National and subnational burden of disease attributable to risk factors in Italy, 1990–2023: a systematic analysis from the Global Burden of Disease Study 2023

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Summary

Background The increasing prevalence of most non-communicable diseases in Italy represents a major public health challenge, largely influenced by modifiable risk factors. This study aims to analyse time trends and subnational differences in the burden of disease attributable to risk factors in Italy, from 1990 to 2023.

Methods We used estimates from the Global Burden of Diseases, Injuries, and Risk Factors Study 2023 to assess the disease burden attributable to risk factors across five Italian macro regions between 1990 and 2023. Burden was measured using disability-adjusted life years (DALYs), reported as all-age and age-standardised rates per 100 000 population. Correlations between the Socio-demographic Index (SDI) and DALYs attributable to behavioural, metabolic, and environmental or occupational risk factors were assessed.

Findings Between 1990 and 2023, metabolic risks in males declined nationally (–7·3% [95% uncertainty interval (UI) –14·1 to –0·2]) but rose in the South and remained stable in the Islands. In females, they were stable overall (–0·4% [–10·3 to 8·4]) but increased in the South and Islands. Behavioural risks decreased across all macro regions in both sexes. DALYs from metabolic risks were strongly and inversely correlated with SDI in both sexes (r=–0·79, p<0·001), whereas behavioural risks correlated negatively with SDI only in males (r=–0·66, p=0·001). During the same time, the proportion of unattributable DALYs increased from 48% to 58% in males and from 60% to 65% in females.

Interpretation Despite overall improvements in attributable burden between 1990 and 2023, substantial geographical disparities and sex differences persist, underscoring the need for stronger tobacco control, gender-sensitive interventions on metabolic risks, and the integration of social determinants into health policy.

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See **Comment** page e271

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Introduction

Non-communicable diseases, including cardiovascular diseases, cancers, diabetes, and chronic respiratory diseases, remain the leading cause of death and disability in the WHO European Region.[1] Each year, an estimated 1·8 million deaths are considered avoidable, with 60% modifiable through reduced exposure to risk factors and effective public health interventions. In Italy, the prevalence of most non-communicable diseases has steadily increased in the past three decades, posing a major health and social challenge. This burden, largely driven by cardiovascular diseases and cancers, is partly attributable to population ageing and strongly linked to modifiable risk factors.[2,3]

Promoting healthy lifestyles by addressing behavioural risks (eg, smoking, alcohol use, and physical inactivity), regularly monitoring metabolic indicators (eg, lipids and glycaemia), and consistently assessing environmental exposures, such as air quality, are key strategies to prevent and reduce this burden.[3]

Across Europe, numerous studies have underscored the growing effect of modifiable risk factors on population health. A 2023 scoping review identified 48 European studies estimating the disease burden attributable to risk factors, reflecting the growing use of the burden of disease approach to characterise patterns of health loss and inform health-care system responses.[4]

In Italy, however, evidence remains fragmented and often disease specific. The most extensive estimates concern cancer, of which smoking stands out as a leading contributor, accounting for 23·9% of cases in men and 7·7% in women in 2020.[5] Alcohol use is another important modifiable risk factor for cancer, also contributing to the progression of precancerous lesions.[6,7]

Dietary risks likewise have a role, with unhealthy dietary habits responsible for 6·3% of cases in males and 4·5% in females in the same year. Although the cancer burden attributable to diet in Italy is lower than in other high-income countries (likely reflecting the protective effects of the Mediterranean diet), the latest data show a decline in the intake of healthy foods, and the

Research in context

Evidence before this study

Several European studies have highlighted the growing effect of non-communicable diseases and their associated risk factors. A scoping review identified 48 European studies focusing on the burden of disease attributable to risk factors since 1980, indicating increased attention to this approach for understanding patterns of health loss and the health-care system's response. In Italy, recent studies provided systematic assessments of the effect of modifiable risk factors on cancers, showing that tobacco smoking accounts for 23·9% and 7·7% of new cancer cases in men and women, respectively. Conversely, studies on cardiovascular and cerebrovascular diseases attributable to risk factors are sparse. Recent analyses of environmental risk factors showed reduced air pollution levels, although $PM_{2·5}$ still accounts for 11·7% of annual deaths, with significant geographical variability.

Added value of this study

This study provides the first comprehensive analysis of disease burden attributable to behavioural, metabolic, environmental, and occupational risk factors across Italian macro regions from 1990 to 2023 using Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) estimates. It highlights marked subnational and sex disparities in health outcomes. The increase in unattributed disability-adjusted life-years (DALYs), together with the well documented decline in age-standardised DALYs, suggests improvements in population health, although important challenges persist. Smoking emerged as the leading risk factor for males across all macro regions, whereas high systolic blood pressure predominated among females. Substantial reductions in behavioural risk factors were observed in males, particularly in northern regions, whereas metabolic risks showed concerning upward trends in the South. The analysis highlights strong correlations between the burden of risk factors and socioeconomic indicators (ie, the Socio-demographic Index), emphasising the role of social determinants in health outcomes.

Implications of all the available evidence

The findings emphasise the contribution of metabolic and behavioural risks to the burden of disease in Italy. Their strong correlations with socioeconomic indicators underline that prevention policies must also address upstream social and commercial determinants of health that shape exposure to risk factors. Regional estimates from GBD 2023, integrated with other data and tools, provide valuable support for defining future prevention strategies. These results reinforce the need for targeted interventions to address regional disparities and sex differences, strengthen tobacco control policies, and develop tailored prevention programmes.

contribution of overweight and obesity remains considerable, accounting for 3·6% of cancers in men and 4·0% in women in 2020.[8–10]

Occupational risk factors contribute a comparatively smaller but persistent share of the cancer burden, mainly affecting older generations as a result of past exposures and the effectiveness of occupational health policies in reducing such risks.[11]

As for other diseases, evidence on cardiovascular diseases attributable to risk factors in Italy remains scarce, although available studies suggest a considerable effect, particularly among women in the South.[12,13] In 2023, the burden of cardiovascular diseases attributable to environmental exposures has also been assessed with a national study estimating mortality attributable to long-term exposure to particulate matter (PM), $PM_{2·5}$, and NO_2, including natural, cardiovascular, and respiratory causes, even though restricted to fatal outcomes only.[14]

For these reasons, systematic, comprehensive, and locally disaggregated estimates of the burden of disease attributable to modifiable risk factors are essential for informing health policies and guiding effective prevention strategies. The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) provides an extensive global epidemiological framework, quantifying health loss from hundreds of diseases, injuries, and risk factors across countries worldwide.[15] GBD estimates are essential for policy evaluation and for monitoring progress towards the Sustainable Development Goals and WHO targets.

This study provides a comprehensive overview of the risk factors affecting the health of the Italian population, with the aim of identifying areas where further preventive efforts are needed. To this end, estimates from the GBD 2023 were examined at both national and subnational levels over the period of 1990–2023.

Building on the Italian GBD 2021 subnational analysis published in April, 2025, which focused on causes of death and disability, this work shifts the focus to the burden attributable to risk factors, providing a comprehensive overview across Italy and its macro regions.[16] By ensuring high comparability across risks, locations, sexes and time, this work offers additional insights to support future, more targeted analyses and to inform public health strategies aimed at reducing inequalities and improving health outcomes across the country.

