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Regional And Sex-Specific Disparities in Tobacco and E-Cigarette Use Across WHO Regions: A Comparative Analysis of Global Health Surveillance Data

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Abstract

Background

Tobacco use remains a major preventable risk factor for non-communicable diseases, with substantial regional and sex-based variation across tobacco and nicotine products. This study assessed regional patterns, sex disparities, and temporal trends in tobacco and e-cigarette use across the six WHO regions.

Methods

Data were extracted from the WHO Global Health Observatory (GHO) OData API for adult daily cigarette smoking, e-cigarette use, smokeless tobacco use, tobacco smoking across all smoked forms, and overall tobacco use. Prevalence was compared across WHO regions and between males and females. Sex-based differences were quantified using Cohen's d. Current-use indicators for tobacco smoking and e-cigarette use were additionally analysed to assess temporal trends, with ARIMA models used for near-term forecasting.

Results

Marked regional heterogeneity was observed. Daily cigarette smoking was highest among males in the Western Pacific (30.68%) and European (27.85%) Regions. South-East Asia showed a distinct burden of smokeless tobacco use, with prevalence of 11.43% among males and 6.71% among females, and the highest male prevalence of all-form tobacco smoking (34.15%). Daily e-cigarette use was highest in the Western Pacific Region (8.30% among males and 2.95% among females). Large sex differences were observed, including Cohen's *d* of 2.61 for cigarette smoking in the Eastern Mediterranean Region and 3.59 for all-form tobacco smoking in South-East Asia.

Conclusions

Tobacco and nicotine use demonstrates substantial regional, product-specific, and sex-based heterogeneity. These findings support region-specific, product-specific, and sex-responsive tobacco-control strategies and highlight the importance of strengthening surveillance of emerging nicotine products.

Background

Tobacco use continues to be a critical global public health challenge and remains a leading cause of preventable mortality, contributing to more than 8 million deaths annually [1]. Despite aggressive tobacco-control policies, the global burden of smoked and smokeless forms of tobacco use persists, driven by both traditional combustible cigarettes and an evolving landscape of alternative products such

as electronic cigarettes (e-cigarettes) [2]. The complexity of tobacco use behaviours across cultures, socioeconomic groups, and regions necessitates robust epidemiological monitoring and comparative global analyses.

The World Health Organization (WHO) has repeatedly highlighted stark regional and sex-based differences in tobacco use patterns, with around 80% of the 1.2 billion tobacco users worldwide with in low- and middle-income countries. Men consistently demonstrate higher tobacco use prevalence than women in most regions, though the magnitude of this gap varies widely with the ratio of men to women using tobacco increasing to five in the year 2024 as compared to three in 2000[3]. Community-based studies reinforce this pattern. For instance, a North Indian study among young males documented a smoking prevalence of 20.44%, with peer influence identified as a major determinant of initiation [4]. Additionally, recent analyses from the National Family Health Survey (NFHS-5) revealed that male daily smokers in India had significantly greater odds of hypertension compared with non-smokers (OR ≈ 1.2), while smoking cessation was associated with reduced cardiovascular risk [5]. These findings support the need for sex-stratified analyses that examine patterns and consequences of tobacco use.

A significant contribution to global tobacco surveillance is the Global Adult Tobacco Survey (GATS), a standardised, nationally representative survey conducted in multiple low- and middle-income countries. GATS provides detailed information on the use of cigarettes, bidis, smokeless tobacco, second-hand smoke exposure, cessation behaviours, perceptions, and policy impact [6]. GATS data from countries such as India, Bangladesh, and Thailand have illustrated large gender disparities in tobacco use, particularly smokeless tobacco, while also highlighting the emerging role of e-cigarettes in several regions. For example, GATS India has consistently shown high smokeless tobacco use among males, aligning with global patterns observed in the South-East Asia region [6]. The integration of GATS with global WHO datasets offers a more comprehensive picture of tobacco use trends, particularly in countries where smokeless tobacco is culturally embedded.

Despite the availability of regional and national surveys, few studies have systematically compared all major forms of tobacco use, including cigarettes, smokeless tobacco, and e-cigarettes, across all six WHO regions, particularly using standardised global datasets. The WHO Global Health Observatory (GHO) OData API enables extraction of harmonised prevalence data by sex, region, and product type, facilitating accurate cross-regional comparisons [3]. Such cross-regional analyses are critical for understanding both the magnitude of tobacco use and the variation in tobacco product profiles driven by cultural preferences, regulatory structures, and market environments.

