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The Global, Regional, and National Burden of Benign Prostatic Hyperplasia in 204 Countries and Territories From 2000 to 2019: A Systematic Analysis for the Global Burden of Disease Study 2019

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Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019

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Summary

Background Regularly updated data on stroke and its pathological types, including data on their incidence, prevalence, mortality, disability, risk factors, and epidemiological trends, are important for evidence-based stroke care planning and resource allocation. The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) aims to provide a standardised and comprehensive measurement of these metrics at global, regional, and national levels.

Methods We applied GBD 2019 analytical tools to calculate stroke incidence, prevalence, mortality, disability-adjusted life-years (DALYs), and the population attributable fraction (PAF) of DALYs (with corresponding 95% uncertainty intervals [UIs]) associated with 19 risk factors, for 204 countries and territories from 1990 to 2019. These estimates were provided for ischaemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage, and all strokes combined, and stratified by sex, age group, and World Bank country income level.

Findings In 2019, there were 12·2 million (95% UI 11·0–13·6) incident cases of stroke, 101 million (93·2–111) prevalent cases of stroke, 143 million (133–153) DALYs due to stroke, and 6·55 million (6·00–7·02) deaths from stroke. Globally, stroke remained the second-leading cause of death (11·6% [10·8–12·2] of total deaths) and the third-leading cause of death and disability combined (5·7% [5·1–6·2] of total DALYs) in 2019. From 1990 to 2019, the absolute number of incident strokes increased by 70·0% (67·0–73·0), prevalent strokes increased by 85·0% (83·0–88·0), deaths from stroke increased by 43·0% (31·0–55·0), and DALYs due to stroke increased by 32·0% (22·0–42·0). During the same period, age-standardised rates of stroke incidence decreased by 17·0% (15·0–18·0), mortality decreased by 36·0% (31·0–42·0), prevalence decreased by 6·0% (5·0–7·0), and DALYs decreased by 36·0% (31·0–42·0). However, among people younger than 70 years, prevalence rates increased by 22·0% (21·0–24·0) and incidence rates increased by 15·0% (12·0–18·0). In 2019, the age-standardised stroke-related mortality rate was 3·6 (3·5–3·8) times higher in the World Bank low-income group than in the World Bank high-income group, and the age-standardised stroke-related DALY rate was 3·7 (3·5–3·9) times higher in the low-income group than the high-income group. Ischaemic stroke constituted 62·4% of all incident strokes in 2019 (7·63 million [6·57–8·96]), while intracerebral haemorrhage constituted 27·9% (3·41 million [2·97–3·91]) and subarachnoid haemorrhage constituted 9·7% (1·18 million [1·01–1·39]). In 2019, the five leading risk factors for stroke were high systolic blood pressure (contributing to 79·6 million [67·7–90·8] DALYs or 55·5% [48·2–62·0] of total stroke DALYs), high body-mass index (34·9 million [22·3–48·6] DALYs or 24·3% [15·7–33·2]), high fasting plasma glucose (28·9 million [19·8–41·5] DALYs or 20·2% [13·8–29·1]), ambient particulate matter pollution (28·7 million [23·4–33·4] DALYs or 20·1% [16·6–23·0]), and smoking (25·3 million [22·6–28·2] DALYs or 17·6% [16·4–19·0]).

Interpretation The annual number of strokes and deaths due to stroke increased substantially from 1990 to 2019, despite substantial reductions in age-standardised rates, particularly among people older than 70 years. The highest age-standardised stroke-related mortality and DALY rates were in the World Bank low-income group. The fastest-growing risk factor for stroke between 1990 and 2019 was high body-mass index. Without urgent implementation of effective primary prevention strategies, the stroke burden will probably continue to grow across the world, particularly in low-income countries.

Funding Bill & Melinda Gates Foundation.

Introduction

Disease and population distribution patterns, life expectancy, mortality, causes of death, and sociodemographic factors continue to change across the world, including ageing of populations and changes in the prevalence of risk factors for non-communicable disorders. Timely estimates of the burden of stroke and its pathological types, the burden attributable to risk factors, and trends in the burden over time are necessary at the global, regional, and national levels to guide

Research in context

Evidence before this study

The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) produces the most comprehensive estimates of the global, regional, and country-specific burden of stroke. Population-level estimates for stroke incidence or mortality have been published by WHO and independent research groups, but those of GBD include more extensive estimates by age, sex, location, and year. To evaluate the availability of evidence, we did a structured review of the published scientific literature in Medline, Scopus, Google Scholar, and PubMed for relevant reports published in any language up to June 30, 2021, using search terms that included "stroke", "cerebral infarction", "isch(a)emic stroke", "intracerebral h(a)emorrage", "h(a)emorrhagic stroke", or "subarachnoid h(a)emorrage", AND "incidence", "prevalence", "mortality", or "epidemiology" or "population attributable fraction (PAF)", "risk factor(s)", or "disability-adjusted life-year(s) (DALYs)". GBD 2017 included stroke in its analysis, but the most recent paper by the GBD Collaborator Network on the topic of stroke was from GBD 2016. The report concluded that because the decrease in global age-standardised incidence rates from 1990 to 2016 was minimal, the burden of stroke was likely to remain high well into the future.

Added value of this study

As part of GBD 2019, this study provides updated estimates of the burden of overall stroke, ischaemic stroke, intracerebral haemorrhage, and subarachnoid haemorrhage for 204 countries and territories in 21 GBD regions from 1990 to 2019, by age, sex, and country income level (by the World Bank classification). Stroke burden was measured by incidence, prevalence, mortality, and DALYs as well as the PAF of stroke-related DALYs associated with potentially modifiable behavioural, environmental and occupational, and metabolic risk factors or risk factor clusters. Until GBD 2017, intracerebral haemorrhage and subarachnoid haemorrhage were not estimated separately, so this is the first report by the GBD Collaborator Network to present the global, regional, and national burden of haemorrhagic strokes by intracerebral haemorrhage and subarachnoid haemorrhage separately. This study is also the first systematic analysis to determine the effect of non-optimal temperature on stroke burden.

Implications of all the available evidence

The findings from this study can help guide evidence-based health-care planning, prevention, and resource allocation for stroke and its pathological types, including country-specific prioritisation of these measures. By evaluating the risk-attributable burden of different stroke types in different geographical locations, this study can be used to develop location-specific strategies for reducing the burden of stroke. Based on the available evidence, public health and research priorities should include: expanding evidence-based prevention strategies that reduce exposure to stroke risk factors; reducing the gaps in acute and chronic stroke prevention, screening, and treatment services between high-income and low-income to middle-income countries; and further epidemiological research on stroke risk and outcomes across different countries and populations.

evidence-based health-care policy, planning, and resource allocation for stroke.