Methods

Overview

GBD 2023 produces annual estimates of prevalence, incidence, and mortality for 371 causes and 88 risk factors, continuously integrating newly available data, refining modelling strategies, and adhering to the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER). Each iteration of the

study updates the full time series, thereby replacing previous estimates to incorporate methodological enhancements and expanded data sources. A comprehensive description of the GBD methodology is available in the capstone publication.[3]

Data sources

Relative risk (RR) estimates for each risk–outcome pair were derived by synthesising evidence from primary sources (eg, cohort studies or case–control studies) reporting RRs of mortality or morbidity as a function of risk exposure. In addition, meta-analyses summarising risk–outcome associations were incorporated where available. All data were obtained from systematic reviews, including updates of reviews conducted in previous GBD cycles and newly conducted reviews. Italy is the fifth-largest contributor of data to the GBD Study. In GBD 2023, estimates of the burden of risk factors were informed by 338 distinct citations, corresponding to 270 627 rows of source metadata available in the Global Health Data Exchange. Specifically, among the 338 data sources included, 155 (45·9%) consisted of scientific publications and 129 (38·2%) of surveys, followed by administrative databases (14 [4·1%]), reports (14 [4·1%]), and vital registration sources (12 [3·6%]); the remaining 14 (4·1%) sources comprised epidemiological surveillance systems, environmental monitoring data, census data, or model-based estimates. Moreover, metadata are broadly evenly distributed across Italian regions, with each region contributing around 3% of the total and national-level sources accounting for approximately 36% (appendix 1 p 3). This homogeneous distribution, paired with the borrowing-strength approach used in the estimation process, supports the absence of major geographical imbalances in data availability that could differentially affect subnational estimates.

Estimates of the Socio-demographic Index (SDI) are also accessible at the same source. SDI is a composite indicator combining three key dimensions—income per capita, average educational attainment among those aged 15 years or older, and total fertility rate for those younger than 25 years—scaled from 0 to 1. Higher values indicate higher levels of socio-demographic development.

Risk factor hierarchy

GBD organises all risk factors into a hierarchical structure consisting of four levels, with an overarching category that aggregates all risk factors.[3] At Level 1, risk factors are grouped into three broad categories: environmental and occupational, behavioural, and metabolic. These are further disaggregated at Level 2 into 20 individual risk factors or clusters. At Level 3, nine of the Level 2 categories are subdivided into 42 more specific risks or clusters, whereas the remaining 11 Level 2 risks are retained without further disaggregation. Level 4 represents the most granular level of classification, comprising 22 additional specific risk factors derived from the disaggregation of five Level 3 risks.

Risk factor estimation

This analysis followed the Comparative Risk Assessment framework developed by GBD to estimate the burden attributable to modifiable risk factors.[3] RRs were estimated for each risk–outcome pair through

See Online for appendix 1

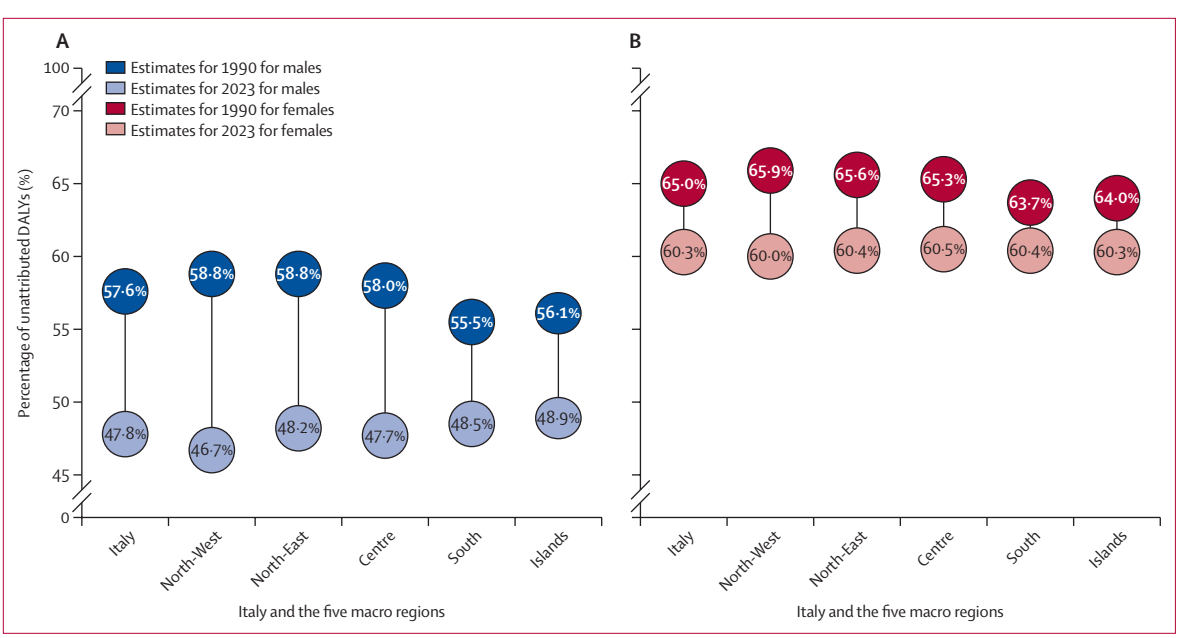

Figure 1: **Percentage of non-attributable all-age DALYs for all causes in Italy and in the five macro regions by sex in 1990 and 2023**
(A) Estimates for 1990 and 2023 for males. (B) Estimates for 1990 and 2023 for females. Vertical lines indicate the range between the two years. DALYs=disability-adjusted life years.

meta-regression using the burden of proof approach. In this framework, risk–outcome pairs were included if the 95% uncertainty interval for the RR excluded the null.

Exposure levels and distributions were estimated using a Bayesian approach based on spatiotemporal Gaussian process regression and DisMod-MR 2.1, which enabled the integration of heterogeneous data while adjusting for potential biases. Counterfactual scenarios were defined using theoretical minimum risk exposure levels (TMRELs), corresponding to the exposure levels associated with the lowest population risk. Based on estimated RRs, exposure distributions, and TMRELs, population attributable fractions were computed for each risk–outcome pair to quantify the proportional reduction in disease burden if the exposure was reduced to TMREL levels. Summary exposure values were calculated to reflect the age-specific,

