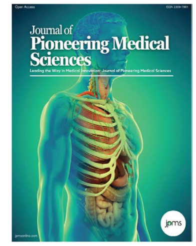

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Adult Diabetes Prevalence in Saudi Arabia (2000–2022): A Secondary Retrospective Analysis of Internationally Harmonized Indicator Series with a 2024 Cross-Series Anchor

Faisal Holil AlAnazi[1]*
[1]Department of Internal Medicine, College of Medicine, Majmaah University, Majmaah 11952, Saudi Arabia

Author Designation: [1]Assistant Professor

*Corresponding author: Faisal Holil AlAnazi (e-mail: Fh.alanazi@mu.edu.sa).

Abstract **Background:** The burden of diabetes in adults requires robust and comparable long-term data because of the changing estimates depending on the definition of diabetes, age groups and standardization of data. Therefore, a secondary retrospective analysis of internationally harmonized indicator series was conducted to describe trends in diabetes prevalence and treatment coverage in Saudi Arabia, using NCD-RisC as the main analytical series for 2000–2022 and IDF/WDI estimates as a descriptive 2024 cross-series anchor. **Methods:** A country-level ecological time-series analysis was conducted using internationally harmonized annual indicators. The primary outcome was the age-standardized prevalence of diabetes in adults aged 18 years and older, with sex differentiation as appropriate. Secondary outcomes were treatment coverage in people with diabetes aged 30 years and older and sex gap measures (female minus male; percentage points). **Results:** In the main NCD-RisC 18+ series, pooled age-standardized prevalence of diabetes decreased from 25.10% to 20.62% (decrease of 4.48 percentage points) between 2000 and 2022, with a temporary mid-series rise around 2014-2016 before resuming its downward trend. Over the period 2000-2022, prevalence demonstrated a significant linear decrease in both men (slope = -0.181 pp/year; $R^2 = 0.817$; $p = 3.3\times10^{-9}$) and women (slope = -0.276 pp/year; $R^2 = 0.957$; $p = 7.4\times10^{-16}$), with strong monotonic correlations (Spearman ρ: men = -0.878, women = -0.987). Treatment coverage in people with diabetes (≥30 years) increased from 40.44% to 51.50% (increase of 11.06 pp) and generally increased, with highly significant linear increases in men (slope = +0.574 pp/year; $R^2 = 0.977$; $p = 9.1\times10^{-19}$) and women (slope = +0.469 pp/year; $R^2 = 0.981$; $p = 1.1\times10^{-19}$). **Conclusion:** Using harmonized national indicators, adult diabetes prevalence was found to statistically decrease from 2000 to 2022, while treatment coverage in people with diabetes significantly and substantially increased, with small but measurable changes in sex differences.

Key Words Saudi Arabia, Diabetes Mellitus, Prevalence, Treatment Coverage, Time Trends, Age-Standardisation, Secondary Analysis, Ecological Study

INTRODUCTION

Diabetes mellitus is a significant source of preventable illness and death globally. This is aided by the shift in population, increased urbanization, new dietary patterns, reduced physical activity and increased contact with risk factors for cardiovascular and metabolic diseases from early in life [1]. Currently, diabetes is recognized not only as a problem of blood sugar levels but also as a condition that impacts many other parts of the body. It is a risk factor for issues related to blood vessels, kidneys, eyes and nerves. However, for Saudi Arabia, one of the main challenges is not simply the absence of diabetes estimates, but the difficulty of interpreting trends across multiple international series that use different age bands, standardization procedures and case definitions. As a result, apparent differences between sources may reflect methodological variation rather than true epidemiologic change. This makes source-preserving analysis of harmonized indicators especially important for valid interpretation of long-term national trends. [2-3].

The way in which we monitor diabetes is highly dependent on the definition of diabetes (cut points, whether treated or untreated cases), age groups, adjustments for age in the data and the statistical analysis techniques used to identify trends from different data sources. These issues have driven the need for the development of indicator series to enable the comparison of data across countries and over time [4-5].