The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2017 showed that stroke was the third-leading cause of death and disability combined (as measured by disability-adjusted life-years [DALYs]) and the second-leading cause of death in the world in 2017.[1,2] A GBD 2017 stroke analysis found that, although age-standardised mortality rates for stroke decreased sharply from 1990 to 2017,[2] the decrease in age-standardised incidence was much less steep, suggesting that prevention efforts have been less successful than treatment efforts. The results from GBD 2016[3] showed that 87·9% of ischaemic stroke DALYs and 89·5% of haemorrhagic stroke DALYs were due to potentially modifiable risk factors measured in GBD, demonstrating the enormous potential to reduce the burden of stroke through reductions in risk factor exposure. According to WHO, effective stroke prevention strategies include reducing the risk associated with hypertension (high systolic blood pressure), elevated lipids, diabetes (high fasting plasma glucose), smoking, low physical activity, unhealthy diet, and abdominal obesity (high body-mass index [BMI]),[4] which is similar to the findings from GBD 2016[3] and GBD 2017.[5]

See Online for appendix

In this study, we estimated the global, regional, and national burden of overall stroke, ischaemic stroke, intracerebral haemorrhage, and subarachnoid haemorrhage in terms of their incidence, prevalence, mortality, and DALYs, as well as stroke-related DALYs associated with 19 potentially modifiable behavioural, environmental and occupational, and metabolic risk factors or groups of risk factors. We present data for 204 countries and territories, 21 GBD regions, and four World Bank income level groups from 1990 to 2019, by age group and sex. This manuscript was produced as part of the GBD Collaborator Network and in accordance with the GBD Protocol.

Methods

Overview and case definition

Details of the GBD 2019 eligibility criteria, the literature search strategy, and data extraction are described in detail elsewhere[6,7] (appendix sections 1.1–4.3). In brief, stroke was defined by WHO clinical criteria[8] as rapidly developing clinical signs of (usually focal) disturbance of cerebral function lasting more than 24 h or leading to death. Ischaemic stroke was defined as an episode of neurological dysfunction due to focal cerebral, spinal, or retinal infarction. Intracerebral haemorrhage was defined as stroke with a focal collection of blood in the brain not due to trauma. Subarachnoid haemorrhage was defined as non-traumatic stroke due to bleeding into the subarachnoid space of the brain. The GBD methods for assigning cause of death to stroke and stroke subtypes in regions where neuroimaging was not available have been previously described.[9] GBD classifies causes into four levels, from the broadest (Level 1; eg, non-communicable diseases), to the most specific (Level 4; eg, intracerebral haemorrhage). Stroke is a Level 3 cause, within the Level 2 category of cardiovascular diseases, while its subtypes are Level 4 causes.

Fatal disease modelling

We used vital registration and verbal autopsy data as inputs into the Cause of Death Ensemble modelling (CODEm) framework to estimate deaths due to overall stroke and stroke subtypes. CODEm is a flexible modelling tool that utilises geospatial relationships and information from covariates to produce estimates of death for all locations across the time series (1990–2019). Deaths from vital registration systems coded to impossible or intermediate causes of death or unspecified stroke were reassigned by use of statistical methods (appendix sections 1.4, 1.7, 1.8).[10]

Non-fatal disease modelling

Estimates of the incidence and prevalence of stroke were generated with the DisMod-MR 2.1 (disease-model-Bayesian meta-regression) modelling tool.[3] DisMod-MR is a Bayesian geospatial disease modelling software that uses data on various disease parameters, the epidemiological relationships between these parameters, and geospatial relationships to produce estimates of prevalence and incidence (appendix section 3). All available high-quality data on incidence, prevalence, and mortality were used to estimate non-fatal stroke burden. We modelled first-ever ischaemic stroke, intracerebral haemorrhage, and subarachnoid haemorrhage from the day of incidence through 28 days and separately modelled survival beyond 28 days.

Risk factor estimation

To analyse the attributable burden of stroke due to 19 risk factors currently available for such analysis in GBD 2019, we calculated population attributable fractions (PAFs) of DALYs (appendix section 2).[7] This work was done within the comparative risk assessments framework of GBD by use of four datasets: the burden estimates for stroke and its three pathological types; the exposure level for each risk factor; the relative risk of stroke as an outcome of exposure to the risk factor; and the theoretical minimum risk exposure level (TMREL), which is the level of exposure that minimises risk for each individual in the population.[11] The relative risks included in this analysis were generated from meta-analyses of epidemiological studies reporting associations between the risk factors of interest and stroke; these analyses are not stroke-type specific. The PAF (estimated independently for each risk factor) is the proportion of the cause that would be decreased if the exposure to the risk factor in the past had been reduced to the counterfactual level of the TMREL.

Risks included in the analysis were ambient particulate matter pollution; household air pollution from solid fuels; non-optimal temperature—ie, low temperature (daily temperatures below the TMREL) and high temperature (daily temperatures above the TMREL); lead exposure; diet high in sodium; diet high in red meat; diet low in fruits; diet low in vegetables; diet low in whole grains; alcohol consumption (any dosage); low physical activity (only for ischaemic stroke burden); smoking; secondhand smoke; high BMI; high fasting plasma glucose; high systolic blood pressure; high LDL cholesterol (only for ischaemic stroke burden); and kidney dysfunction, as measured by low glomerular filtration rate (GFR; not assessed for subarachnoid haemorrhage burden). As with causes, GBD organises risk factors into four levels, from the broadest (Level 1) to the most specific (Level 4). In addition to the specific risk factors above, we assessed the Level 1 groups of risks: behavioural, environmental and occupational, and metabolic. The PAFs of risk factor groups took into account interactions between risk factors included in the group, as explained elsewhere.[12] Percentages and number of DALYs are not mutually exclusive. The crude sum of the PAF of the risk factors might exceed 100% because the effects of many of these risk factors are mediated partly or wholly through another risk factor or risk factors. Definitions of risk factors and risk groups and further details of risk factors are provided in the appendix (section 2.1).

Data sources and presentation

For GBD 2019, we used data from 3686 vital registration sources, 147 verbal autopsy sources, 368 incidence sources, 117 prevalence sources, 229 excess mortality sources, 7753 risk factor exposure sources, and 2733 risk factor relative risk sources. Further details of the data sources used in this analysis are available on the Global Health Data Exchange website.