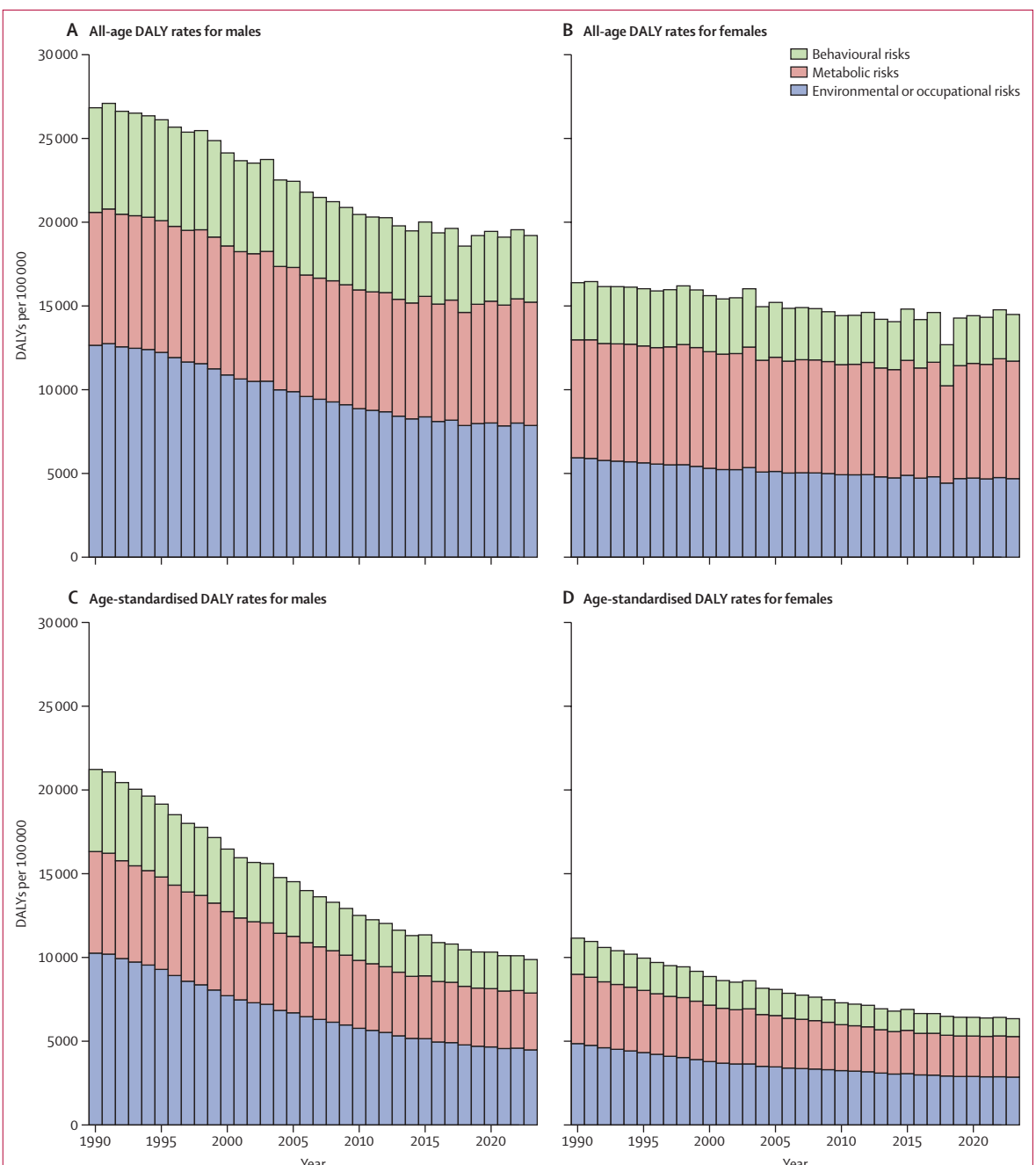

Figure 2: **Trend of all-age DALYs for all causes and attributable to risk factors in Italy and in the five macro regions for both sexes**
(A) All-age DALY rates for males. (B) All-age DALY rates for females. (C) Age-standardised DALY rates for males. (D) Age-standardised DALY rates for females. DALYs=disability-adjusted life years.

risk-weighted prevalence of exposure, scaled from 0 (population at TMREL) to 100 (population at the highest observed risk level). To account for interdependencies among risk factors, mediation effects among risk factors were incorporated to avoid overestimating population attributable fractions and to allocate the burden across interrelated risks. Finally, the attributable burden was calculated as the product of population attributable fractions and the corresponding outcome burden, disaggregated by age, sex, location, and year. Although the standard pipeline was applied to most risk–outcome pairs, alternative approaches were used when required by the nature of the evidence; for example, the direct attribution for outcomes inherently caused by a specific risk.

Within the Comparative Risk Assessment framework, attributable burden is assigned to the calendar year in which the health outcome is observed, using age-sex-location-year-specific exposure distributions and RRs indexed to that outcome year. This approach reflects the timing of outcome measurement rather than exposure occurrence; accordingly, for diseases with long induction or latency periods, burden observed in a given year might result from exposures that occurred years or decades earlier.

In this framework, it is important to emphasise that estimates of attributable burden for individual risks or risk groups should be interpreted as marginal, counterfactual-specific quantities, not as mutually exclusive components of total burden; by contrast, the estimate for all risk factors combined represents the non-overlapping burden that would be avoided under simultaneous reduction of all risks.

Data presentation

The burden of disease was quantified using disability-adjusted life years (DALYs), which represent the sum of years of life lost due to premature mortality and years of life lived with disability. Estimates were presented as both all-age and age-standardised rates per 100 000 population. Age-standardisation was done with the GBD reference population to allow for comparisons across regions and over time. All estimates were reported with 95% uncertainty intervals (UIs), defined as the 2·5th and 97·5th percentiles of a 250-draw posterior distribution generated through the GBD modelling process. Non-overlapping 95% UIs were considered indicative of statistically significant differences.

Statistical analysis

Analyses were conducted for Italy at national and macro-regional levels (ie, North-West, North-East, Centre, South, and Islands), according to the NUTS-1 classification.[17] Specifically, Italian regions and autonomous provinces are grouped as follows: (1) North-West: Piemonte, Valle D'Aosta, Liguria, and Lombardia; (2) North-East: Provincia Autonoma di Bolzano, Provincia Autonoma di Trento, Veneto, Friuli Venezia-Giulia, and Emilia Romagna; (3) Centre: Toscana, Umbria, Marche, and Lazio; (4) South: Abruzzo, Molise, Campania, Puglia, Basilicata, and Calabria; and (5) Islands: Sicilia and Sardegna. Aggregation at the macro-regional level was adopted to leverage relative homogeneity in risk factor