By integrating product-specific, regional, and sex-disaggregated perspectives and quantifying male to female differences using a common effect-size framework, this study extends existing WHO surveillance by providing a comparative assessment of the magnitude and distribution of daily tobacco and nicotine-product use across the six WHO regions. The findings of this analysis are expected to generate robust and policy-relevant evidence to inform, prioritise, and strengthen regional tobacco control strategies, particularly in resource-constrained settings. By identifying patterns and disparities in tobacco use, the

study will support the design of targeted, evidence-based interventions and contribute to monitoring progress in tobacco control efforts. These insights are closely aligned with the strategic priorities of the World Health Organization Framework Convention on Tobacco Control (WHO FCTC) [7], which provides a comprehensive framework for reducing tobacco demand and supply, as well as the United Nations Sustainable Development Goal (SDG) target 3.4, which aims to reduce premature mortality from noncommunicable diseases by one-third through prevention and treatment by 2030 [8, 9].

The primary objective of this study was to assess and compare the prevalence of adult daily cigarette smoking, daily e-cigarette use, daily smokeless tobacco use, and overall daily tobacco use across the six WHO regions using data from the WHO Global Health Observatory (GHO). The study to compares the prevalence of different forms of tobacco and nicotine use between males and females across the six WHO regions, determine the magnitude and distribution of sex-based disparities across regions and product categories, and examine temporal patterns in adult daily cigarette smoking and daily e-cigarette use across the six WHO regions using all available years of data in the WHO GHO.

Methodology

Study Design

A secondary data analysis was conducted using publicly available, country-level tobacco use data obtained from the World Health Organization (WHO) Global Health Observatory (GHO) OData API [10]. The study employed a descriptive and analytical ecological design, with WHO regions as the primary unit of comparison.

Data Source

Data were retrieved from the WHO Global Health Observatory (GHO) OData API

(https://ghoapi.azureedge.net/api.

The GHO OData API provides standardised, harmonised indicators compiled from nationally representative surveys, modelled estimates, and WHO surveillance systems. The API allows programmatic access to tobacco-related indicators disaggregated by region, sex, year, and indicator type.

Study Indicators

The following WHO GHO tobacco-use indicators were included in the analysis: adult daily cigarette smoking, adult daily e-cigarette use, adult daily smokeless tobacco use, adult daily tobacco smoking (all smoked forms), and adult daily tobacco use (smoked and smokeless forms).Each indicator represents the percentage prevalence among adults aged ≥ 15 years, as defined by WHO metadata.

In addition to the daily-use indicators, corresponding current-use indicators were extracted separately for cigarette smoking, e-cigarette use, smokeless tobacco use, and tobacco smoking. Current use was defined as use of the respective tobacco or nicotine product within the preceding 30 days, irrespective of whether use was daily or non-daily. These current-use indicators were used specifically for the global and regional trend visualisations and time-series forecasting. And the daily-use indicators constituted the primary dataset for the cross-regional and sex-based comparisons (Table 1).

Table 1
Definition of Variables

Indicator	Operational Definition
Adult daily cigarette smoking	Percentage of adults (≥ 15 years) who smoke cigarettes (manufactured or hand-rolled, including bidis) every day at the time of survey [17].
Adult daily e-cigarette use	Percentage of adults (≥ 15 years) who use electronic cigarettes (ENDS) daily at the time of survey [12].
Adult daily smokeless tobacco use	Percentage of adults (≥ 15 years) who use smokeless tobacco (chewing, snuff, gutka, khaini, etc.) daily [18].
Adult daily tobacco smoking (all smoked forms)	Percentage of adults (≥ 15 years) who smoke any tobacco product (cigarettes, cigars, pipes, hookah, bidis, etc.) daily [17].
Adult daily tobacco use (smoked + smokeless)	Percentage of adults (≥ 15 years) who use any form of tobacco (smoked or smokeless) daily at the time of survey [17].
Adult current cigarette smoking	Percentage of adults (≥ 15 years) who currently smoke cigarettes (manufactured or hand-rolled, including bidis), within the previous 30 days, whether daily or non-daily, at the time of survey [11].
Adult current e-cigarette use	Percentage of adults (≥ 15 years) who currently use electronic cigarettes (ENDS), within the previous 30 days, whether daily or non-daily, at the time of survey [10].
Adult current smokeless tobacco use	Percentage of adults (≥ 15 years) who currently use smokeless tobacco (chewing, snuff, gutka, khaini, etc.), within the previous 30 days, whether daily or non-daily, at the time of survey [13].
Adult current tobacco smoking (all smoked forms)	Percentage of adults (≥ 15 years) who currently smoke any tobacco product (cigarettes, cigars, pipes, hookah, bidis, etc.), within the previous 30 days, whether daily or non-daily, at the time of survey [14].

Study Population and Stratification

The study population consisted of adults (females, males and both sexes) aged 15 years or more. The data was stratified into six WHO regions, namely Africa, Americas, Eastern Mediterranean, Europe, South-East Asia and Western Pacific Regions.

All available years for which data were reported in the WHO GHO OData API for each indicator were covered.

Data Extraction and Management

Data were programmatically extracted using structured OData queries specifying indicator code, parent location (WHO region), sex, and year. Extracted datasets were cleaned by removing duplicate records, excluding entries with missing or invalid numeric values and harmonising region and sex labels for each indicator and region, mean prevalence values and standard deviations (SD) were calculated across all available country-level observations.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics, Version 31.

