	Males			Females		
	Estimate	95% CI		Estimate	95% CI	
		Lower	Upper		Lower	Upper
Intercept	8.12	7.54	8.73	6.58	5.97	7.25
Ages 25-34	1.18	1.15	1.22	1.14	1.06	1.22
Ages 35-44	1.29	1.25	1.33	1.16	1.08	1.25
Ages 45-54	1.32	1.28	1.37	1.18	1.08	1.28
Ages 55-69	1.24	1.19	1.29	1.06	0.96	1.17
Ages 70+	0.97	0.91	1.04	0.84	0.72	0.97

[3] The estimate and the 95% confidence interval show the values of the intercept and coefficients on age from the sex-specific regression of age group on log consumption. The values in Table 2 are exponentiated to be interpreted in normal space rather than log space.

Table 3. Top 10 countries with the lowest consumption by age and sex

sex	rank	Ages 15-24		Ages 25-34		Ages 35-44		Ages 45-54		Ages 55-69		Ages 70+	
		country	cigarettes/ smoker/day	country	cigarettes/ smoker/day	country	cigarettes/ smoker/day	country	cigarettes/ smoker/day	country	cigarettes/ smoker/day	country	cigarettes/ smoker/day
Males	1	Mauritania	2.5 (2.2–2.7)	Bhutan	3.2 (2.7–3.8)	Mauritania	3.4 (3.1–3.7)	Mauritania	3.0 (2.7–3.3)	Mauritania	2.8 (2.4–3.2)	Congo	2.4 (1.9–3.0)
	2	Bhutan	2.5 (2.1–2.9)	Mauritania	3.2 (2.9–3.6)	Bhutan	3.4 (2.9–4.0)	Bhutan	3.1 (2.5–3.6)	Bhutan	2.9 (2.4–3.4)	Mauritania	2.4 (1.9–3.0)
	3	Congo	2.6 (2.3–2.9)	Congo	3.4 (3.1–3.8)	Congo	3.6 (3.2–4.0)	Congo	3.2 (2.8–3.7)	Congo	3.0 (2.5–3.4)	Bhutan	2.5 (1.9–3.2)
	4	Ghana	3.1 (2.7–3.5)	Ghana	3.8 (3.4–4.4)	Ghana	4.3 (3.8–4.8)	Ghana	4.0 (3.6–4.6)	Ghana	4.0 (3.4–4.6)	Swaziland	3.3 (2.5–4.4)
	5	Swaziland	3.4 (2.9–4.1)	Myanmar	4.3 (3.9–4.6)	Swaziland	4.7 (3.9–5.5)	Swaziland	4.3 (3.6–5.3)	Swaziland	4.1 (3.3–5.0)	Ghana	3.6 (3.0–4.4)
	6	Myanmar	3.4 (3.1–3.7)	Swaziland	4.3 (3.6–5.2)	Myanmar	4.7 (4.4–5.1)	Myanmar	4.5 (4.1–4.9)	Myanmar	4.4 (3.9–4.8)	Bangladesh	3.7 (3.1–4.3)
	7	Ecuador	3.6 (3.0–4.1)	Ecuador	4.3 (3.7–5.1)	Ecuador	5.0 (4.3–5.7)	Ecuador	4.9 (4.1–5.7)	Guatemala	4.6 (3.9–5.5)	Guatemala	3.8 (3.0–4.7)