	Risk factor	DALYs (95% UI)	Percentage difference since 1990 (95% UI)
Italy			
1	Smoking	3432·5 (2751·5–4204·5)	−47·5 (−53·8 to −42·3)
2	High SBP	3044·4 (2527·2–3552·9)	−31·9 (−38·5 to −25·8)
3	High BMI	2582·6 (1177·2–3927·3)	40·9 (13·4 to 72·8)
4	High FPG	2398·5 (2003·2–2881·9)	22·6 (−1·5 to 50·0)
5	Ambient PM pollution	1320·2 (942·1–1759·8)	−50·0 (−65·0 to −21·9)
6	High alcohol use	1213·9 (909·0–1589·9)	−38·2 (−46·9 to −28·5)
7	High LDL	1129·9 (726·1–1569·7)	−48·0 (−54·3 to −41·9)
8	Kidney dysfunction	1016·0 (875·8–1191·3)	12·8 (2·0 to 25·4)
9	Lead exposure	803·2 (619·5–992·6)	−35·2 (−42·9 to −28·6)
10	Occupational carcinogens	699·3 (542·0–868·9)	−31·7 (−37·3 to −25·3)
North-West			
1	Smoking	3497·4 (2712·1–4310·8)	−53·4 (−60·8 to −48·1)
2	High SBP	2915·0 (2364·2–3396·4)	−39·5 (−46·6 to −33·7)
3	High BMI	2189·2 (944·6–3379·9)	22·5 (−4·1 to 51·8)
4	High FPG	1866·2 (1565·0–2168·3)	8·2 (−10·9 to 26·3)
5	Ambient PM pollution	1511·9 (1115·8–1998·4)	−56·9 (−68·2 to −36·3)
6	High alcohol use	1216·9 (923·2–1590·1)	−47·0 (−54·3 to −38·3)
7	High LDL	1083·6 (701·9–1528·8)	−54·4 (−60·2 to −49·0)
8	Kidney dysfunction	939·8 (800·4–1109·9)	0·4 (−9·1 to 11·3)
9	Occupational carcinogens	838·9 (670·0–1028·2)	−47·2 (−53·4 to −40·6)
10	Lead exposure	702·3 (542·5–847·2)	−44·5 (−50·9 to −39·1)
North-East			
1	Smoking	3056·5 (2357·7–3783·4)	−57·3 (−63·7 to −51·6)
2	High SBP	2841·6 (2373·6–3279·8)	−42·8 (−47·9 to −37·6)
3	High BMI	2480·5 (1094·2–3773·4)	27·1 (4·2 to 53·7)
4	High FPG	2258·7 (1851·5–2784·4)	14·5 (−12·7 to 48·7)
5	Ambient PM pollution	1407·4 (1007·5–1893·5)	−58·0 (−70·2 to −35·7)
6	High alcohol use	1263·3 (916·0–1608·0)	−43·4 (−53·0 to −33·1)
7	High LDL	1038·2 (667·9–1452·3)	−57·0 (−62·6 to −51·9)
8	Kidney dysfunction	946·1 (797–1108·8)	−2·4 (−12·9 to 9·2)
9	Lead exposure	673·0 (523·9–833·6)	−48·7 (−54·8 to −42·8)
10	Occupational carcinogens	644·6 (500·2–792·8)	−48·0 (−53·8 to −41·0)
Centre			
1	Smoking	3268·8 (2581·4–4041·8)	−50·7 (−56·9 to −44·7)
2	High SBP	2977·8 (2393·2–3470·8)	−36·7 (−44·0 to −30·7)
3	High BMI	2532·1 (1147·2–3846·3)	34·4 (8·4 to 63·0)
4	High FPG	2366·9 (1916·8–2957·1)	17·1 (−11·6 to 54·4)
5	Ambient PM pollution	1218·5 (834·2–1654·2)	−48·4 (−65·7 to −14·3)
6	High alcohol use	1168·6 (860·0–1532·1)	−33·7 (−43·9 to −21·3)
7	High LDL	1101·7 (695·8–1545·9)	−49·8 (−56·9 to −43·0)
8	Kidney dysfunction	1007·1 (850·6–1183·7)	6·8 (−3·2 to 18·3)
9	Lead exposure	774·8 (607·6–950·1)	−38·6 (−46·7 to −32·7)
10	Occupational carcinogens	654·9 (504·6–835·7)	−24·1 (−34·5 to −13·3)

(Table 1 continues on next page)

	Risk factor	DALYs (95% UI)	Percentage difference since 1990 (95% UI)
(Continued from previous page)			
South			
1	Smoking	3761·8 (2988·5–4631·4)	−32·3 (−39·1 to −25·7)
2	High SBP	3380·7 (2721·9–3900·2)	−9·7 (−21·2 to 2·9)
3	High BMI	2909·6 (1392·2–4298·1)	70·3 (34·3 to 114·3)
4	High FPG	2648·0 (2231·4–3216·8)	43·7 (17·5 to 76·3)
5	High alcohol use	1258·1 (952·3–1660·7)	−26·0 (−35·9 to −13·6)
6	High LDL	1225·7 (790·2–1698·5)	−33·7 (−43·4 to −24·5)
7	Ambient PM pollution	1212·4 (849·4–1603·9)	−35·7 (−58·1 to 10·2)
8	Kidney dysfunction	1106·7 (952·3–1293·3)	40·8 (27·9 to 57·1)
9	Lead exposure	982·1 (747·3–1256·6)	−14·2 (−24·2 to −4·9)
10	Diet low in whole grains	570·7 (252·5–881·2)	−6·2 (−33·0 to 31·0)
Islands			
1	Smoking	3557·8 (2848·9–4371·2)	−33·5 (−41·4 to −26·2)
2	High FPG	3505·8 (2957·6–4109)	35·6 (16·2 to 55·9)
3	High BMI	3145·2 (1478·2–4607·2)	63·1 (34·3 to 101·3)
4	High SBP	3144·2 (2065·1–4255·4)	−23·0 (−47·5 to 5·8)
5	High LDL	1260·8 (800·5–1785·6)	−36·6 (−45·2 to −28·3)
6	Kidney dysfunction	1156·4 (987·3–1363·9)	30·7 (17·1 to 47·7)
7	Ambient PM pollution	1099·0 (693·1–1549·0)	−32·9 (−59·7 to 24·7)
8	High alcohol use	1105·3 (838·2–1451·7)	−35·1 (−43·8 to −25·3)
9	Lead exposure	964·1 (706·9–1323·9)	−21·8 (−31·9 to −10·9)
10	Diet low in whole grains	744·3 (328·7–1133·4)	−2·0 (−24·0 to 25·0)

Rankings are based on point estimates. DALYs=disability-adjusted life years. UI=uncertainty interval. SBP=systolic blood pressure. FPG=fasting plasma glucose. PM=particulate matter.

Table 1: **All-age DALY rates (per 100 000 population) in 2023 for all causes attributable to the top 10 Level 4 risk factors among males in Italy and its five macro regions**

For the **Global Health Data Exchange tool** see https://ghdx.healthdata.org/gbd-2023

distributions, thereby improving estimate stability and reducing uncertainty while maintaining meaningful geographic contrasts.

The first part of the analysis focused on the unattributable burden, defined as the share of all-cause DALYs not linked to risk factors included in the GBD framework. As a residual measure, changes in the unattributable burden might reflect multiple underlying mechanisms beyond trends in exposure to known risk factors. These might include determinants not currently captured by the GBD framework: demographic and epidemiological shifts, such as population ageing, that increase the relative contribution of more complex conditions; improvements in prevention or treatment of diseases strongly attributable to established risks; and methodological constraints inherent to the Comparative Risk Assessment approach. However, a high attributable burden highlights opportunities for improved prevention and more effective action on established risk factors.

In the second part, we evaluated trends in all-age and age-standardised DALY rates attributable to Level 1 risk categories (ie, metabolic, behavioural, and environmental or occupational) between 1990 and 2023, disaggregated by sex. Furthermore, the top ten Level 4 risk factors contributing to all-cause, all-age, and age-standardised DALYs in 2023 were identified nationally and by macro region. Percentage changes since 1990 were calculated to capture temporal shifts.

The analysis adopted a dual perspective: all-age DALY rates were used to evaluate the actual burden across populations with differing age structures; and age-standardised DALY rates were used to facilitate comparisons over time and among regions, adjusting for different age structures.

To explore the association between risk-attributable burden and socioeconomic conditions, we assessed the correlation between age-standardised DALY rates for behavioural, metabolic, and environmental or occupational risks and SDI in 2023. In this third part of the analysis, estimates were analysed at the level of Italy's 21 regions and autonomous provinces to enhance statistical robustness. SDI estimates were retrieved from the Global Health Data Exchange tool. Scatterplots displayed Spearman correlation coefficients with corresponding p values to quantify the strength of a monotonic association between SDI and risk-attributable DALY rates, whereas the locally estimated scatterplot smoothing curves were added solely as a visual aid to show the overall trends in the data. Statistical significance was set at 0·05. All the analyses were done using R (version 2024.12.1).

Role of the funding source

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

Results

Burden unattributed to risk factors

Between 1990 and 2023, the proportion of total DALYs from all causes that were unattributed to risk factors increased in Italy from 53·8% to 61·4% (+7·6%). This growth was more pronounced in males (from 47·8% to 57·6%) than in females (from 60·3% to 65·0%; figure 1). In 1990, females consistently showed a higher proportion of unattributed DALYs than males across all macro regions, reaching levels that males had not attained even by 2023. The smallest increases over time were observed in the South and the Islands.