Mean prevalence and standard deviation (Mean ± SD) were calculated for each tobacco indicator by WHO region and Sex. Region-wise comparisons were summarised using tabular and graphical methods, including heatmaps.

Sex differences in prevalence were assessed by comparing male and female mean prevalence values for each indicator within each WHO region.

Cohen's d was used to quantify the magnitude of sex-based differences across all WHO regions. Cohen's d was calculated as the difference between the mean prevalence among males and females divided by the pooled standard deviation of the two groups. The magnitude of sex-based differences in tobacco use prevalence was interpreted using Cohen's d effect size, with males compared to females. An effect size of 0.2 was considered small, indicating minimal difference between sexes; 0.5 was interpreted as a medium effect, reflecting a moderate and potentially meaningful difference; and 0.8 was classified as a large effect, signifying a substantial disparity, following conventional Cohen's d benchmarks. Effect sizes exceeding 1.2 were regarded as very large, denoting pronounced sex-based differences, while values greater than 2.0 were interpreted as extremely large, indicating exceptionally strong male-to-female differences in prevalence, following the extended thresholds proposed by Sawilowsky [16].

For indicators with multi-year data availability, year-wise mean prevalence values were calculated for each WHO region and temporal trends were visualised using line plots.

Time-Series Analysis

Historical data for adult daily cigarette smoking and adult daily e-cigarette use were extracted for all available years from the WHO Global Health Observatory (GHO) OData API. For each WHO region, sex-stratified annual prevalence values were compiled into time-series datasets. Only years with complete regional records were included to maintain consistency in the modelling process.

Forecasting Model

Forecasting was conducted using the Auto-Regressive Integrated Moving Average (ARIMA) approach. Separate ARIMA models were fitted for daily cigarette smoking (by region, both sexes combined) and daily e-cigarette use (by region, both sexes combined). These two indicators were specifically selected for the temporal trend analysis to enable comparison between the established pattern of tobacco smoking and the emerging and increasingly important public health concern of e-cigarette use.

Forecast Generation

Using the optimal ARIMA model for each region, forecasts were generated for the period 2024–2026. Forecasts were reported with point estimates and 95% confidence intervals (CI). Forecast plots display historical data, fitted values, and prediction intervals.

Ethical Considerations

The study used publicly available, aggregated secondary data with no individual-level identifiers. Ethical approval was therefore not required, in accordance with institutional and WHO data-use guidelines.

Results

A total of 5,208 observations were included in the analysis across the six WHO regions (Table 2). The European Region (EUR) contributed the largest share of observations (n = 1,476; 28.3%), followed by the African Region (AFR) (n = 1,230; 23.6%) and the Region of the Americas (AMR) (n = 912; 17.5%). The Western Pacific Region (WPR) accounted for 702 observations (13.5%), while the Eastern Mediterranean Region (EMR) contributed 558 observations (10.7%). The South-East Asia Region (SEAR) had the lowest representation, with 330 observations (6.3%).

Table 2
Data Availability as Per Region

Region	First Year with Data	Last Year with Data	Frequency (N = 5208)	Percentage (%)
AFR (African Region)	2005	2021	1230	23·6
AMR (Region of the Americas)	2001	2022	912	17·5
EMR (Eastern Mediterranean Region)	1999	2022	558	10·7
EUR (European Region)	2011	2022	1476	28·3
SEAR (South-East Asia Region)	2016	2022	330	6·3
WPR (Western Pacific Region)	2011	2022	702	13·5

Regarding temporal coverage, data were available from 1999 onwards (EMR), with the starting year varying across WHO regions. Data extended up to 2022 in all regions except the African Region, where the latest available data were from 2021.

Table 3
Tobacco Use Variation as Per Gender Across Various Regions Globally

Adult Daily Cigarette Smoking					
Region	**Female (Mean)**	**Female (SD)**	**Male (Mean)**	**Male (SD)**	**Cohen's d**
Europe	8·91	7·57	27·85	14·84	1·61
Americas	4·41	5·48	12·14	7·57	1·17
South-East Asia	2·2	2·99	19	10·4	2·2
Western Pacific Region	7·98	8·78	30·68	12·36	2·12
Africa	1·88	2·75	15·91	9·49	2·01
Eastern Mediterranean	1·25	0·95	26·1	13·42	2·61
Adult Daily E-cigarette Use					
Europe	1·37	1·36	1·92	1·84	0·34
Americas	0·8	1·04	1·73	1·11	0·85
South-East Asia	0	0	0·6	0	Undefined (SD = 0)
Western Pacific Region	2·95	2·9	8·3	1·13	2·19
Africa	0·1	0	0·5	0	Undefined (SD = 0)
Eastern Mediterranean	1·3	1·49	2·4	2·57	0·78
Adult Daily Smokeless Tobacco Use					
Europe	1·17	2·16	6·16	7·04	0·92
Americas	0·11	0·15	0·31	0·33	0·75
South-East Asia	6·71	9·02	11·43	13·02	0·4
Western Pacific Region	2·8	3·78	0·5	0·32	–0·70 (female >male)
Africa	2·88	3·71	3·6	5·07	0·17
Eastern Mediterranean	1·19	2·09	6·97	10·24	0·78
Interpretation of Cohen's D (effect size of males as compared to females):					
0·2 = small; 0·5 = medium; 0·8 = large; >1·2 = very large; >2·0 = extremely large					