In Saudi Arabia, diabetes has been a significant public health problem for many years. This is consistent with rapid economic and social change, dietary change and increasing body fat and other risk factors [6]. National and sub-regional data show a high prevalence of diabetes and variation by age, sex and social factors, underlining the need for robust and comparable surveillance over time and across groups [7]. However, even with high-quality surveillance data, variation in “prevalence of diabetes” across studies can arise from differences in methods rather than actual changes in the disease. This includes variation in age groups considered (for example, 18+ Vs 20-79 years), differences in age standardization and whether diagnosed and undiagnosed cases are included [8].

International indicator platforms attempt to address these comparability problems by combining data into straightforward, easy-to-understand outputs. The NCD Risk Factor Collaboration is a large-scale pooled analysis of global trends in diabetes and country-by-year estimates of age-standardized adult prevalence, with uncertainty ranges derived from the models [5,9]. The World Bank’s World Development Indicators publish a widely used series of diabetes prevalence in adults 20-79 years, based on the International Diabetes Federation’s Diabetes Atlas, with details on what is included [10]. The IDF also publishes country profiles and atlas summaries that relate prevalence to population numbers, which aids health planning. WHO also provides further information, such as country profiles and descriptions of indicators, to help country estimates fit into the overall non-communicable disease surveillance framework and clarify definitions of indicators. In particular, differences between these platforms may arise from variation in age inclusion criteria, diagnostic definitions, modeled versus directly reported estimates and reference populations used for standardization. For this reason, estimates from different sources should not be merged into a single continuous series unless direct comparability is established. Instead, within-source trend interpretation and cross-source triangulation provide a more methodologically defensible framework for national trend assessment [8-11].

Nevertheless, with these resources available, it is helpful to integrate them into one narrative that is time-bound, methodologically valid and appropriate to the context of Saudi Arabia’s policy and health system. By integrating several series of internationally harmonized data into one framework, we can determine if trends over time are similar across series, if differences by sex remain the same or change and if trends in treatment coverage are related to trends in prevalence, taking into account uncertainty and preventing unfair comparisons. Thus, the purpose of this study was to conduct a secondary retrospective analysis of international indicator series for Saudi Arabia. The primary objective was to evaluate trends in age-standardized adult diabetes prevalence within the main harmonized analytical series. Secondary objectives were to assess treatment coverage trends and sex-gap measures, while cross-source comparisons were presented descriptively for triangulation rather than pooled estimation.

METHODS

Study Design and Setting

We conducted a secondary, retrospective time-series analysis to examine the trend of adult diabetes prevalence in Saudi Arabia from 2000 to 2024 using internationally harmonized indicators. This was an ecological study at the country level, with annual estimates and was reported according to the usual guidelines for observational studies using aggregate, routinely collected data.

The unit of analysis was the country of Saudi Arabia as a whole. The target population was adults as defined by each data source (e.g., adults aged 18+ for some age-standardized prevalence series; adults aged 20-79 for IDF-derived country prevalence series). As we analyzed aggregated country-level data without any personal information, there was no sampling frame or participants to recruit.

Data Sources and Criteria

We extracted internationally harmonized diabetes indicators from:

- NCD Risk Factor Collaboration (NCD-RisC) for age-standardized adult prevalence (18+) and, if available, treatment coverage in people with diabetes (30+)
- World Bank World Development Indicators (WDI) sourced from the International Diabetes Federation (IDF) Diabetes Atlas (indicator SH.STA.DIAB.ZS; adults 20-79)
- For the main trend analyses, NCD-RisC was treated as the primary analytical source because it provided internally comparable annual age-standardized estimates with sex stratification across the study period. WHO materials were used mainly for contextual interpretation of indicator definitions, whereas IDF/WDI estimates were used as descriptive cross-series anchors rather than as part of the same modeled trend line

We included data points with annual estimates that applied to Saudi Arabia, ranged from 2000 to 2024 and were provided with a specified denominator and information on the age group and standardization. We excluded data points if the definition of the indicator was not clear, the year was not in the range, or if there were duplicates after the harmonization.

Variables and Operational Definitions

The primary outcome was the prevalence of diabetes, expressed as a percentage, stratified by sex when possible and using the standard definition for each source (e.g., age-standardized prevalence in adults ≥18 years for NCD-RisC, age-standardized prevalence in adults 20-79 years for IDF/WDI). In this manuscript, treatment coverage refers to the proportion of people living with diabetes who were receiving treatment according to the original source definition. Because this definition originates from the harmonized source platform, it should be interpreted as a source-specific treatment indicator rather than a direct measure of all dimensions of diabetes care engagement, adherence, or quality of management. For uncertainty, we retained the uncertainty intervals as reported by the source (e.g., 95% UI) and quantified the width of uncertainty as the difference between the upper and lower bounds of the UI. We did not attempt to reverse-engineer individual-level risks or numbers unless the source provided compatible denominators and numbers.