For more on the **Global Health Data Exchange** see http://ghdx.healthdata.org/

Estimates in this Article are presented in absolute numbers and as age-standardised rates per 100 000 population (with 95% uncertainty intervals [UIs]) and are stratified by age, sex, 21 GBD regions, seven GBD super-regions (appendix figure 6.1), and four income levels (as determined by the World Bank).[13] Count data are presented in tables to two decimal places (and rounded to one decimal place in the text), and percentage data (including percentage change) are presented to one decimal place.

Role of the funding source

The funder had no role in study design, data collection, data analysis, interpretation of the study results, writing

of the report, or the decision to submit the manuscript for publication.

Results

Overall stroke burden

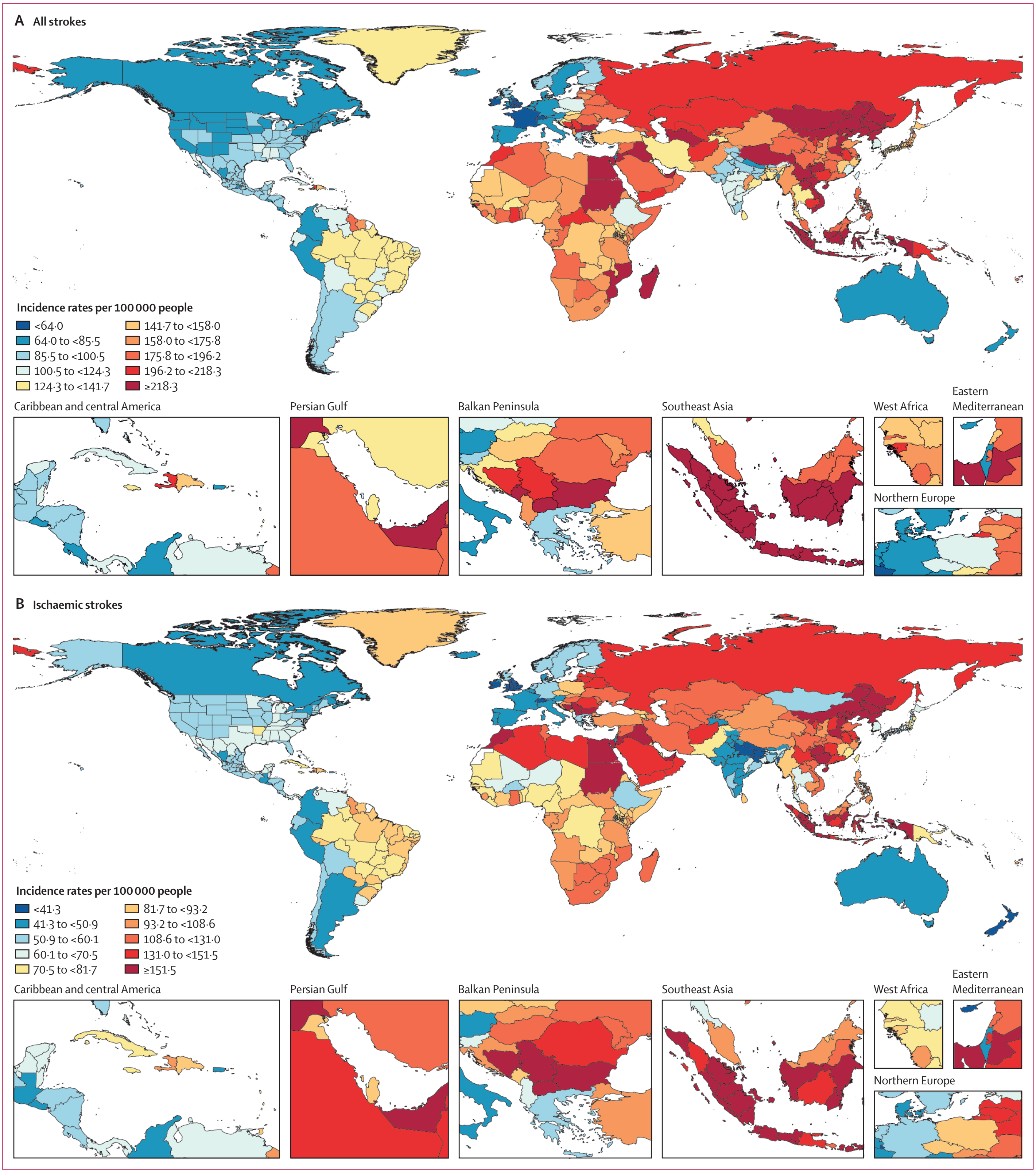
In 2019, there were 12·2 million (95% UI 11·0–13·6) incident strokes and 101 million (93·2–111) prevalent strokes, 143 million (133–153) DALYs due to stroke, and 6·55 million (6·00–7·02) deaths from stroke (table 1). Globally, stroke was the second-leading Level 3 cause of death (11·6% [10·8–12·2] of total deaths) after ischaemic heart disease (16·2% [15·0–16·9]). Stroke was also the third-leading Level 3 cause of death and disability combined in 2019 (5·7% [5·1–6·2] of total DALYs), after neonatal disorders (7·3% [64·4–8·4]) and ischaemic heart disease (7·2% [6·5–8·0]; appendix section 4.1 and figure S2). In 2019, the World Bank low-income group of countries had an age-standardised stroke-related mortality rate 3·6 (3·5–3·8) times higher and an age-standardised stroke-related DALY rate 3·7 (3·5–3·9) times higher than those of high-income countries (see appendix tables S1, S3, and S5 and figures S2–7 for more detailed results by country and World Bank income group). In 2019, 86·0% (85·9–86·9) of all stroke-related deaths and 89·0% (88·9–89·3) of stroke-related DALYs occurred in lower-income, lower-middle-income, and upper-middle-income countries (appendix table S1). There were substantial between-country variations (figure 1A) in age-standardised stroke incidence rates and regional variations (figure 2) in age-standardised incidence, prevalence, mortality, and DALY rates. The absolute number of incident strokes globally increased by 70·0% (67·0–73·0) from 1990 to 2019, whereas prevalent strokes increased by 85·0% (83·0–88·0), deaths from stroke increased by 43·0% (31·0–55·0), and DALYs due to stroke increased by 32·0% (22·0–42·0; table 1, appendix figure S3). Although absolute numbers increased over the study period, age-standardised rates all decreased between 1990 and 2019: by 17·0% (15·0–18·0) for incidence; by 6·0% (5·0–7·0) for prevalence; by 36·0% (31·0–42·0) for mortality; and by 36·0% (31·0–42·0) for DALYs (table 1). However, among those younger than 70 years, age-specific stroke prevalence and incidence rates increased substantially over the study period (22·0% [21·0–24·0] increase in prevalence and 15·0% [12·0–18·0] increase in incidence; incidence data are shown in appendix figure 7, prevalence data are available on the Global Health Data Exchange).