Adult Daily Cigarette Smoking					
Region	**Female (Mean)**	**Female (SD)**	**Male (Mean)**	**Male (SD)**	**Cohen's d**
Adult Daily All Forms of Tobacco Smoking					
Europe	11·78	7·27	26·46	13·22	1·38
Americas	2·64	2·49	12·62	6·27	2·09
South-East Asia	1·94	2·4	34·15	12·45	3·59
Western Pacific Region	9·76	11·68	30·79	12·37	1·75
Africa	1·73	2·26	14·3	8·33	2·06
Eastern Mediterranean	4·02	5·23	28·56	15·05	2·18
Interpretation of Cohen's D (effect size of males as compared to females):					
0·2 = small; 0·5 = medium; 0·8 = large; >1·2 = very large; >2·0 = extremely large					

Adult Daily Cigarette Smoking (Cohen's d range: 1·17 to 2·61)

The results from Table 2 show that across all WHO regions, male adults demonstrated substantially higher daily cigarette smoking prevalence compared to females, with Cohen's d values consistently within the large to extremely large effect-size range.

The strongest gender disparity was observed in the Eastern Mediterranean Region (d = 2.61), indicating that male smoking prevalence is dramatically higher as compared to females. Similar large effect sizes were noted in South-East Asia (d = 2.20), Western Pacific Region (d = 2.12), and Africa (d = 2.01). Even in regions with relatively lower baseline prevalence, such as the Americas (d = 1.17) and Europe (d = 1.61), the differences remained large.

Adult Daily E-cigarette Use (Cohen's d range: 0·34 to 2·19)

Gender differences in daily e-cigarette use varied more widely across regions compared to cigarette smoking.

In Europe (d = 0.34), gender differences were minimal. Conversely, a very large effect size was observed in the Western Pacific Region (d = 2.19), where men reported markedly higher e-cigarette usage. Moderate differences were seen in the Americas (d = 0.85) and Eastern Mediterranean (d = 0.78). In South-East Asia and Africa, both female and male standard deviations were zero, so Cohen's d is mathematically undefined rather than indicative of "no difference"; this reflects the very small number of

country-level observations available for this indicator in these regions rather than a true absence of a sex gap.

Adult Daily Smokeless Tobacco Use (Cohen's d range: −0·70 to 0·92)

Patterns for smokeless tobacco use demonstrated substantial regional heterogeneity.

In most regions, including Europe (d = 0.92), Americas (d = 0.75), Africa (d = 0.17), and Eastern Mediterranean (d = 0.78), males exhibited higher smokeless tobacco use as compared to females, but the magnitude of differences ranged from small to moderate.

Interestingly, the Western Pacific Region showed a negative effect size (d = − 0.70), indicating higher smokeless tobacco use among females, in contrast to all other regions. In South-East Asia (d = 0.40), both genders demonstrated elevated prevalence, with males having moderately higher rates.

Adult Daily Total Tobacco Smoking (Cohen's d range: 1·38–3·59)

Total tobacco smoking in any form echoed the strong gender gradients, with all regions showing large or extremely large effect sizes.

The most pronounced gender disparity occurred in South-East Asia (d = 3.59), the highest effect size across all indicators, reflecting disproportionately high tobacco consumption among males. Similarly, large to extremely large differences were seen in the Americas (d = 2.09), Africa (d = 2.06), Eastern Mediterranean (d = 2.18), and Western Pacific Region (d = 1.75).

Marked regional heterogeneity observed in the heatmap was also reflected in the sex-disaggregated estimates (Table 3). Daily cigarette smoking was highest in the Western Pacific and European Regions, particularly among males (30.68% and 27.85%, respectively), whereas South-East Asia showed a distinct burden of smokeless tobacco use, with prevalence of 11.43% among males and 6.71% among females. Similarly, daily tobacco smoking across all smoked forms was highest among males in South-East Asia (34.15%), followed by the Western Pacific Region (30.79%). Daily e-cigarette use showed a different pattern, with the highest prevalence in the Western Pacific Region (8.30% among males and 2.95% among females). Substantial sex differences were observed across regions, with the largest effect sizes for daily cigarette smoking in the Eastern Mediterranean Region (Cohen's *d* = 2.61) and for all-form tobacco smoking in South-East Asia (*d* = 3.59), highlighting important regional and sex-specific variation in tobacco and nicotine use. Overall, the results indicate that although tobacco use remains prevalent globally, the type and intensity of tobacco consumption vary considerably across WHO regions, emphasizing region-specific patterns in tobacco use behaviours.