Data Extraction and Management

For each source, we extracted annual estimates, along with their uncertainty bounds and stratification (sex stratification when available). We organized a data dictionary with structured information about the indicator name, source, year, age group, method of standardization, formulation of the numerator/denominator (according to the source) and uncertainty details. We processed the data by coercing it to numeric types, standardizing year formats and performing range and consistency checks (UI lower bound ≤ point estimate ≤ UI upper bound). Duplicates were removed and variables were harmonized to a common structure before analysis.

Harmonisation Strategy Across Sources

Due to differences in age bands and case definitions across international datasets, we applied a “source-preserving” method of harmonization. In practical terms, this means that an 18+ NCD-RisC prevalence estimate was interpreted only alongside other 18+ NCD-RisC values, while a 20–79 IDF/WDI estimate was interpreted only as a separate, descriptively comparable indicator. We did not stitch these sources together into one line because doing so would imply comparability that the underlying definitions do not fully support. When both NCD-RisC (≥18) and IDF/WDI (20-79) data were available, we presented them together with clear labels regarding age bands and standardization to prevent any confusion between them. We did not perform any conversion between age bands because these conversions require age-specific distributions that are not available for all years.

Statistical Analysis

We used descriptive statistics (mean, SD, median, min, max) to summarize annual patterns by sex and pooled (the source's own pooled time series, not a simple average of the sexes, if such a time series existed) and absolute change (percentage points) from year to year to assess short-term change. Linear trend models were estimated using ordinary least squares with year as the predictor to assess average annual change (slope, points per year) for each outcome, with model fit assessed using R^2 and CIs for the slope. To check results without assuming a distribution, we also performed non-parametric trend tests using rank correlations (Spearman’s rho and Kendall’s tau) and Sen’s slope. Sex differences were analyzed as time series (female minus male) using both OLS and non-parametric tests. Because the study was designed as a descriptive ecological trend analysis, we did not apply formal autocorrelation-adjusted time-series models or joinpoint/segmented regression. Therefore, the linear and non-parametric analyses should be interpreted as summary approaches to overall trend direction rather than as full models of temporal structure or turning points.

Data Visualization

We generated plots amenable to publication to display (i) sex-stratified and combined trends with uncertainty ribbons for prevalence and treatment coverage, (ii) 3D surfaces showing the combined structure of sex and time and (iii) heatmaps of standardized (z-score) metrics and uncertainty widths to provide a compact summary of trends in multiple metrics over time. Plots were exported at high resolution with proper labeling and spacing for journal publication.

Software and Reproducibility

All data analysis, statistical analysis and figure generation were performed using fully reproducible code in a standard scientific computing environment (Python; pandas/numpy libraries for data manipulation; matplotlib library for plotting). Derived quantities (yearly changes, sex gaps, uncertainty widths, z-scores) were calculated deterministically from the extracted numbers and intermediate datasets were version-controlled to allow full traceability from raw data to final tables and figures.

Ethical Considerations

This study used publicly available, aggregated country-level data and did not involve individual-level data, personal identifiers, or interventions. Thus, ethics committee approval and informed consent were not necessary; this research fell under standard exemptions for secondary analysis of non-identifiable public data.

RESULTS

For descriptive purposes, the study period was divided into 2000–2007, 2008–2015 and 2016–2022 to summarize early, middle and later phases of the observed series. These windows were chosen to aid interpretation of visibly different phases in the data and were not intended to represent formally estimated change-points. For males, prevalence increased slightly in 2000-2007 (positive slope; $p<0.05$), then decreased substantially in 2008-2015 and 2016-2022 (negative slopes; very small p-values), so the overall decrease is due to the post-2000s decline. For females, prevalence decreased significantly in all periods (negative slopes; significant p-values) (Table 1).