In 2023, the highest proportions of unattributed DALYs were found in the North-West for both sexes (58·8% in males and 65·9% in females), while the South showed the lowest (55·5% in males and 63·7% in females).

Burden attributable to risk factors

Trends in all-age and age-standardised DALY rates from 1990 to 2023 by sex are shown in figure 2 and regional patterns are shown in appendix 1 (pp 2–6). In Italy, among males, all-age DALY rates attributable to metabolic risk factors showed a modest overall decline between 1990 and 2023 (–7·3% [95% UI –14·1 to –0·2]; appendix 1 p 7). However, at the macro-regional level, rates increased significantly in the South (14·6% [5·0–24·9]) and

remained stable in the Islands (9·3% [–1·0 to 20·2]). For behavioural risk factors, all-age DALYs declined significantly in all macro regions from 1990 to 2023, with no significant differences across regions in 2023. DALYs attributable to environmental or occupational risks also decreased significantly in all macro regions, with no regional variation detected in 2023.

Among females, all-age DALY rates attributable to behavioural risk factors declined markedly between 1990 and 2023 (–21·1% [95% UI –31·2 to –9·2]), whereas those attributable to metabolic risks remained stable (–0·4% [–10·3 to 8·4]), with no significant regional differences observed in 2023 (appendix 1 p 8).

Age-standardised analyses confirmed the absence of significant regional variation in DALY rates for behavioural risk factors in both sexes, in both 1990 and 2023 (appendix 1 pp 9–10). However, across the study period, males consistently bore a higher burden than females. Age-standardised DALY rates for metabolic risks did not differ significantly by macro region or sex. For environmental and occupational risk factors, rates were systematically higher in males, but no macro-regional differences were found.

Leading risk factors in 2023

In 2023, smoking was the leading contributor to all-age DALYs among males in Italy (3432·5 per 100 000; 95% UI [2751·5–4204·5]), followed by several metabolic risks: high systolic blood pressure (SBP), high BMI, high fasting plasma glucose (FPG), high LDL cholesterol, and kidney dysfunction (table 1).

Among females, high SBP was the leading risk factor nationally (2783 per 100 000; 95% UI 2109·9–3389·6), and in all macro regions except the Islands, where high BMI ranked first (table 2). Six of the ten leading risks for females were metabolic: high SBP, high BMI, high FPG, kidney dysfunction, high LDL cholesterol, and low bone mineral density.

When age-standardised rates were considered, smoking remained the leading risk factor among males in 2023 across all five macro regions, with a national rate of 1676·3 DALYs per 100 000 (95% UI 1333·1–2058·1) and no significant macro-regional variation (appendix 1 pp 11–12). In contrast, high BMI emerged as the leading risk factor among females, with 929·5 age-standardised DALYs per 100 000 (338·3–1546·5) at the national level and no relevant differences across macro regions (appendix 1 pp 13–14).

Temporal trends of disability-adjusted life years

Trends in all-age and age-standardised DALY rates in Italy from 1990 to 2023, by sex, for the five leading risk factors overall (ie, the top five across both sexes combined) are shown in figure 3. In 2023, these risk factors collectively accounted for 52% among males and 54% among females of all-age DALYs, and 49% among males and 46% among females of age-standardised DALYs.

Compared with 1990, males showed significant national-level reductions in all-age DALY rates for most of the top 10 risk factors, whereas rates increased for high BMI (40·0% [95% UI 13·4–72·8]) and kidney dysfunction (12·8% [2·0–25·4]), and remained stable for high FPG (22·6% [–1·5 to 50·0]; table 1).

	Risk factor	DALYs (95% UI)	Percentage difference since 1990 (95% UI)
Italy			
1	High SBP	2783·0 (2109·9–3389·6)	–22·9 (–34·8 to –13·0)
2	High BMI	2432·5 (930·5–3888·3)	38·1 (5·5 to 75·4)
3	High FPG	2040·9 (1662·2–2534·5)	10·6 (–10·1 to 37·8)
4	Ambient PM pollution	1363·6 (808·8–2224·0)	–30·0 (–56·5 to 4·2)
5	Smoking	1181·8 (781·5–1707·6)	–18·9 (–45·5 to 6·0)
6	Kidney dysfunction	967·4 (763·5–1158·7)	24·3 (12·0 to 43·5)
7	High LDL	760·9 (414·8–1202·9)	–45·9 (–54·4 to –37·3)
8	Low bone mineral density	621·1 (464·6–788·4)	23·8 (16·0 to 31·0)
9	Lead exposure	518·4 (331·4–724·4)	–27·4 (–40·4 to –17·1)
10	Low temperature	436·9 (333·2–500·2)	–26·4 (–36·1 to –20·4)
North-West			
1	High SBP	2652·1 (1997·8–3189·2)	–32·0 (–43·2 to –22·2)
2	High BMI	2009·6 (714·1–3327)	23·2 (–7·4 to 61·2)
3	High FPG	1648·9 (1357·1–1966·9)	–0·1 (–15·5 to 16·7)
4	Ambient PM pollution	1601·5 (969·6–2574·9)	–37·1 (–59·5 to –11·1)
5	Smoking	1380·2 (859·4–1987·1)	–20·1 (–47·2 to 4·9)
6	Kidney dysfunction	885·1 (703·8–1075·6)	5·1 (–6·2 to 21·7)
7	High LDL	735·1 (396·2–1171·5)	–52·7 (–60·4 to –45·0)
8	Low bone mineral density	622·5 (465–789·9)	8·4 (–0·4 to 14·7)
9	Lead exposure	442·3 (287·3–615·1)	–40·9 (–51·4 to –31·6)
10	Low temperature	403·1 (305·7–464·9)	–36·9 (–44·4 to –30·2)
North-East			
1	High SBP	2540·2 (1874·2–3090·4)	–32·8 (–43·1 to –24·6)
2	High BMI	2232·9 (805·1–3640·9)	29·4 (1·9 to 64·3)
3	High FPG	1929·6 (1501·5–2476·8)	11·7 (–17·2 to 50·1)
4	Ambient PM pollution	1499·3 (897·5–2432·0)	–37·5 (–60·6 to –8·7)
5	Smoking	1292·6 (853·2–1883·7)	–29·6 (–51·9 to –3·9)
6	Kidney dysfunction	867·8 (674·7–1050·1)	8·3 (–4·0 to 24·6)
7	High LDL	673·0 (362·1–1049)	–55·1 (–63·0 to –48·3)
8	Low bone mineral density	634·1 (466·3–808·6)	10·1 (3·6 to 16·2)
9	Lead exposure	417·6 (263·5–583)	–43·3 (–55·0 to –33·6)
10	High alcohol use	394·9 (259·4–533·3)	–42·6 (–58·5 to –24·7)
Centre			
1	High SBP	2682 (1980·1–3277·4)	–25·6 (–37·4 to –14·9)
2	High BMI	2364·5 (868·8–3773)	36·8 (4·7 to 73·8)
3	High FPG	1942·4 (1547·3–2506·8)	13·8 (–11·0 to 51·8)
4	Ambient PM pollution	1276·2 (714·7–2121·5)	–27·6 (–55·1 to 14·4)
5	Smoking	1253·7 (854·0–1789·5)	–23·2 (–46·8 to –0·5)
6	Kidney dysfunction	963·1 (744·6–1153·1)	22·4 (8·2 to 41·7)
7	High LDL	759·5 (407·2–1212·6)	–46·1 (–54·6 to –37·0)
8	Low bone mineral density	697·0 (521·5–889·8)	25·2 (16·8 to 32·7)
9	Lead exposure	516·7 (344·6–705·5)	–28·5 (–41·3 to –17·9)
10	Low temperature	441·6 (337·3–507·6)	–25·8 (–35·8 to –19·2)