Analysis of time-series trends in adult current cigarette smoking (2001–2022) revealed a consistent male predominance across all WHO regions. Males exhibited substantially higher smoking prevalence

compared with females and the combined-sex estimates throughout the study period. The European and Western Pacific Regions showed the highest levels of cigarette smoking, although a gradual decline was observed in recent years, particularly among females. In contrast, the African Region maintained comparatively lower prevalence across sexes, while the South-East Asia Region demonstrated notable fluctuations with persistently higher male smoking rates.

Time-series analysis of adult current e-cigarette use (available from 2014 onwards) indicated overall low prevalence globally, with emerging upward trends in selected regions. The Western Pacific Region, European Region, and Region of the Americas showed relatively higher uptake of e-cigarettes, particularly among males, whereas prevalence remained minimal in the African and Eastern Mediterranean Regions. Sex-based differences were evident, with males consistently reporting higher e-cigarette use than females across most regions.

The forecasts (2024–2026) for cigarette smoking suggest a continued decline or stabilization in most regions, especially in the Western Pacific and European Regions, with more pronounced reductions among females. However, male smoking prevalence is projected to remain substantially higher than female prevalence across all regions. In contrast, e-cigarette use is projected to increase modestly in the European Region, Region of the Americas, and South-East Asia Region, particularly among males, while remaining stable or declining in the Western Pacific Region.

Overall, these findings demonstrate diverging temporal patterns between conventional cigarette smoking and e-cigarette use, with declining trends in combustible tobacco use but emerging and region-specific increases in e-cigarette consumption, underscoring the need for adaptive, region- and sex-specific tobacco control strategies.

Substantial regional variation was observed in tobacco smoking and smokeless tobacco use. The median tobacco-smoking rate was highest in the Western Pacific Region of about 29%, followed by Europe (26%) and South-East Asia (21%), while Africa had the lowest median rate of 10%. The Eastern Mediterranean Region and the Americas had intermediate median smoking rates of about 19% and 15%, respectively.

Smokeless tobacco use showed a distinctly different regional pattern, with the highest median prevalence in South-East Asia of 8%, followed by the Western Pacific Region (3%) and Europe, Africa, and the Eastern Mediterranean Region (3 to 4%). The Americas had the lowest median smokeless tobacco use of about 1%. South-East Asia also demonstrated the greatest variability in smokeless tobacco use, with several high outlying observations reaching about 58%, whereas smoking rates showed particularly wide distributions in the Western Pacific and South-East Asia.

Overall, these findings highlight pronounced regional disparities in both smoking and smokeless tobacco use, with combustible tobacco predominating in the Western Pacific and European Regions, and smokeless tobacco use concentrated predominantly in South-East Asia.

Discussion

This study provides one of the first systematic, cross-regional comparisons of daily cigarette smoking, e-cigarette use, smokeless tobacco use, and total tobacco smoking across all six WHO regions using harmonised data from the WHO Global Health Observatory OData API. Consistent with prior WHO and survey-based reports [3, 6], male tobacco use exceeded female use in nearly every region and product category, though the size and consistency of this gap varied considerably by product.

The consistently large to extremely large gender gap in cigarette smoking across all WHO regions suggests that smoking remains highly gendered worldwide, likely reflecting strong cultural, social, and behavioural determinants that disproportionately drive tobacco use among men. This finding is consistent with community-based evidence from India, where smoking prevalence among young males has been documented at over 20%, with peer influence identified as a key driver of initiation [4], and with NFHS-5 data linking male daily smoking to elevated cardiovascular risk [5]. The near-universal magnitude of the gender gap for cigarette smoking, ranging from large in the Americas to extremely large in the Eastern Mediterranean Region, suggests that whatever combination of social norms, tobacco marketing, and economic factors drives this disparity operates similarly across otherwise very different regional contexts.

The region-specific pattern of e-cigarette gender disparities may reflect differing regulatory environments, market penetration, and cultural acceptance of vaping products across WHO regions. The exceptions were South-East Asia and Africa, where zero variance in both sexes made the effect size mathematically undefined; these are regions where e-cigarette prevalence data were sparse, and the pattern should be interpreted as reflecting data availability rather than a genuine absence of a sex gap.

The comparatively inconsistent gendered pattern of smokeless tobacco use, including the reversal observed in the Western Pacific Region, suggests this behaviour is shaped more by local traditions, cultural norms, and product availability than by the more uniform gender gradient seen in cigarette smoking. This is consistent with GATS findings showing high smokeless tobacco use among South and South-East Asian men, where products such as khaini and gutka are deeply embedded in everyday life [6], and it points to the need for product-specific rather than uniformly framed tobacco control messaging.