Table 2 presents treatment coverage data, which increased significantly in all periods for both sexes (positive slopes; very small p-values). The trends appear linear and smooth and the period-wise analysis indicates that the increase in coverage continued throughout the entire period. Table 3 presents the linear trends for 2000-2022. Prevalence decreased significantly in both males and females (negative slopes; significant p-values). Treatment coverage increased significantly in both males and females (positive slopes; very small p-values) with a very high R^2 value, especially for treatment.

Table 1: Period Summaries-Prevalence (18+), by Sex (with Within-Period Trend p-Values)

Sex	Period	Years	n	Mean	SD	Median	Min	Max	Mean_UI_width	Slope_per_year	p_trend
Men	2000–2007	2000-2007	8	25.18	0.29	25.31	24.61	25.42	9.86	0.097	0.0108
	2008–2015	2008-2015	8	24.42	0.60	24.45	23.54	25.19	11.84	-0.243	5.1e-08
	2016–2022	2016-2022	7	22.26	0.78	22.26	21.19	23.31	20.65	-0.362	9.1e-09
Women	2000–2007	2000-2007	8	25.60	0.26	25.66	25.11	25.84	9.74	-0.077	0.0346
	2008–2015	2008-2015	8	23.79	0.75	23.79	22.74	24.84	12.02	-0.305	4.9e-11
	2016–2022	2016-2022	7	21.11	0.95	21.13	20.05	22.74	21.50	-0.384	1.2e-09

Table 2: Period Summaries-Treatment Coverage (30+), by Sex (with Within-Period Trend p-Values)

Sex	Period	Years	n	Mean	SD	Median	Min	Max	Mean_UI_width	Slope_per_year	p_trend
Men	2000–2007	2000-2007	8	41.35	1.76	41.33	39.05	43.75	42.48	0.664	3.8e-08
	2008–2015	2008-2015	8	45.86	1.07	45.86	44.36	47.32	43.71	0.421	7.5e-10
	2016–2022	2016-2022	7	49.50	1.04	49.26	48.15	51.17	50.87	0.488	2.2e-07
Women	2000–2007	2000-2007	8	44.21	1.52	44.01	41.84	45.95	41.54	0.582	1.1e-07
	2008–2015	2008-2015	8	47.95	1.03	47.80	46.43	49.53	42.99	0.446	5.7e-10
	2016–2022	2016-2022	7	50.97	0.67	51.01	50.02	51.82	45.70	0.300	3.7e-07

Table 3: Overall Linear Trend Models (2000–2022): Slope, 95% CI, p-Value, R^2

Sex	Outcome	n	Slope (%-points/yr)	95%CI_lo	95%CI_hi	p	R^2
Men	Diabetes prevalence (18+), %	23	-0.181	-0.220	-0.142	3.3e-09	0.817
	Treatment coverage (30+), %	23	0.574	0.534	0.613	9.1e-19	0.977
Women	Diabetes prevalence (18+), %	23	-0.276	-0.302	-0.249	7.4e-16	0.957
	Treatment coverage (30+), %	23	0.469	0.440	0.498	1.1e-19	0.981

Table 4: Non-Parametric Trend Tests (2000-2022): Spearman, Kendall, Sen Slope

Sex	Outcome	Spearman_rho	p_rho	Kendall_tau	p_tau	Sen_slope(%-points/yr)
Men	Prevalence (18+), %	-0.878	3.6e-08	-0.771	5.3e-09	-0.210
	Treatment (30+), %	1.000	0.0000	1.000	7.7e-23	0.599
Women	Prevalence (18+), %	-0.987	3.3e-18	-0.953	2.8e-17	-0.292
	Treatment (30+), %	1.000	0.0000	1.000	7.7e-23	0.484

Table 5: Sex-Gap Statistics (2000–2022) + Cross-Series Anchors (NCD-RisC Vs World Bank/IDF)

Section	Metric	Period/Year	N	Mean (pp)	SD (pp)	Min	Max	Trend (pp/year)	p-trend	R^2
Sex differences (F–M)	Prevalence gap (F–M), pp	2000–2022	23	-0.234	0.632	-1.14	0.99	-0.087	6.64e-11	0.874
Sex differences (F–M)	Treatment gap (F–M), pp	2000–2022	23	1.972	0.659	0.65	2.82	-0.090	2.38e-10	0.858
Cross-series anchor	NCD-RisC pooled prevalence (18+), %	2000	NA	25.10	NA	NA	NA	NA	NA	NA
Cross-series anchor	NCD-RisC pooled prevalence (18+), %	2022	NA	20.62	NA	NA	NA	NA	NA	NA
Cross-series anchor	IDF / WDI SH.STA.DIAB.ZS (20–79), age-standardised %	2024	NA	23.1	NA	NA	NA	NA	NA	NA

This indicates that treatment coverage followed a highly linear increasing pattern, whereas prevalence showed an overall declining trend with non-uniform temporal shape, including a temporary mid-series rise before further decline.