Although the absolute number of DALYs due to stroke in males (76·9 million [95% UI 70·2–83·5]) exceeded that in females (66·4 million [60·5–72·3]) at the global level in 2019, the point estimates of incident and prevalent strokes were higher in females (6·44 million [5·81–7·17] incident strokes and 56·4 million [52·0–61·5] prevalent strokes) than in males (5·79 million [5·24–6·45] incident strokes and 45·0 million [41·1–49·3] prevalent

	Incidence (95% UI)		Deaths (95% UI)		Prevalence (95% UI)		DALYs (95% UI)	
	2019	Percentage change, 1990–2019	2019	Percentage change, 1990–2019	2019	Percentage change, 1990–2019	2019	Percentage change, 1990–2019
Ischaemic stroke								
Absolute number, millions	7·63 (6·57 to 8·96)	88·0% (83·0 to 92·0)	3·29 (2·97 to 3·54)	61·0% (46·0 to 75·0)	77·19 (68·86 to 86·46)	95·0% (92·0 to 99·0)	63·48 (57·83 to 68·99)	57·0% (43·0 to 68·0)
Age-standardised rate, per 100 000 people	94·51 (81·9 to 110·76)	–10·0% (–12·0 to –8·0)	43·50 (39·08 to 46·77)	–34·0% (–39·0 to –28·0)	951·0 (849·2 to 1064·1)	–2·0% (–3·0 to 0·0)	798·8 (727·5 to 866·9)	–29·0% (–35·0 to –23·0)
Intracerebral haemorrhage								
Absolute number, millions	3·41 (2·97 to 3·91)	43·0% (41·0 to 45·0)	2·89 (2·64 to 3·10)	37·0% (22·0 to 51·0)	20·66 (18·02 to 23·42)	58·0% (56·0 to 60·0)	68·57 (63·27 to 73·68)	25·0% (12·0 to 36·0)
Age-standardised rate, per 100 000 people	41·81 (36·53 to 47·88)	–29·0% (–30·0 to –28·0)	36·04 (32·98 to 38·67)	–36·0% (–43·0 to –29·0)	248·8 (217·1 to 281·4)	–17·0% (–18·0 to –15·0)	823·8 (769·2 to 894·7)	–37·0% (–43·0 to –31·0)
Subarachnoid haemorrhage								
Absolute number, millions	1·18 (1·01 to 1·39)	61·0% (56·0 to 65·0)	0·37 (0·33 to 0·42)	–12·0% (–25·0 to 26·0)	8·40 (7·19 to 9·83)	65·0% (60·0 to 68·0)	11·18 (9·89 to 12·67)	–14% (–26·0 to 17·0)
Age-standardised rate, per 100 000 people	14·46 (12·33 to 16·94)	–17·0% (–19·0 to –15·0)	4·66 (4·13 to 5·17)	–57·0% (–64·0 to –39·0)	101·6 (87·1 to 118·5)	–37·0% (–43·0 to –31·0)	136·5 (120·8 to 154·7)	–54·0% (–61·0 to –37·0)
Total stroke								
Absolute number, millions	12·22 (11·04 to 13·59)	70·0% (67·0 to 73·0)	6·55 (6·00 to 7·02)	43·0% (31·0 to 55·0)	101·47 (93·21 to 110·53)	85·0% (83·0 to 88·0)	143·23 (133·10 to 153·24)	32·0% (22·0 to 42·0)
Age-standardised rate, per 100 000 people	150·8 (136·5 to 167·5)	–17·0% (–18·0 to –15·0)	84·2 (76·8 to 90·2)	–36·0% (–42·0 to –31·0)	1240·3 (1139·7 to 1353·0)	–6·0% (–7·0 to –5·0)	1768·1 (1640·7 to 1889·4)	–36·0% (–42·0 to –31·0)

Absolute numbers in millions and age-standardised rates per 100 000 people are presented to two decimal places and percentage change is shown to one decimal place. UI=uncertainty interval. DALY=disability-adjusted life-year.

Table 1: **Absolute number and age-standardised rates per year of incident and prevalent strokes, deaths from stroke and DALYs due to stroke in 2019, and percentage change globally for 1990–2019, by pathological types of stroke**



(Figure 1 continues on next page)