Taken together, the total tobacco smoking findings point to a persistently higher male tobacco burden across all regions, consistent with deeply rooted structural and sociocultural influences on tobacco use behaviours that regional tobacco control strategies will need to address directly. These findings reinforce the WHO FCTC's call for comprehensive, demand-reduction strategies [7] and are directly relevant to progress toward SDG target 3.4, which aims to reduce premature mortality from noncommunicable diseases by one-third by 2030 [8, 9]; without a specific focus on male tobacco use, this target is unlikely to be met in several of the regions studied here.

The time-series analysis adds a forward-looking dimension to these cross-sectional patterns. Forecasts through 2026 suggest that cigarette smoking is likely to continue declining or stabilizing in most regions, with the sharpest reductions projected among women, while male prevalence is expected to remain substantially higher throughout the forecast period. At the same time, e-cigarette use is projected to rise modestly in the European Region, the Region of the Americas, and South-East Asia, particularly among men. Read together, these trends raise the possibility that gains from declining cigarette smoking could be partially offset by emerging e-cigarette uptake in some regions, underscoring the importance of monitoring both product categories rather than treating combustible tobacco decline as the sole marker of progress.

Implications

The findings have several important implications for tobacco-control policy and public health practice. The marked regional heterogeneity indicates that a uniform global tobacco-control strategy may be insufficient, and interventions should be tailored to the dominant tobacco-use patterns within individual WHO regions. The relatively high smoking prevalence observed in the Western Pacific and European Regions underscores the need for sustained implementation of comprehensive tobacco-control measures, including taxation, smoke-free policies, cessation services, and restrictions on tobacco advertising and promotion. In contrast, the substantially higher burden of smokeless tobacco use in South-East Asia highlights the need for product-specific interventions addressing culturally embedded smokeless tobacco practices, stronger regulation, public education, and improved cessation support.

The distinct regional pattern observed for e-cigarette use also has important implications. The relatively higher prevalence in the Western Pacific Region, together with the temporal patterns observed in the study, suggests that e-cigarettes should be incorporated into routine tobacco and nicotine surveillance rather than being considered separately from the broader tobacco-control agenda. Continued monitoring is particularly important because emerging nicotine products may alter established patterns of tobacco use and potentially create new populations of nicotine users.

The substantial sex-based differences identified across regions further support the need for gender-responsive tobacco-control strategies. The large effect sizes observed for several indicators, particularly for daily cigarette smoking and all-form tobacco smoking, suggest that interventions should account for differences in tobacco-use patterns between males and females rather than relying solely on sex-neutral approaches. At the same time, regions or products showing smaller or reversed sex differences should not be overlooked, as these may represent emerging patterns requiring targeted surveillance.

Finally, the study demonstrates the value of disaggregating tobacco use by product, region, sex, and time. Monitoring overall tobacco prevalence alone may obscure important differences, particularly in regions where smokeless tobacco or emerging nicotine products contribute substantially to the overall burden. Integrating these dimensions into global surveillance systems can help identify changing patterns earlier, support more targeted allocation of tobacco-control resources, and inform progress

towards the WHO Framework Convention on Tobacco Control (WHO FCTC) and Sustainable Development Goal (SDG) target 3.4 which calls for a one-third reduction in premature mortality from non-communicable diseases (NCDs) by 2030. As tobacco use is a major preventable risk factor for NCDs, including cancers, cardiovascular diseases, and chronic respiratory diseases, strengthening comprehensive tobacco-control measures is critical to achieving the targets outlined under SDG 3.4 [19].

Strengths and Limitations

This study's principal strength is its use of a single, standardised data source, the WHO GHO OData API, to compare five tobacco indicators across all six WHO regions over more than two decades, something few prior analyses have attempted at this scale. Quantifying sex differences using Cohen's d allowed disparities to be compared on a common scale despite very different baseline prevalence levels across regions and products, and the addition of ARIMA-based forecasting extends the analysis beyond a static snapshot toward near-term projections that can inform planning.

Several limitations should be considered when interpreting these findings. First, this is an ecological analysis of country-level aggregated data; associations observed at the regional or country level cannot be assumed to hold at the individual level, and the results should not be interpreted as evidence of individual-level risk. Second, the number and timing of country-level observations varied substantially by region and indicator, from a low of 330 observations in the South-East Asia Region to 1,476 in the European Region, and from data beginning as early as 1999 to as late as 2016 depending on the region; this uneven coverage limits the comparability of estimates across regions and should be borne in mind when interpreting cross-regional differences. Third, for e-cigarette use in South-East Asia and Africa, the number of underlying country-level observations was small enough to produce zero variance in both sexes, making the corresponding Cohen's d values uninterpretable as conventional effect sizes; these should be treated as provisional rather than robust estimates. Fourth, the underlying WHO GHO indicators combine data from nationally representative surveys and modelled estimates of varying quality and methodology across countries, which may introduce heterogeneity not captured by the descriptive statistics presented here. Finally, this analysis did not adjust for age structure, urbanisation, or socioeconomic status, all of which are known to influence tobacco use patterns, and it relied on descriptive comparisons of means and effect sizes rather than formal significance testing; the Cohen's d values reported here should therefore be interpreted as descriptive indicators of the magnitude of sex differences rather than as evidence of statistically confirmed disparities.