Table 4 confirms the results using non-parametric tests. The Spearman's ρ and Kendall's τ correlation coefficients indicate strong and very significant monotonic decreases in prevalence and near-perfect monotonic increases in treatment coverage (very small p-values). The Sen's slopes are consistent with the linear models, confirming that the results are not due to parametric assumptions. Table 5 describes the statistics for the sex gap and anchors for the series. The prevalence gap (female-male) has a negative mean over 2000-2022 and a significant time trend, indicating that the relative gap between the sexes is not constant, despite the absolute values being small. The treatment gap remains positive and changes over time, as suggested by women maintaining higher coverage while the gap closes.

Figure 1 indicates that the pooled prevalence decreased from the early 2000s to 2022. Both sexes followed a similar trend of decreasing, with a slight peak around 2016 before continuing the decrease. Figure 2 indicates that the treatment coverage increased from 2000 to 2022 for men, women and the pooled group, without significant drops. The trend lines for both sexes indicate that women had a slightly higher coverage than men for most of the time and the overall trend line also increased. Figure 3 broadly reflects the same pattern seen in Figure 1, namely an overall decline over time for both sexes with modest mid-series variation rather than a perfectly uniform decrease. The surface and the points on it indicate that the series for males and females are similar across the years, with no significant difference between them.

Figure 4 indicates a steadily increasing surface, indicating a linear increase in the treatment coverage over the years for both males and females. The fact that the points for males and females are very close to the surface and are steadily diverging indicates that women had a slight but real advantage in coverage. Figure 5 summarizes the timing of the trends, indicating that the treatment metrics increased to higher standardized values over time, while the prevalence metrics decreased to lower standardized values in the later years.

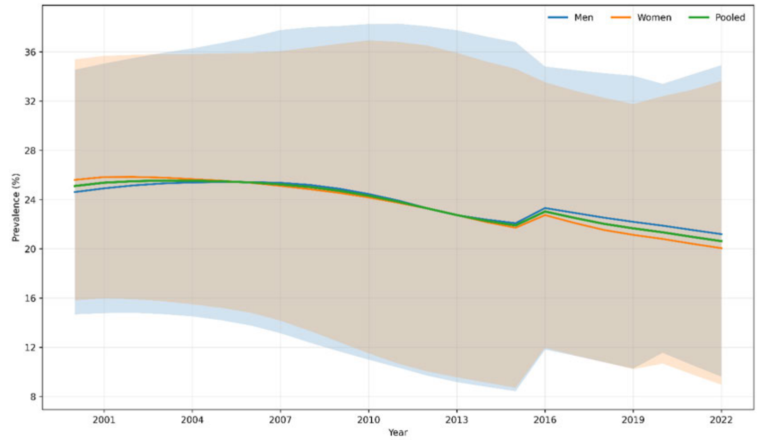

Figure 1: Saudi Arabia, 2000-2022: Age-Standardised Diabetes Prevalence (%) in Adults (18+), by Sex, with 95% Uncertainty Intervals; Pooled Series Shown for Reference