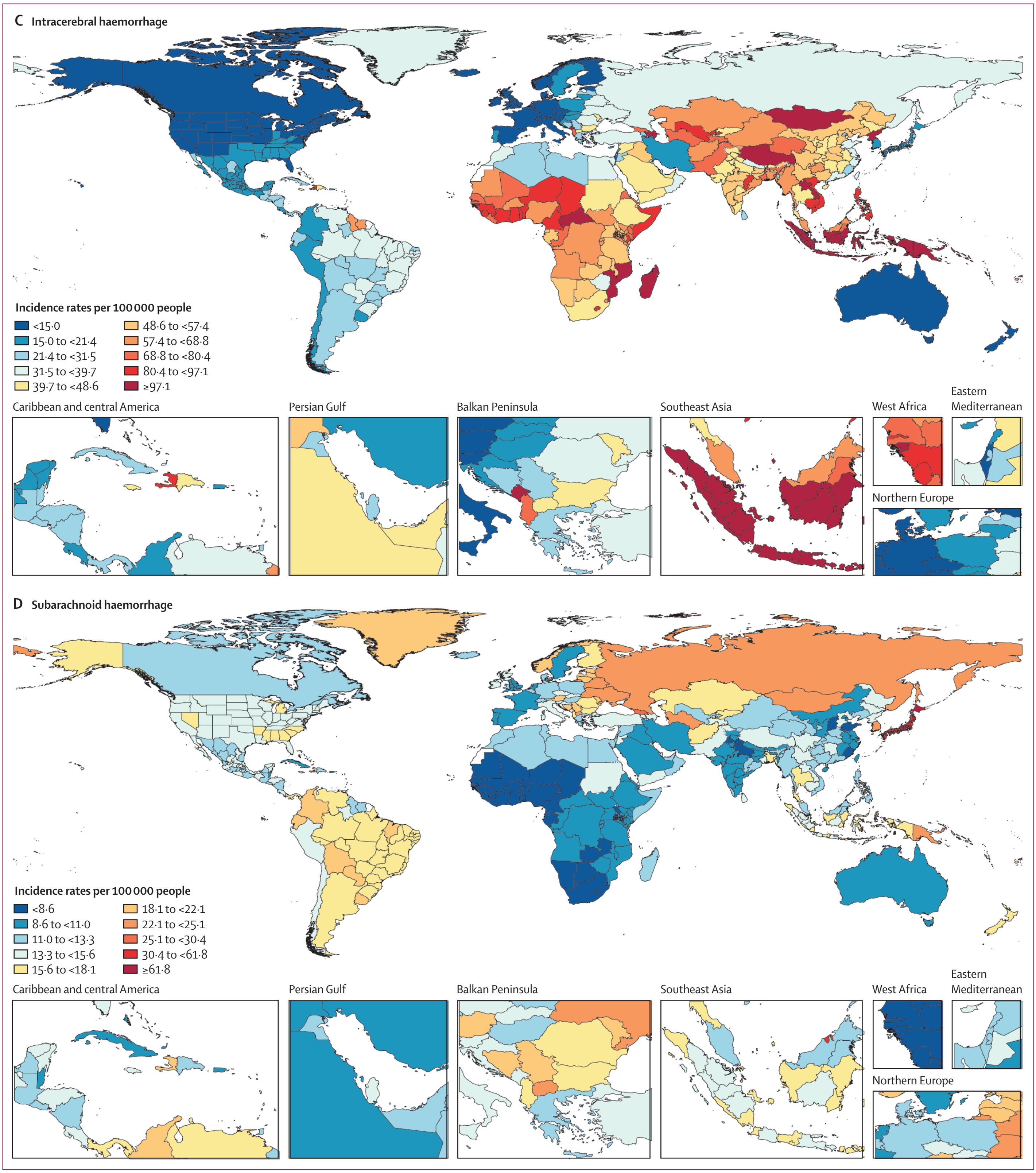


Figure 1: **Age-standardised stroke incidence rates per 100 000 people by stroke type and country, for both sexes, 2019**
(A) All strokes. (B) Ischaemic stroke. (C) Intracerebral haemorrhage. (D) Subarachnoid haemorrhage.

strokes), and there were no noticeable sex differences in the number of stroke-related deaths (appendix table S2). Although age-standardised incidence rates did not differ significantly between males and females, age-standardised death rates were greater in males than in females (96·4 [87·6–104·2] per 100 000 *vs* 73·5 [65·2–80·7] per 100 000) as were DALY rates (2024·3 [1852·4–2195·6] per 100 000 *vs* 1531·3 [1397·1–1667·6] per 100 000; see appendix section 4.1 for details of age-specific trends by country).

Burden of pathological types of stroke

Ischaemic stroke constituted 62·4% of all new strokes in 2019 (7·63 million [95% UI 6·57–8·96] strokes), intracerebral haemorrhage constituted 27·9% (3·41 million [2·97–3·91]), and subarachnoid haemorrhage constituted 9·7% (1·18 million [1·01–1·39]; table 1). Intracerebral haemorrhage and subarachnoid haemorrhage showed larger reductions in age-standardised rates from 1990 to 2019 than ischaemic stroke (table 1; appendix section 4·2, tables S3–5, and figure S8). There were substantial between-country variations in the age-standardised incidence (figures 1B–D), prevalence, mortality, and DALY rates (appendix figures S8–11) of these three pathological types of stroke by GBD regions, country income level, and sex (appendix section 4.2), with an almost two-fold greater proportion of intracerebral haemorrhage in World Bank low-income to upper-middle-income countries compared with high-income countries (29·5% [28·4–30·3] *vs* 15·8% [15·5–16·2]), but a lower proportion of subarachnoid haemorrhage in low-income to upper-middle-income countries compared with high-income countries (7·9% [7·5–8·3] *vs* 19·7% [18·4–21·0]).

Stroke-related DALYs attributable to risk factors

GBD stroke estimates for 1990–2019 are available to download from the GBD Results Tool. In 2019, 87·0% (95% UI 84·2–89·8) of total stroke DALYs were attributable to the 19 risk factors modelled in GBD 2019. The PAF of DALYs attributable to all risk factors combined was similar for ischaemic stroke (85·7% [81·2–90·3]), intracerebral haemorrhage (88·7% [85·2–91·0]), and subarachnoid haemorrhage (84·6% [81·3–87·6]; appendix section 4.3 and tables S6–8). From 1990 to 2019, the total number of stroke-related DALYs due to risk factors increased from 91·5 million (85·8–98·3) to 125 million (115–134), with a decrease in the high-income group (from 16·4 million [15·4–17·4] in 1990 to 13·1 million [11·8–14·4] in 2019) and an increase in the low-income to upper-middle-income groups (from 75·1 million [68·5–82·3] DALYs in all three income groups combined in 1990 to 111 million [100·3–122·5] DALYs in 2019). From 1990 to 2019, the largest increase in the age-standardised stroke PAF globally was for high BMI, increasing from 15·4% (8·2–24·2) to 24·3% (15·7–33·2), a 57·8% increase. In other words, if high BMI exposure were reduced to its TMREL, there would be a 24·3% reduction in stroke in 2019, compared to just a 15·4% reduction in 1990. Other risk factors with an increasing age-standardised stroke PAF from 1990 to 2019 included high systolic blood