Conclusion

This cross-regional analysis confirms that tobacco use remains a profoundly gendered global health issue, with men showing substantially higher prevalence than women across nearly every WHO region and tobacco product studied. Cigarette smoking showed the most consistent and universal gender gap, smokeless tobacco use was concentrated in South-East Asia with a less consistent gender pattern, and e-cigarette use showed the greatest region-to-region variability, both in magnitude and, in some cases, direction. Together with the forecasted decline in cigarette smoking alongside a modest rise in e-

cigarette use in several regions, these findings support gender-responsive, product-specific, and region-specific tobacco control strategies, and highlight the continued need for strengthened data collection in currently underrepresented regions such as South-East Asia to support more precise monitoring of global progress toward the WHO FCTC and SDG 3.4 targets.

Declarations

Ethical Approval: Not required. The study involved secondary analysis of publicly available, aggregated WHO Global Health Observatory data and did not involve identifiable individual-level information or human participant interaction.

Consent to participate: The study involves no direct intervention and only secondary use of data available in public domain.

Human Ethics and Consent to Participate declarations: Not applicable (secondary data analysis)

Consent to Publish: This study is based on secondary analysis of anonymized data· No individual consent to publish was required, as the dataset did not contain any personally identifiable information.

Availability of data and materials: The data used in this study are publicly available from the WHO Global Health Observatory (GHO) OData API. The datasets can be accessed by researchers through the WHO GHO data platform.

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Figures

Figure 1: Global and Regional Trend of Tobacco Consumption (2001 to 2022)

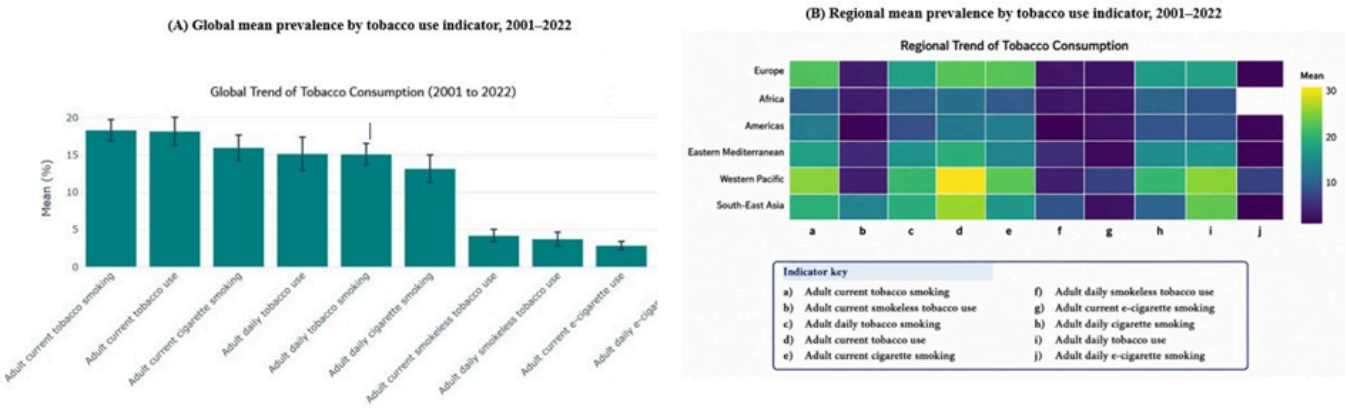


Figure 1

See image above for figure legend.