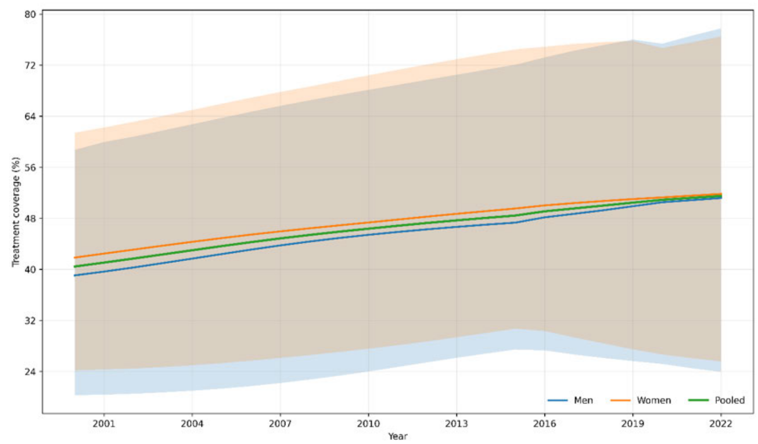

Figure 2: Saudi Arabia, 2000-2022: Treatment Coverage (%) among People Living with Diabetes Aged ≥30 Years, by Sex, with 95% Uncertainty Intervals; Pooled Series Shown for Reference

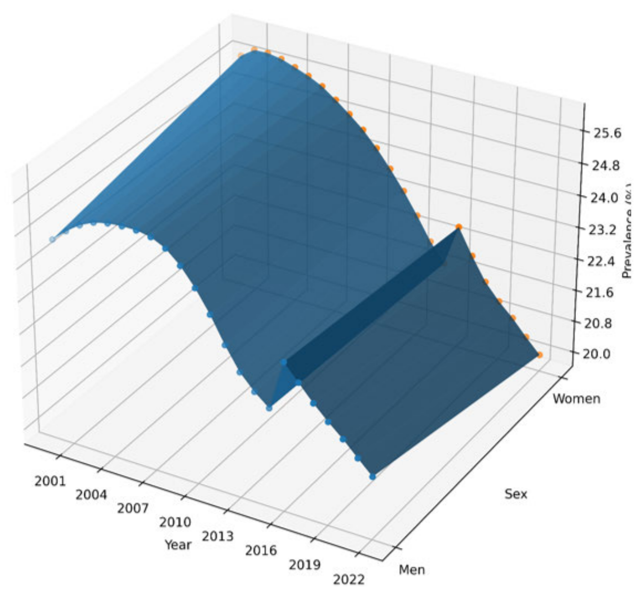

Figure 3: Saudi Arabia, 2000-2022: 3D Surface Representation of Age-Standardised Diabetes Prevalence (18+) Across Years, Stratified by Sex (Men Vs Women)

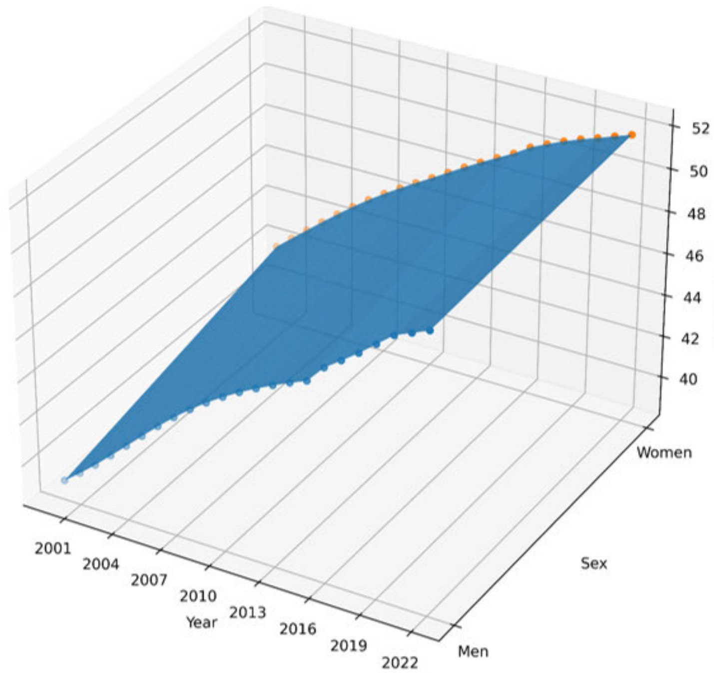

Figure 4: Saudi Arabia, 2000-2022: 3D Surface Representation of Diabetes Treatment Coverage (30+) Across Years, Stratified by Sex (Men Vs Women)