(Table 2 continues on next page)

	Risk factor	DALYs (95% UI)	Percentage difference since 1990 (95% UI)
(Continued from previous page)			
South			
1	High SBP	3129·0 (2478·2–3795·2)	–4·8 (–18·2 to 6·7)
2	High BMI	2886·3 (1214·5–4451·9)	55·4 (19·5 to 95·3)
3	High FPG	2249·1 (1818·2–2815·2)	17·8 (–4·3 to 48·7)
4	Ambient PM pollution	1180·9 (686·7–1904·4)	–17·1 (–48·4 to 33·8)
5	Kidney dysfunction	1082·9 (863·7–1278·3)	55·8 (39·0 to 78·7)
6	Smoking	961·3 (609·2–1429·1)	–0·7 (–36·6 to 42·2)
7	High LDL	825·7 (465·3–1286)	–31·9 (–43·8 to –20·0)
8	Lead exposure	654·3 (413·9–940)	–2·0 (–18·2 to 11·9)
9	Low bone mineral density	576·0 (429·6–727·6)	54·2 (44·1 to 64·6)
10	Low temperature	494·1 (391·1–559)	–11·6 (–23·3 to –4·1)
Islands			
1	High BMI	3005·3 (1185·3–4762·8)	52·6 (13·9 to 94·3)
2	High SBP	3000·7 (1936–4114·8)	–10·5 (–37·5 to 23·0)
3	High FPG	2954·2 (2464–3522·4)	14·9 (–1·3 to 34·4)
4	Kidney dysfunction	1114·4 (878·1–1322·8)	48·0 (32·0 to 71·5)
5	Ambient PM pollution	1078·1 (565·8–1799·0)	–15·1 (–51·7 to 47·4)
6	High LDL	849·6 (455·4–1332·2)	–35·3 (–47·0 to –23·4)
7	Smoking	823·9 (488·7–1301·6)	–14·7 (–49·1 to 28·2)
8	Lead exposure	604·2 (354·5–947·9)	–11·9 (–28·3 to 5·2)
9	Low bone mineral density	548·5 (411–689·4)	39·4 (29·8 to 49·7)
10	Low temperature	474·1 (363·6–540·6)	–13·7 (–25·9 to –5·3)

Rankings are based on point estimates. DALYs=disability-adjusted life years. UI=uncertainty interval. BMI=body mass index. SBP=systolic blood pressure. FPG=fasting plasma glucose. PM=particulate matter.

Table 2: **All-age DALY rates (per 100 000 population) in 2023 for all causes attributable to the top 10 Level 4 risk factors among females in Italy and its five macro regions**

Among females, substantial reductions were observed for high SBP (–22·9% [95% UI –34·8 to –13·0]), high LDL cholesterol (–45·9% [–54·4 to –37·3]), lead exposure (–27·4% [–40·4 to –17·1]), and low temperature (–26·4% [–36·1 to –20·4]; table 2). In contrast, substantial increases were found for high BMI (38·1% [5·5–75·4]), kidney dysfunction (24·3% [12·0–43·5]), and low bone mineral density (24·3% [12·0–43·5]). All-age DALY rates attributable to smoking, ambient PM pollution, and high FPG remained stable.

By macro region, the largest declines in smoking-attributable all-age DALY rates in males were observed in the North-West (–53·4% [95% UI –60·8 to –48·1]) and North-East (–57·3% [–63·7 to –51·6]), with more moderate reductions in the Centre (–50·7% [–56·9 to –44·7]), South (–32·3% [–39·1 to –25·7]), and Islands (–33·5% [–41·4 to –26·2]).

At the national level, the greatest reductions in age-standardised DALY rates from 1990 to 2023 in males were attributable to ambient PM pollution (–71·2% [95% UI –79·3 to –56·1]), high LDL (–66·8% [–70·6 to –63·0]), and lead exposure (–63·4% [–67·2 to –59·9]). In females, the largest declines were seen for high LDL (–70·3% [–74·8 to –66·2]), ambient PM pollution (–63·4% [–74·8 to –46·9]), and high SBP (–60·7% [–65·7 to –55·7]). In 2023, smoking remained the leading contributor to age-standardised DALYs among males across all macro regions (appendix 1 pp 11–12), whereas high BMI ranked first among females (appendix 1 pp 13–14).

Socio-demographic Index and burden of risk factors

In 2023, age-standardised DALY rates attributable to behavioural risk factors showed a negative correlation with SDI based on point estimates, and only among males (r=–0·59, p=0·005; appendix 1 p 15). In contrast, metabolic risk factors showed an inverse correlation with SDI in both sexes, again based on point estimates, with comparable magnitudes (r=–0·77, p<0·001 for both females and males; appendix 1 p 15). No significant association was observed between age-standardised DALY rates due to environmental or occupational risk factors and SDI in either sex (appendix 1 p 15). The sex-specific pattern observed for behavioural risk factors prompted a post-hoc analysis focusing on the three leading Level 4 behavioural risk factors in Italy for both sexes: smoking, high alcohol use, and sexual violence against children. Age-standardised DALY rates attributable to smoking were correlated with SDI based on point estimates for females only (r=0·52, p=0·016; appendix 1 p 16). Regarding high alcohol use, a positive correlation with SDI was found only among females (r=0·66, p=0·001), whereas no association emerged for males, despite their overall higher burden from this risk factor (appendix 1 p 16). No correlation between SDI and age-standardised DALY rates attributable to sexual violence against children was observed in either sex (appendix 1 p 16). Although statistically significant correlations were found based on point estimates, the overlapping 95% UIs across regions suggests caution in interpreting the robustness of the observed associations. Moreover, the apparent visual separation between northern or central regions and southern or Island regions reflects the underlying distribution of SDI values and should not be interpreted as evidence of clear discrete clusters.

Discussion

Between 1990 and 2023, the proportion of DALYs not attributable to risk factors increased substantially, particularly among males. This pattern is consistent with an evolving and multifaceted structure of the disease burden. At the same time, the documented decline in total age-standardised DALYs over time indicates overall improvements in population health during the study period, likely reflecting progress in the prevention and control of conditions strongly linked to established risk factors, alongside changes in population behaviours, such as reductions in tobacco use, particularly among males.[18,19] Less pronounced increases in unattributed DALYs in the South and Islands might be partly explained by a slower reduction in smoking-related burden in these areas. Despite this trend, estimates over the past three decades reveal