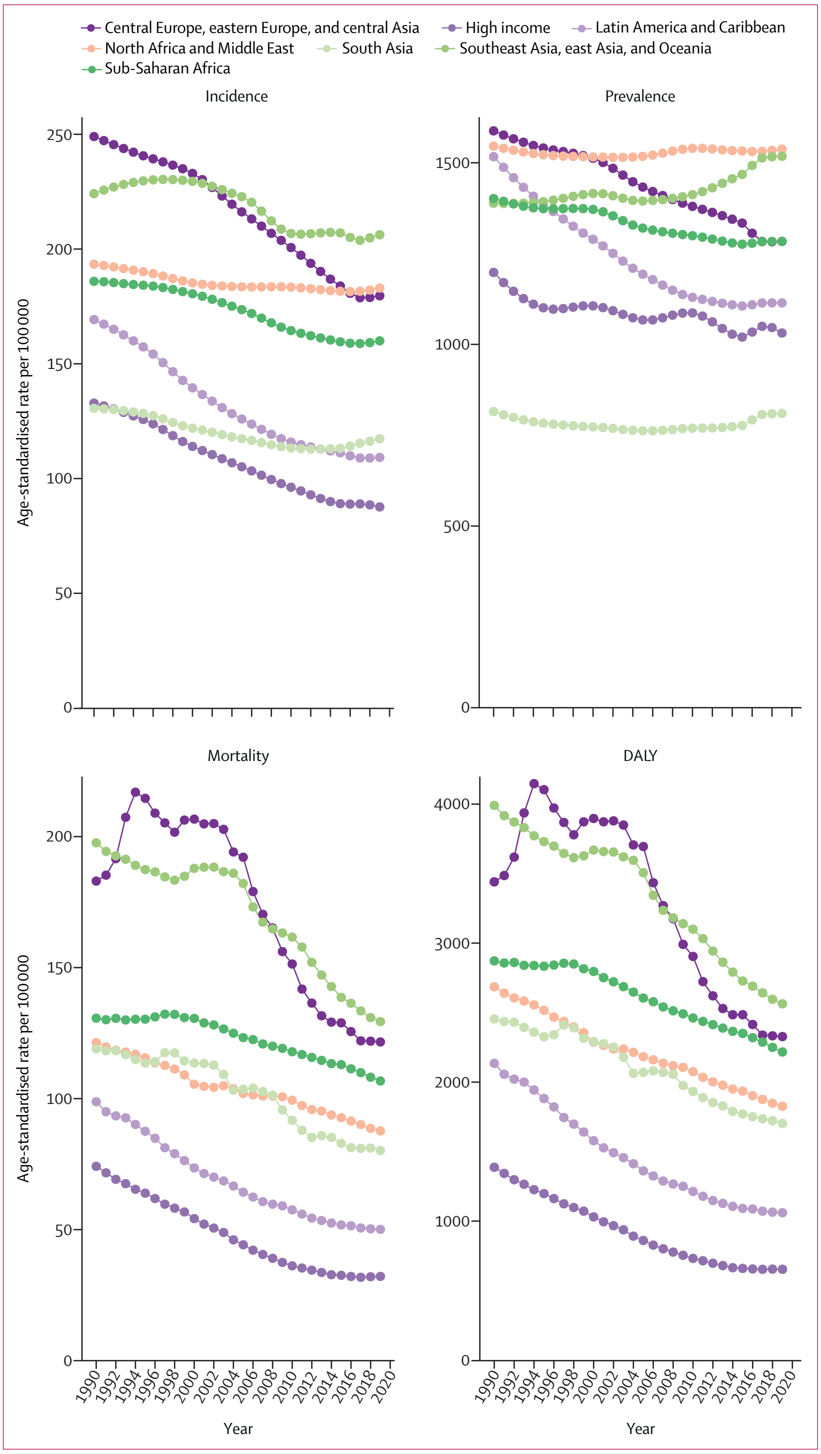


Figure 2: **Age-standardised incidence, prevalence, mortality, and DALY rates (per 100 000 people per year) in seven GBD super regions, 1990–2019, for both sexes and all ages**
DALY=disability-adjusted life-year. GBD=Global Burden of Diseases, Injuries, and Risk Factors Study.