	8	Guatemala	3.8 (3.3–4.5)	Guatemala	4.8 (4.1–5.6)	Guatemala	5.2 (4.5–6.0)	Guatemala	4.9 (4.2–5.8)	Ecuador	4.9 (4.2–5.8)	Myanmar	3.8 (3.2–4.4)
	9	Sri Lanka	4.3 (3.9–4.7)	Sri Lanka	5.0 (4.6–5.4)	Lesotho	5.8 (5.2–6.5)	Mozambique	5.6 (5.1–6.2)	Mozambique	5.0 (4.5–5.7)	Mozambique	3.9 (3.2–4.8)
	10	Lesotho	4.3 (3.8–4.9)	Lesotho	5.4 (4.7–6.1)	Sri Lanka	6.0 (5.5–6.4)	Lesotho	5.6 (4.9–6.4)	Lesotho	5.3 (4.6–6.1)	Lesotho	4.4 (3.4–5.5)
Females	1	Mali	2.9 (1.9–4.2)	Mauritania	2.5 (2.3–2.9)	Mauritania	2.2 (1.9–2.5)	Mauritania	1.2 (1.0–1.5)	Mauritania	0.9 (0.7–1.2)	Mauritania	0.4 (0.2–0.6)
	2	Mauritania	2.9 (2.3–3.6)	Mali	2.8 (2.0–3.8)	Mali	2.5 (1.6–3.5)	Mali	1.9 (1.4–2.3)	Mali	1.4 (1.1–1.7)	Mali	0.9 (0.7–1.1)
	3	Malawi	3.0 (2.3–3.9)	Malawi	3.1 (2.7–3.6)	Malawi	2.8 (2.3–3.3)	Myanmar	3.2 (2.8–3.6)	Myanmar	2.8 (2.4–3.2)	Paraguay	2.0 (1.6–2.4)
	4	Myanmar	3.4 (2.6–4.3)	Myanmar	3.4 (3.1–3.7)	Myanmar	3.1 (2.7–3.4)	Côte d'Ivoire	3.3 (2.8–3.8)	Sri Lanka	3.0 (2.4–3.7)	Botswana	2.0 (1.2–3.1)
	5	Tanzania	3.4 (2.5–4.3)	Côte d'Ivoire	3.6 (3.2–4.1)	Côte d'Ivoire	3.3 (2.8–3.8)	Sri Lanka	3.7 (3.0–4.6)	Côte d'Ivoire	3.2 (2.8–3.6)	Côte d'Ivoire	2.2 (1.4–3.3)
	6	Mozambique	3.4 (2.6–4.5)	Mozambique	3.6 (3.2–4.1)	Mozambique	3.3 (2.8–3.8)	Malawi	3.8 (3.3–4.4)	Pakistan	3.3 (2.6–4.2)	Tunisia	2.3 (1.6–3.1)
	7	Papua New Guinea	3.5 (3.1–3.9)	Tanzania	3.7 (3.3–4.2)	Tanzania	3.4 (3.0–3.9)	Pakistan	3.9 (3.1–5.0)	Botswana	3.5 (3.0–4.0)	Pakistan	2.3 (1.3–3.9)
	8	Côte d'Ivoire	3.6 (3.0–4.3)	Sri Lanka	4.4 (3.4–5.5)	Sri Lanka	4.2 (3.1–5.4)	Tanzania	4.0 (3.2–5.0)	Malawi	3.7 (3.1–4.4)	Sri Lanka	2.4 (1.3–3.8)
	9	Kiribati	3.7 (3.2–4.2)	Bhutan	4.5 (3.5–5.6)	Bhutan	4.2 (3.1–5.6)	Botswana	4.1 (3.5–4.8)	Bhutan	3.8 (2.2–6.3)	Myanmar	2.4 (2.0–2.9)
	10	Bhutan	4.2 (2.9–5.7)	Pakistan	4.7 (3.6–6.0)	Pakistan	4.5 (3.3–5.9)	Bhutan	4.2 (2.8–6.3)	South Africa	3.8 (3.2–4.5)	Namibia	2.4 (2.0–3.0)