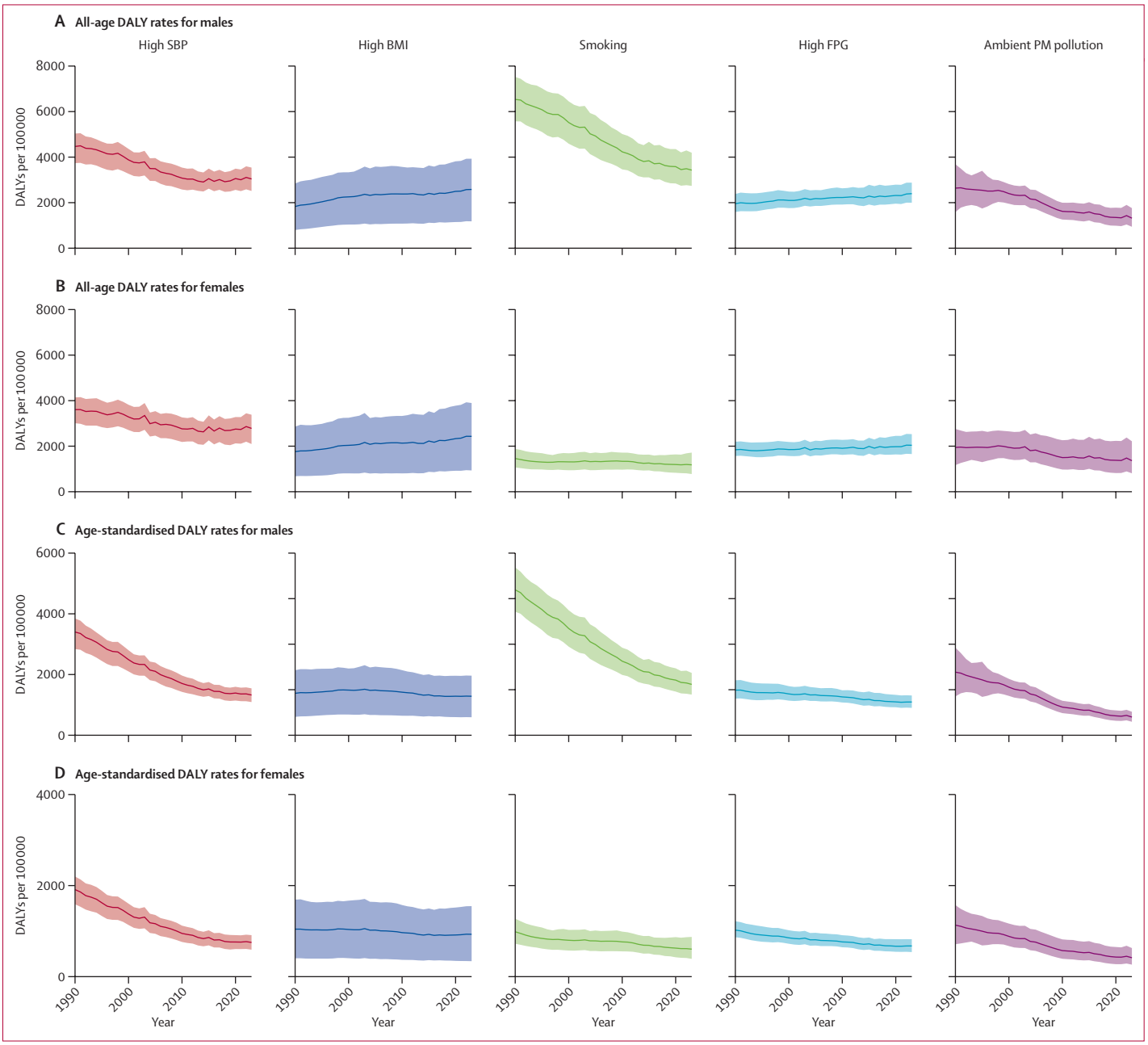

Figure 3: **Temporal trends of all-age and age-standardised DALY rates attributable to the five leading risk factors (based on both sexes combined) in Italy, stratified by sex**
(A) All-age DALY rates for males. (B) All-age DALY rates for females. (C) Age-standardised DALY rates for males. (D) Age-standardised DALY rates for females. Solid lines represent the trend in the mean DALY rate, and shaded areas indicate the 95% uncertainty intervals. DALYs=disability-adjusted life years. SBP=systolic blood pressure. FPG=fasting plasma glucose. PM=particulate matter.

a persistent sex gap in unattributed DALYs, with males consistently showing lower proportions across all macro regions.

Among attributable risks, behavioural and metabolic factors still accounted for the largest share of DALYs, with substantial sex-based differences. Males had a greater burden from behavioural risks, primarily smoking and high alcohol use, in line with results from the PASSI surveillance system and national surveys, although these apply different definitions of high alcohol use from those used by GBD.[20–22] However, males also showed a more pronounced decline in behavioural risk exposure over the past two decades, mainly driven by reductions in smoking. Although smoking remains the leading risk factor for males, part of this decline might reflect a shift to e-cigarettes and vaping, highlighting the need for future research to assess whether these products could undermine progress in tobacco control. In contrast, the slower decline in smoking among females is possibly influenced by targeted industry marketing or social factors, underscoring the need for gender-specific public health interventions.[23,24]

Although relatively stable over time, metabolic risks continued to represent the leading contributors to disease burden among females in 2023: high SBP was the primary contributor to all-age DALYs, whereas high BMI ranked first in terms of age-standardised DALYs across all macro regions. Moreover, five of the top ten risk factors

for both sexes were metabolic in nature (ie, high SBP, high FPG, high BMI, high LDL, and kidney dysfunction), with four of these (ie, high BMI, high SBP, high FPG, and high LDL) being directly linked to modifiable lifestyle behaviours. This pattern is consistent with European-level findings and is particularly concerning in the context of the Sustainable Development Goals, as progress towards non-communicable disease-related targets remains off track.[1,25] Moreover, the increase in high FPG is also crucial given the rising burden of diabetes, which adds further strain to already overstretched health systems.[26]

The burden of metabolic risks showed an inverse correlation with SDI for both sexes, suggesting that improvements in socioeconomic conditions might help reduce their effect and underscoring the complex interplay between healthy lifestyles and socioeconomic factors. Reducing the burden of metabolic risks requires comprehensive strategies that start early in life, promoting healthy behaviours, and addressing the social determinants of health, such as food affordability, access to green spaces, and social inequalities. Fiscal policies can also have a role by incentivising active transport and participation in physical activity programmes.[27]

Notably, age-standardised DALY rates attributable to behavioural risks showed a negative correlation with SDI among males, whereas no association was observed for females. However, when behavioural risks were disaggregated into the main contributing Level 4 components for each sex, divergent patterns emerged. Specifically, in areas with higher SDI, the burden of smoking was higher among females but lower among males. Conversely, for high alcohol use, no significant association with SDI was found in males, whereas a positive correlation was observed in females, suggesting that the alcohol burden increases among women in more socioeconomically developed regions.

For environmental and occupational risks, exposure to particulate matter remained a leading contributor to disease burden for both sexes in 2023, despite a substantial decline over time. Unlike behavioural and metabolic risks, no association was observed between their attributable burden and SDI. This trend highlights the health co-benefits of climate and environmental policies aimed at reducing air pollution. Measures such as the European Green Deal and national energy transition strategies are expected to further reduce emissions, with important public health gains.[28] Incorporating health impact assessments into these policies will be essential to ensure that improvements in air quality translate into longer and healthier lives across Italian regions.

As the 2020–25 National Prevention Plan approaches its conclusion, subnational GBD estimates provide crucial input for evaluating its impact and informing future priorities. Several initiatives already leverage GBD estimates to inform decision making. For example, the Prevention Laboratory uses predictive models and burden estimates to support planning, combining epidemiological data with evaluations of impact, cost, and equity.[29,30] The ACAB project in Tuscany also produced subregional burden estimates for key diseases and risk factors.[31,32]

Despite progress, major challenges remain, particularly in reducing behavioural and metabolic risks. The slower decline in smoking-attributable burden in the South and Islands compared with the rest of Italy highlights the need to complement national measures with locally tailored interventions and prevention campaigns to effectively reduce health inequalities.