For the **GBD Results Tool** see http://ghdx.healthdata.org/gbd-results-tool

	Globally		World Bank high-income countries		World Bank upper-middle-income countries		World Bank lower-middle-income countries		World Bank low-income countries	
	Absolute number (millions)	Percentage	Absolute number (millions)	Percentage	Absolute number (millions)	Percentage	Absolute number (millions)	Percentage	Absolute number (millions)	Percentage
Environmental risks										
Ambient $PM_{2·5}$ pollution	28·70 (23·40–33·40)	20·1% (16·6–23·0)	1·57 (1·20–1·95)	9·9% (7·8–12·3)	16·10 (13·20–18·90)	23·9% (20·5–26·7)	10·30 (8·04–12·60)	20·0% (15·7–24·1)	0·75 (0·42–1·16)	8·7% (5·0–13·4)
Household air pollution from solid fuels	14·70 (10·10–20·10)	10·3% (7·1–14·0)	0·03 (0·01–0·07)	0·2% (0·1–0·5)	3·64 (1·86–6·14)	5·4% (2·8–9·0)	8·09 (5·59–10·90)	15·7% (11·0–21·0)	2·96 (2·29–3·69)	34·4% (28·5–40·2)
Low ambient temperature	8·36 (6·19–10·80)	5·8% (4·4–7·5)	1·28 (0·96–1·64)	8·2% (6·1–10·5)	5·47 (4·07–7·29)	8·1% (6·2–10·7)	1·26 (0·45–2·03)	2·4% (0·9–3·9)	0·35 (0·22–0·50)	4·0% (2·6–5·6)
High ambient temperature	1·09 (0·11–2·38)	0·8% (0·1–1·6)	0·03 (0·01–0·06)	0·2% (0·1–0·4)	0·14 (0·00–0·39)	0·2% (0·0–0·6)	0·82 (0·06–1·72)	1·6% (0·1–3·4)	0·10 (0·02–0·28)	1·2% (0·3–3·1)
Lead exposure	6·74 (3·91–9·82)	4·7% (2·8–6·8)	0·25 (0·06–0·50)	1·6% (0·4–3·2)	3·13 (1·80–4·60)	4·7% (2·8–6·7)	2·94 (1·78–4·17)	5·7% (3·5–8·0)	0·42 (0·23–0·64)	4·9% (2·7–7·2)
Dietary risks										
Diet high in sodium	17·70 (5·75–34·90)	12·3% (4·1–24·3)	1·03 (0·15–2·59)	6·5% (0·9–16·4)	11·60 (4·77–20·20)	17·3% (7·3–29·6)	4·33 (0·56–10·50)	8·4% (1·1–20·3)	0·69 (0·09–1·88)	8·0% (1·0–21·6)
Diet high in red meat	10·10 (6·37–13·50)	7·1% (4·5–9·3)	1·45 (0·98–1·85)	9·2% (6·2–11·5)	6·73 (4·46–8·84)	10·0% (6·7–12·8)	1·63 (0·75–2·44)	3·2% (1·5–4·7)	0·29 (0·10–0·47)	3·4% (1·1–5·3)
Diet low in fruits	10·50 (6·24–16·00)	7·3% (4·4–11·2)	0·81 (0·41–1·30)	5·1% (2·6–8·2)	3·70 (1·92–5·97)	5·5% (2·9–8·8)	5·17 (3·23–7·74)	10·0% (6·2–14·9)	0·81 (0·47–1·27)	9·4% (5·6–14·4)
Diet low in vegetables	4·15 (1·54–6·84)	2·9% (1·1–4·8)	0·30 (0·10–0·54)	1·9% (0·6–3·4)	0·73 (0·31–1·19)	1·1% (0·5–1·8)	2·52 (0·80–4·30)	4·9% (1·5–8·2)	0·60 (0·24–0·95)	7·0% (2·8–11·1)
Diet low in whole grains	3·26 (0·98–4·76)	2·3% (0·7–3·3)	0·42 (0·12–0·62)	2·7% (0·8–3·9)	1·73 (0·48–2·57)	2·6% (0·7–3·7)	0·96 (0·31–1·43)	1·9% (0·6–2·8)	0·13 (0·04–0·20)	1·6% (0·5–2·3)
Alcohol consumption	8·54 (6·02–11·10)	6·0% (4·3–7·6)	1·00 (0·67–1·34)	6·3% (4·2–8·4)	4·99 (3·48–6·64)	7·4% (5·3–9·5)	2·13 (1·46–2·82)	4·1% (2·8–5·5)	0·42 (0·25–0·60)	4·9% (3·1–6·7)
Physical activity										
Low physical activity	2·41 (0·43–6·38)	1·7% (0·3–4·5)	0·46 (0·07–1·26)	2·9% (0·5–8·0)	1·23 (0·23–3·29)	1·8% (0·4–4·9)	0·65 (0·12–1·78)	1·3% (0·2–3·4)	0·07 (0·01–0·20)	0·8% (0·1–2·3)
Tobacco smoking										
Smoking	25·30 (22·60–28·20)	17·6% (16·4–19·0)	2·68 (2·44–2·94)	17·0% (15·8–18·3)	13·90 (11·90–16·10)	20·7% (19·0–22·4)	7·81 (6·94–8·74)	15·1% (13·9–16·4)	0·88 (0·72–1·06)	10·2% (9·1–11·3)
Second-hand smoking	5·09 (3·79–6·56)	3·5% (2·7–4·5)	0·31 (0·24–0·39)	2·0% (1·5–2·5)	2·62 (1·93–3·37)	3·9% (2·9–4·9)	1·93 (1·41–2·56)	3·7% (2·8–4·8)	0·22 (0·15–0·30)	2·6% (1·9–3·4)
Physiological factors										
High body-mass index	34·90 (22·30–48·60)	24·3% (15·7–33·2)	3·99 (2·73–5·36)	25·4% (17·2–34·2)	15·70 (9·39–22·80)	23·4% (14·1–33·0)	13·30 (8·65–18·30)	25·8% (17·0–34·7)	1·87 (1·04–2·84)	21·8% (12·9–31·6)
High fasting plasma glucose	28·90 (19·80–41·50)	20·2% (13·8–29·1)	3·88 (2·45–6·35)	24·7% (15·7–40·4)	12·30 (8·28–18·30)	18·3% (12·4–26·5)	11·30 (7·73–15·90)	21·9% (15·2–30·6)	1·37 (0·92–1·96)	15·9% (11·1–22·7)
High systolic blood pressure	79·60 (67·70–90·80)	55·5% (48·2–62·0)	7·71 (6·44–9·07)	48·9% (41·3–56·5)	37·20 (31·10–43·40)	55·4% (47·2–62·6)	30·00 (25·50–34·00)	58·1% (50·4–64·4)	4·57 (3·60–5·56)	53·2% (45·6–59·6)
High LDL cholesterol	13·70 (7·72–23·40)	9·6% (5·5–16·4)	2·02 (0·87–3·91)	12·8% (5·5–24·3)	7·34 (4·07–12·50)	10·9% (6·2–18·9)	3·84 (2·37–6·23)	7·4% (4·6–12·1)	0·50 (0·31–0·77)	5·8% (3·7–9·0)
Kidney dysfunction	11·90 (9·75–14·10)	8·3% (7·0–9·7)	1·07 (0·73–1·38)	6·8% (4·7–8·7)	5·62 (4·48–6·65)	8·4% (7·0–9·7)	4·70 (3·88–5·55)	9·1% (7·6–10·6)	0·56 (0·44–0·69)	6·5% (5·5–7·7)

(Table 2 continues on the next page)

pressure (from 52·0% [44·6–58·6] to 55·5% [48·2–62·0], a 6·7% increase) and high fasting plasma glucose (from 14·4% [9·9–20·8] to 20·2% [13·8–29·1], a 40·3% increase). By contrast, from 1990 to 2019, the stroke PAF of ambient particulate matter with a diameter of <2·5 μm (known as $PM_{2·5}$) pollution decreased from 32·5% (29·6–35·6) to 20·1% (16·6–23·0; a 38·2% decrease), and that of dietary risks decreased from 32·6% (24·7–41·5) to 30·6% (22·6–39·8; a 6·1% decrease).

In 2019, there were moderate between-country (1·3 times), regional (as measured by 21 GBD regions), and country economic development level (as measured by the World Bank income groups) variations in the proportion of stroke-related DALYs and its DALYs related to stroke pathological types that were attributable to risk factors. Between-country variations were more pronounced for subarachnoid haemorrhage (figure 3; appendix tables S6–12 and figures S12–14), and the highest