Table 4. Top 10 countries with the highest consumption by age and sex

		Ages 15-24		Ages 25-34		Ages 35-44		Ages 45-54		Ages 55-69		Ages 70+	
sex	rank	country	cigs/ smoker/day	country	cigs/ smoker/day	country	cigs/ smoker/day	country	cigs/ smoker/day	country	cigs/ smoker/day	country	cigs/ smoker/day
Males	1	Bosnia and Herzegovina	18.9 (15.8–22.2)	Bosnia and Herzegovina	21.0 (17.7–24.7)	Bosnia and Herzegovina	22.9 (19.5–26.8)	Bosnia and Herzegovina	25.6 (21.2–30.7)	Bosnia and Herzegovina	23.8 (19.0–29.2)	Bosnia and Herzegovina	17.6 (13.1–22.9)
	2	Libyan Arab Jamahiriya	17.8 (14.5–21.3)	Libyan Arab Jamahiriya	19.9 (16.3–23.7)	Libyan Arab Jamahiriya	21.8 (18.1–25.7)	Libyan Arab Jamahiriya	24.3 (19.7–29.6)	Libyan Arab Jamahiriya	22.8 (18.1–28.6)	Libyan Arab Jamahiriya	17.0 (12.6–22.6)
	3	Nauru	16.7 (13.6–20.5)	Nauru	18.7 (15.4–22.7)	Nauru	20.5 (16.9–24.6)	Nauru	22.7 (18.3–27.9)	Nauru	21.3 (16.6–26.9)	Nauru	15.9 (11.6–21.8)
	4	Georgia	16.4 (14.5–18.5)	Georgia	18.4 (16.2–21.0)	Georgia	20.1 (18.1–22.6)	Georgia	22.2 (19.5–25.3)	Georgia	20.8 (17.8–24.2)	Georgia	15.8 (12.1–20.0)
	5	Croatia	16.3 (11.5–22.3)	Croatia	18.3 (13.1–24.5)	Croatia	20.0 (14.4–26.9)	Croatia	22.1 (15.4–31.1)	Croatia	20.7 (14.4–29.1)	Croatia	15.6 (10.5–22.5)
	6	Turkey	16.1 (14.5–17.8)	Turkey	18.1 (16.3–20.1)	Turkey	19.8 (18.0–21.7)	Turkey	21.8 (19.5–24.3)	Turkey	20.4 (17.9–23.4)	Turkey	15.5 (12.4–19.2)
	7	Occupied Palestinian Territory	15.8 (13.1–18.8)	Occupied Palestinian Territory	17.7 (14.6–21.1)	Occupied Palestinian Territory	19.5 (16.5–22.7)	Occupied Palestinian Territory	21.6 (18.0–25.5)	Occupied Palestinian Territory	20.3 (16.7–24.6)	Occupied Palestinian Territory	15.4 (11.5–20.0)
	8	Kuwait	15.6 (12.2–19.5)	Kuwait	17.6 (14.1–21.7)	Kuwait	19.2 (15.3–23.5)	Kuwait	21.1 (16.3–26.9)	Kuwait	19.6 (14.8–25.5)	Kuwait	14.8 (10.5–20.1)
	9	Russian Federation	15.0 (13.6–16.5)	Russian Federation	17.0 (15.3–18.7)	Russian Federation	18.5 (16.9–20.1)	Russian Federation	20.2 (18.0–22.3)	Poland	19.1 (16.5–21.9)	Poland	14.7 (11.7–18.1)
	10	Poland	14.7 (12.9–16.6)	Egypt	16.8 (15.2–18.5)	Poland	18.2 (16.3–20.4)	Poland	20.1 (17.7–22.8)	Russian Federation	18.9 (16.6–21.3)	Russian Federation	14.6 (11.9–17.5)
Females	1	Nauru	15.5 (12.2–19.5)	Nauru	18.9 (15.4–23.3)	Nauru	22.7 (17.8–28.6)	Nauru	26.8 (19.9–35.2)	Nauru	25.4 (17.7–36.6)	Nauru	25.9 (12.2–47.5)
	2	Poland	12.4 (10.0–15.2)	Bosnia and Herzegovina	14.2 (10.3–18.8)	Bosnia and Herzegovina	16.3 (11.3–22.7)	Bosnia and Herzegovina	18.0 (11.2–27.6)	Bosnia and Herzegovina	16.8 (9.4–27.8)	Bosnia and Herzegovina	15.5 (6.4–32.6)
	3	Bosnia and Herzegovina	11.9 (8.4–16.1)	Hungary	13.8 (11.4–16.4)	Poland	15.7 (13.5–18.1)	Poland	17.3 (14.8–19.7)	Poland	15.8 (13.1–18.9)	Poland	14.7 (10.3–20.0)
	4	Hungary	11.3 (8.8–13.9)	Poland	13.8 (12.1–15.7)	Hungary	15.7 (12.7–19.3)	Hungary	16.7 (13.1–20.8)	Hungary	15.4 (11.2–20.4)	Turkey	14.0 (8.7–22.1)
	5	Uruguay	11.0 (9.0–13.2)	Spain	12.5 (10.5–15.0)	Spain	13.9 (11.4–17.2)	Slovenia	15.1 (8.9–23.9)	Slovenia	13.9 (7.6–23.6)	Georgia	13.4 (7.5–21.9)
	6	Croatia	10.6 (7.7–14.4)	Croatia	12.4 (9.6–15.8)	Croatia	13.8 (10.2–18.3)	Croatia	15.1 (10.6–21.2)	Croatia	13.8 (9.1–21.2)	Hungary	13.2 (7.2–22.3)
	7	Georgia	10.6 (8.0–14.0)	Slovenia	12.2 (8.3–17.4)	Slovenia	13.7 (8.7–20.5)	Georgia	14.9 (12.0–18.3)	Georgia	13.7 (10.3–18.1)	Slovenia	13.1 (5.2–26.7)
	8	Spain	10.6 (8.4–13.4)	Uruguay	12.2 (10.7–13.9)	Uruguay	13.7 (11.6–15.8)	Uruguay	14.7 (12.5–16.9)	Spain	13.4 (10.0–17.6)	Croatia	12.8 (5.9–24.0)
	9	Russian Federation	10.4 (8.3–13.0)	Georgia	11.9 (10.0–14.1)	Georgia	13.3 (10.8–16.1)	Spain	14.7 (11.9–17.9)	Turkey	13.3 (10.3–17.0)	Uruguay	12.7 (9.2–17.2)
	10	Slovenia	10.4 (6.9–15.3)	Micronesia	11.9 (10.0–14.1)	Micronesia	13.2 (10.8–16.0)	Turkey	14.6 (12.0–17.4)	Uruguay	12.5 (10.1–15.0)	Spain	11.6 (6.9–18.1)