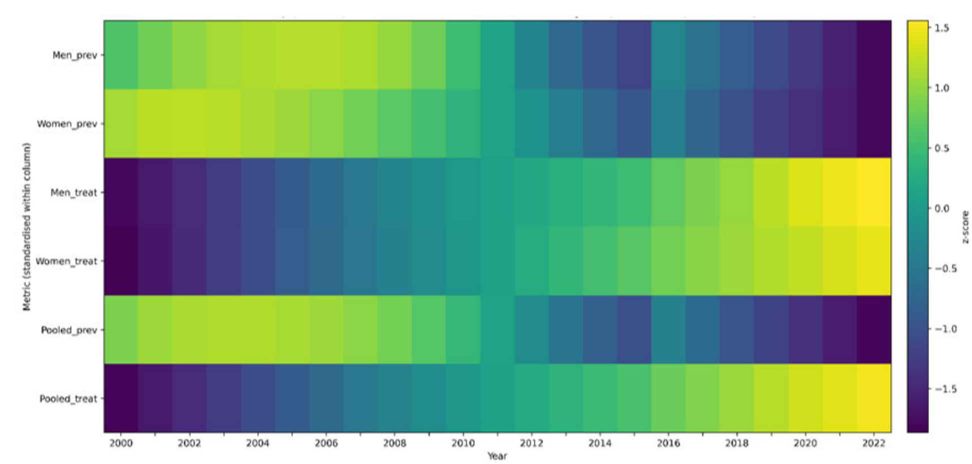

Figure 5: Saudi Arabia, 2000-2022: Standardised Heatmap (z-scores) Summarising Temporal Patterns across Prevalence and Treatment Metrics (Men, Women, Pooled)

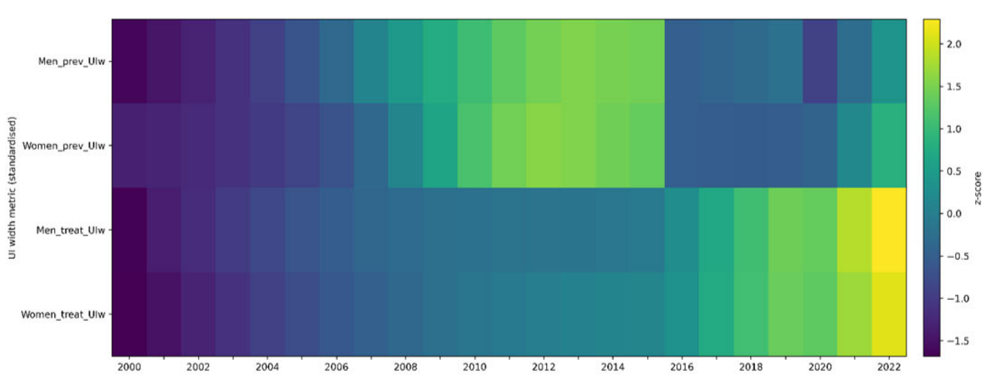

Figure 6: Saudi Arabia, 2000-2022: Standardised Heatmap (z-scores) of Uncertainty Interval Widths (UI_hi − UI_lo) for Prevalence and Treatment Estimates, by Sex, Across Years

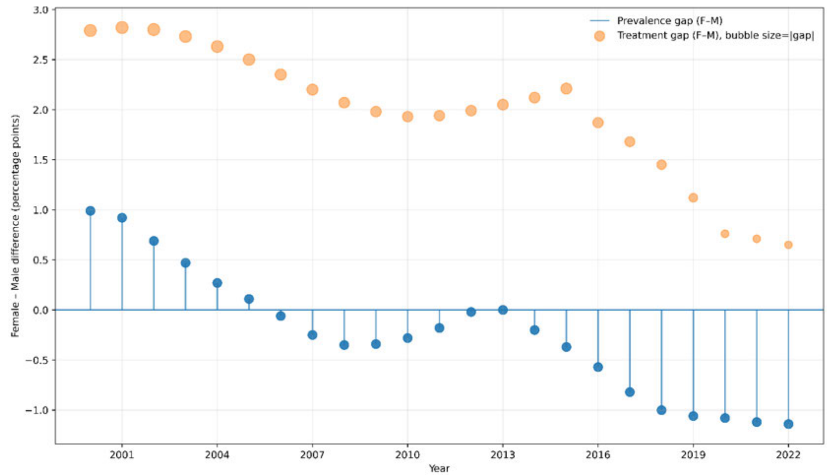

Figure 7: Saudi Arabia, 2000-2022: Sex Gaps in Diabetes Indicators: Prevalence Gap (Female–Male, Percentage Points) Shown as Lollipops and Treatment Gap Shown as Bubbles Scaled to the Absolute Gap Magnitude

Figure 6 indicates that there were large changes in the uncertainty over time, with larger intervals in some years. This indicates that the statistical uncertainty for the prevalence and treatment estimates varied over time and across the metrics. Figure 7 (sex-gap lollipop-bubble plot) illustrates how the difference in prevalence between females and males varies around zero, while the difference in treatment coverage varies mostly above zero, indicating that females had higher coverage on average.