Fiscal measures, such as higher taxes on tobacco, alcohol, and sugary drinks, are both cost-effective and revenue-generating, and are considered quick buys capable of delivering measurable effects within 5 years.[33–37] Despite this evidence, tobacco prices in Italy are still relatively low compared with other European countries. In line with Objective 3 of the WHO Best Buys for non-communicable disease prevention, which prioritises population-level interventions to reduce tobacco and alcohol use while promoting healthy diets and physical activity, increasing excise taxes on tobacco and alcohol products represents one of the most cost-effective policy options.[38]

In addition, reinforcing alcohol control through stricter enforcement of traffic laws, tighter marketing regulations, and broader access to early intervention programmes remains a priority, particularly to mitigate harm among young adults.

For metabolic risks, which contribute substantially to the burden of non-communicable diseases, the WHO package of essential non-communicable disease interventions provides a structured framework for early detection and management within primary care.[39] Indeed, reducing the burden of these risks cannot be achieved through individual behaviour change alone, but requires systematic action on the commercial and structural determinants of health. Policies shaping food environments, equitable access to green spaces, and sustainable mobility fundamentally determine the range of healthy choices available to individuals.

In this context, subnational GBD estimates represent a valuable resource for regional health planning, by enabling the identification of priorities, supporting the targeted implementation of the WHO package of essential non-communicable disease interventions, and facilitating the monitoring of policy impact.[39] Their integration into decision-making processes aligns with the principles of precision public health, fostering more equitable and effective prevention strategies across the country. Specifically, these estimates could provide an evidence base to support the implementation of mission 6 of Italy's National Recovery and Resilience Plan,[40] dedicated to health, by identifying region-specific needs in the burden of risk factors and thereby informing the prioritisation of interventions across territories.

Strengths and limitations

A key strength of this study is the comprehensive and consistent assessment of the burden of disease attributable to a wide range of risk factors across Italy and its macro regions from 1990 to 2023, leveraging the rigorous GBD Comparative Risk Assessment framework to capture the multifaceted determinants of population health. Limitations are partly inherent to the GBD estimation process, as detailed in the GBD 2023 methods paper, and partly related to the availability and quality of data on risk factor exposures in Italy.[2] Despite relatively high-quality and granular data at both national and subnational levels, several gaps persist. Exposure estimates rely on the availability and quality of data for each risk–outcome pair, yet in Italy information is often fragmented, with surveillance data not fully accessible or only available in aggregated form. Estimates for behavioural risk factors are largely based on self-reported information, which might be subject to reporting bias. Consistent with the GBD methodology, rankings are derived from point estimates to ensure comparability across risks, locations, and years, yet overlapping uncertainty intervals indicate that adjacent ranks should be interpreted with caution. Likewise, correlations between SDI and risk-attributable burden are based exclusively on point estimates and should therefore be interpreted with care.

Conclusion

Our analysis shows a substantial increase in unattributed DALYs between 1990 and 2023, reflecting overall improvements in health conditions. Nonetheless, key challenges remain. Smoking continues to be the leading risk factor among males across all macro regions, underscoring the need to strengthen tobacco control efforts. Metabolic risks also contribute significantly to the disease burden—especially among females—highlighting the urgency of implementing targeted interventions to promote healthier lifestyles. In this context, GBD estimates and predictive models can contribute to defining the next National Prevention Plan and to implementing mission 6 of the Piano Nazionale di Ripresa e Resilienza.

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Please see appendix 2 (p 4) for more detailed information about individual author contributions to the research, divided into the following categories: managing the overall research enterprise; writing the first draft of the manuscript; primary responsibility for applying analytical methods to produce estimates; primary responsibility for seeking, cataloguing, extracting, or cleaning data; designing or coding figures and tables; providing data or critical feedback on data sources; developing methods or computational machinery; providing critical feedback on methods or results; drafting the manuscript or revising it critically for important intellectual content; and managing the

See Online for appendix 2

estimation or publications process. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit the manuscript for publication. Members of the core research team for this topic area had full access to the underlying data used to generate estimates presented in this Article. All other authors had access to and reviewed estimates as part of the research evaluation process, which includes additional stages of formal review.

Declaration of interests

MDR reports payments from Sanofi Vaccines Global for work as a scientific consultant on epidemiological analyses and methodological validation, as well as honoraria for invited scientific presentations and media briefings related to the burden of influenza. MDR also serves as an unpaid member of the Global Influenza Initiative Steering Committee, the Scientific Secretariat of the Adult Immunization Board, and the Steering Group on Prevention of Respiratory Infections, and conducts research on respiratory viruses and vaccination strategies, including participation in public–private research initiatives in this field. MLeo reports support for meeting attendance and travel from the European Academy of Neurology (payments made to the Istituto Neurologico Carlo Besta) and reimbursement from the Italian Society of Neurology. PM reports serving as Vice-President of the British Pharmacological Society; Vice-Chair of the Basic and Translational Section of the International Union of Basic and Clinical Pharmacology; Chair of the Translational Research Medical Review Panel for Heart Research UK; Nucleus Member of the European Society of Cardiology Working Group on Atherosclerosis & Vascular Biology and Cell Biology of the Heart; and member of the Executive Committee of the British Atherosclerosis Society. PM also serves as Chair of the Publication Committee of the International Union of Immunological Societies; member of the Translational Clinical Studies Grant Panel for the Chief Scientist Office; co-Director of the ARUA/Guild Africa–Europe CoRE in Non-Communicable Diseases & Multimorbidity; Deputy Editor of *Cardiovascular Research*; Associate Editor of Pharmacological Research; and Editor-in-Chief of the Human Health section of Frontiers for Young Minds. SM reports grants or contracts from Servier, CertMedica, and Novo Nordisk (personal payments or institutional contracts), as well as consulting fees, honoraria for expert testimony, and participation on data safety monitoring or advisory boards for Servier (personal payments). LM, LR, and GZ acknowledge support from the Italian Ministry of Health (Ricerca Corrente 34/2017), with payments made to the Institute for Maternal and Child Health IRCCS Burlo Garofolo. RP reports serving as a member of the data safety monitoring board for the Fondazione Italiana Linfomi phase 2 trial on the consolidation with ADCT-402 (loncastuximab tesirine) after immunochemotherapy in BTKi-treated/ineligible relapsed/refractory mantle cell lymphoma patients, as a member of the EBMT Statistical Committee (European Society for Blood and Marrow Transplantation, Paris, France), and as a biostatistician member of the IRB/IEC Ethics Committee of Azienda Ospedaliero–Universitaria Santi Antonio e Biagio e Cesare Arrigo (Alessandria, Italy) from 2020 to 2023. MS reports contracts with the Istituto Superiore di Sanità and the Italian Ministry of Health; honoraria for lectures and educational events from the Istituto Zooprofilattico Sperimentale della Sardegna; support for meeting attendance and travel from the *Journal of Clinical Medicine* in the role of Editorial Board member; membership of the advisory board of the Blue-Adapt project; and leadership of the national working group for national and international cooperation on antimicrobial resistance and of the subnational working group of GBS collaborators on AMR and healthcare-associated infections. DT reports participation on data safety monitoring or advisory boards for Amarin, Boehringer Ingelheim, and Novo Nordisk, as well as leadership or fiduciary roles in the EASD Early Career Academy and the EASD Committee on Clinical Affairs. All other authors declare no competing interests.

Data sharing

All data and estimates used in this study are publicly available through the Global Burden of Disease (GBD) study. The estimates can be accessed and downloaded from the GBD Sources website: http://ghdx.healthdata.org, or from the GBD Results tool: https://vizhub.healthdata.org/gbd-results/.

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