Table 5. Country-level variation in consumption by age and sex[4]

	Males		Females	
Age group	Variance	Std. Dev.	Variance	Std. Dev.
25-34	0.001	0.033	0.016	0.125
35-44	0.001	0.027	0.022	0.147
45-54	0.002	0.039	0.048	0.219
55-69	0.005	0.072	0.082	0.286
70+	0.017	0.130	0.180	0.425

Table 6. Estimate of the relationship between prevalence and consumption, by age and sex[5]

	Males			Females		
		95% CI			95% CI	
Age group	Estimate	Lower	Upper	Estimate	Lower	Upper
15-24	2.20	1.37	3.53	3.32	1.68	6.56
25-34	3.66	2.80	4.78	6.29	3.43	11.50
35-44	2.62	1.93	3.56	5.28	2.74	10.17
45-54	3.38	2.26	5.05	2.29	1.13	4.63
55-69	1.71	1.03	2.84	5.79	2.98	11.26
70+	0.61	0.25	1.53	0.12	0.04	0.35

[4] Table 5 shows the variance and standard deviation of the country random coefficients on age in log space from the sex-specific regression of age group on log consumption.

[5] The estimate and the 95% confidence interval show the values of the coefficients on age from the age and sex-specific regressions of prevalence on log consumption. The values in Table 6 are exponentiated to be interpreted in normal space rather than log space.

Table 7. Correlation coefficients between prevalence and consumption, by age and sex

Age group	Males		Females	
	correlation coefficient	p-value	correlation coefficient	p-value
15-24	0.521	<.0001	0.470	0.0008
25-34	0.617	<.0001	0.552	<.0001
35-44	0.527	<.0001	0.532	<.0001
45-54	0.488	<.0001	0.356	0.0008
55-69	0.322	0.0003	0.174	0.1338
70+	-0.188	0.1782	-0.396	0.0336