DISCUSSION

In this analysis of harmonized indicators, the adult prevalence of diabetes in Saudi Arabia, when age-adjusted, showed a net decrease over time. Meanwhile, the treatment coverage for those with diabetes increased steadily and in a relatively linear fashion. These findings are best explained by the World Health Organization (WHO) method of tracking, which specifies that "age-adjusted diabetes estimates should be comparable and should use consistent definitions, methods and population structures." [9] Importantly, a decline in age-standardized prevalence does not necessarily imply that fewer people are living with diabetes in absolute terms. Population growth, population ageing and improved survival can sustain or even increase the total number of people affected, even when age-adjusted prevalence declines. [12-14].

In relation to other research specific to Saudi Arabia, the overall trend still indicates a mature diabetes problem with a strong and persistent burden and irregular distribution [15]. National surveys and analyses of cross-sectional studies indicate high levels of diabetes and that the burden of diabetes has remained high in the past few years, although perhaps improving in age-adjusted prevalence as indicated by the harmonized data. Research regarding income and social inequalities, as well as overall health disparities, also indicates that national averages obscure important differences [16-18]. Thus, the trends over time are likely indicative of changes in population demographics, what people are exposed to in terms of risk factors and the ease of access to testing and treatment. As obesity is a major contributor, the trend in prevalence is instead thought to reflect changes in prevention, new cases and survival rates rather than treatment programs [19-23].

The increase in treatment use is consistent with a medical environment in which many people with diabetes have multiple health problems and are at increased risk of complications. Findings of many treatments and cardiovascular conditions among adults with type 2 diabetes in Saudi Arabia support the notion that health care intensity and treatment use may have increased as risk increased [24-28]. Examining risk by social and demographic characteristics and evidence of common related conditions-such as sleep problems, nerve damage, eye disease and certain autoimmune diseases-demonstrates that the medical importance of diabetes remains significant, even if the prevalence has changed slightly. The narrowing treatment gap in the present study appears to reflect improvement in both sexes, with women maintaining a modest advantage in coverage while men show relative catch-up over time. This interpretation is consistent with a closing gap driven more by male improvement than by loss of female treatment coverage. [22,29-32].

Findings from the pandemic era suggest there may have been short-term shifts in the medical environment in which conditions are identified, the course of diabetes and the emergence of new cases, which may account for some year-to-year variation [33]. Taken together, the findings indicate that chronic disease care and treatment access improved substantially over time in Saudi Arabia, while prevalence declined slightly in the harmonized data, in a context in which underlying metabolic risk, inequality and burden of complications continue to shape health need and policy.

Limitations

This secondary analysis had grouped, modeled indicator data instead of individual data. This makes it difficult to show cause-and-effect relationships or compare countries, diagnostic methods, or other health issues that people have.

Variations in age groups, population standardization and the detection of cases for the indicators make it difficult to compare time series. Therefore, we can see trends but cannot prove them. Variations in the accuracy of the estimates from year to year also influenced the results and therefore, small changes from year to year should be viewed cautiously.

CONCLUSION

This secondary analysis of harmonized international indicators suggests that age-standardized adult diabetes prevalence in Saudi Arabia declined overall within the main 2000–2022 analytical series, while treatment coverage increased steadily over the same period. The 2024 IDF/WDI estimate should be interpreted as a descriptive cross-series anchor rather than part of the same modeled trend line. Together, these findings support continued strengthening of standardized national diabetes surveillance, careful interpretation of cross-source estimates and targeted efforts to improve treatment engagement, particularly where sex-based differences in coverage persist.

Ethical Consideration

Because the study relied on modeled public indicators that may inform policy interpretation, particular care was taken to preserve source definitions, avoid inappropriate cross-series pooling and report uncertainty transparently.

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