Figure 2: Time Trend of Cigarette and E-Cigarette Consumption Globally

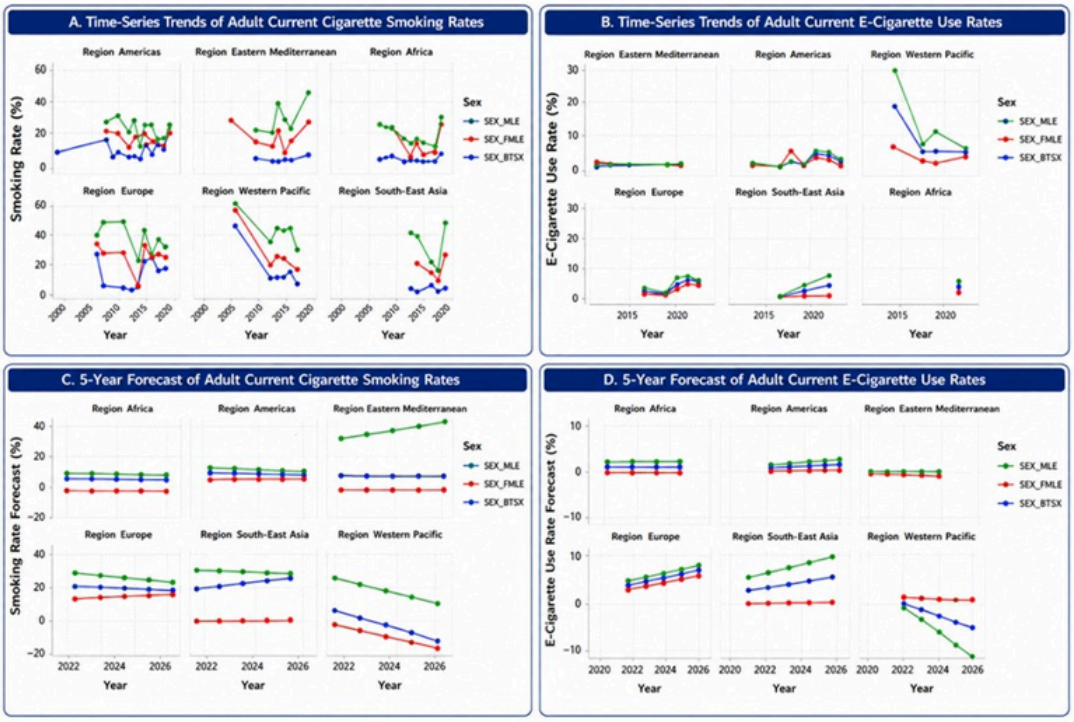


Figure 2

See image above for figure legend.

Figure 3: Regional Variation of Tobacco Smoking and Smokeless Tobacco Use (2001-2022)

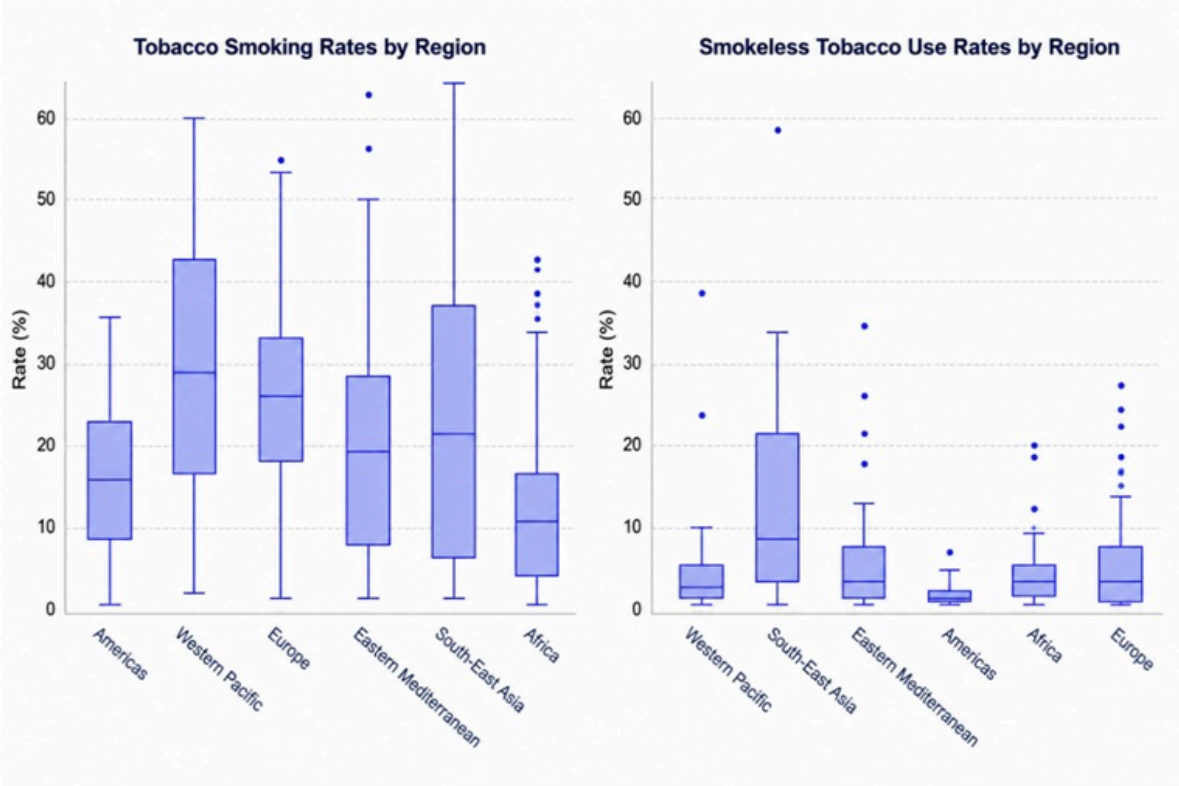


Figure 3

See image above for figure legend.