	Globally		World Bank high-income countries		World Bank upper-middle-income countries		World Bank lower-middle-income countries		World Bank low-income countries	
	Absolute number (millions)	Percentage	Absolute number (millions)	Percentage	Absolute number (millions)	Percentage	Absolute number (millions)	Percentage	Absolute number (millions)	Percentage
(Continued from previous page)										
Cluster of risk factors										
Air pollution*	43·50 (38·40–48·70)	30·4% (27·7–33·1)	1·60 (1·23–2·00)	10·2% (8·0–12·6)	19·70 (16·70–22·80)	29·3% (26·5–32·2)	18·40 (16·20–20·70)	35·7% (32·7–38·8)	3·71 (3·08–4·38)	43·1% (40·1–46·3)
Tobacco smoke†	29·50 (26·30–32·70)	20·6% (19·2–22·0)	2·92 (2·65–3·20)	18·5% (17·3–19·8)	16·00 (13·80–18·50)	23·8% (22·1–25·6)	9·49 (8·44–10·60)	18·4% (16·8–19·8)	1·07 (0·89–1·30)	12·5% (11·2–13·8)
Dietary risks‡	43·80 (32·10–58·10)	30·6% (22·6–39·8)	4·01 (2·98–5·39)	25·5% (18·9–33·6)	22·40 (15·90–29·70)	33·3% (24·4–42·9)	15·00 (10·60–20·00)	29·0% (20·7–38·5)	2·42 (1·61–3·46)	28·2% (19·6–38·9)
Behavioural risks§	67·90 (58·20–79·30)	47·4% (41·3–54·4)	6·88 (5·90–7·99)	43·7% (38·0–49·8)	34·90 (29·10–41·20)	51·9% (45·3–58·6)	22·70 (19·00–27·00)	44·0% (37·7–51·5)	3·42 (2·59–4·43)	39·8% (32·8–48·8)
Environmental or occupational risks¶	54·20 (48·20–60·00)	37·8% (35·0–41·0)	2·98 (2·48–3·53)	18·9% (16·0–22·4)	25·60 (22·00–29·10)	38·1% (34·9–41·4)	21·40 (18·90–24·10)	41·5% (38·4–44·9)	4·17 (3·48–4·87)	48·6% (45·3–51·8)
Metabolic risks‖	102·00 (89·80–112·00)	71·0% (64·6–77·1)	10·90 (9·36–12·50)	69·1% (61·1–77·0)	47·50 (40·70–53·70)	70·7% (64·0–77·0)	37·60 (33·00–41·50)	72·8% (66·6–78·1)	5·63 (4·57–6·70)	65·5% (58·6–71·2)
Combined risk factors										
All factors	125·00 (115·00–134·00)	87·0% (84·2–89·8)	13·10 (11·80–14·40)	83·2% (78·6–88·2)	59·10 (53·00–65·10)	87·9% (84·9–90·7)	45·20 (41·30–49·00)	87·6% (85·2–89·9)	7·18 (6·08–8·41)	83·7% (81·0–86·1)

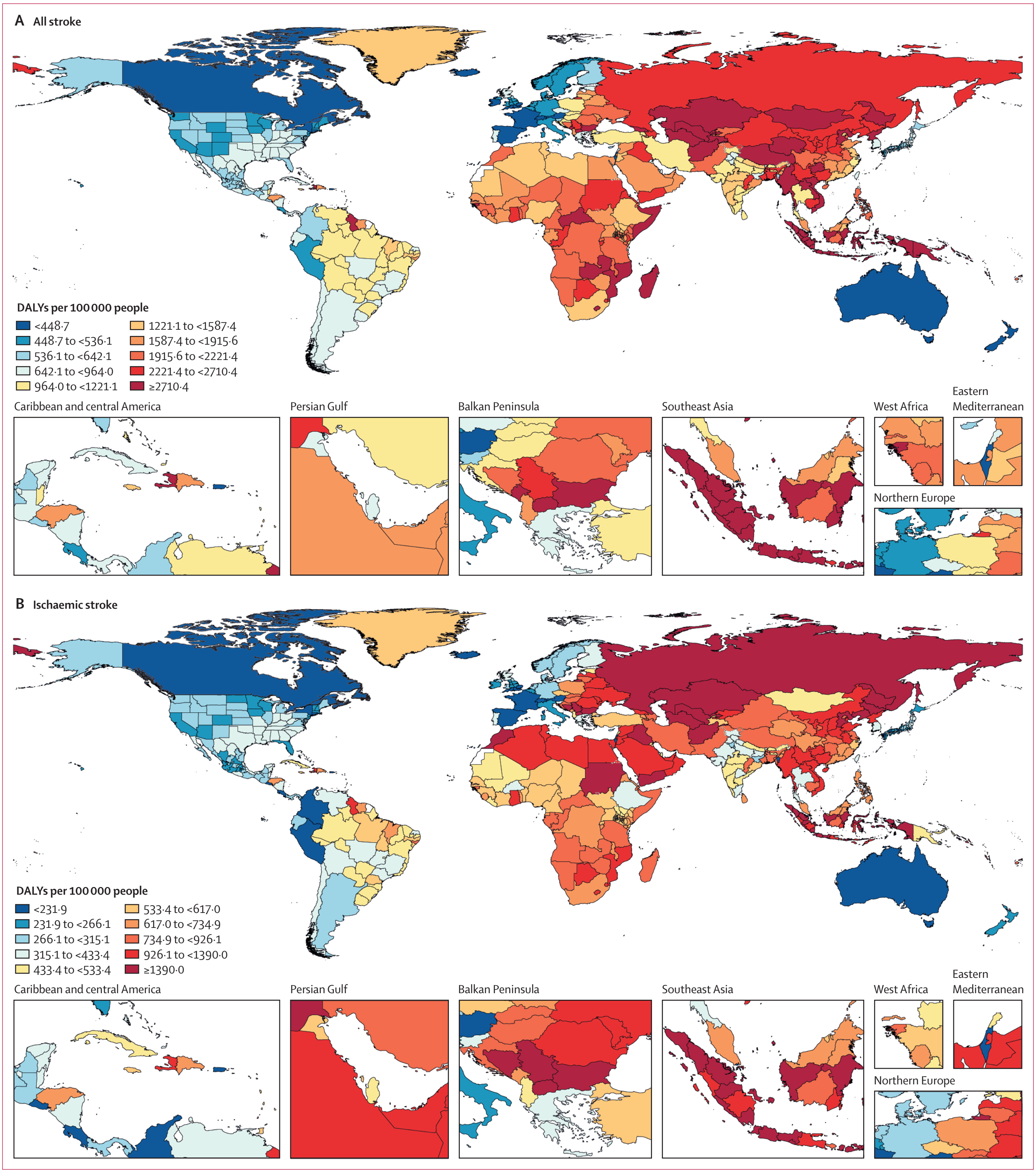
Data in parentheses are 95% uncertainty intervals. Count data in millions are presented to two decimal places and percentage data are presented to one decimal place. Percentages and number of DALYs are not mutually exclusive: the sum of percentages and number of DALYs in the columns exceeds the totals for all risk factors combined because of overlap between various risk factors. The crude sum of population attributable fraction (PAF) of the risk factors might exceed 100% because the effects of many of these risk factors are mediated partly or wholly through another risk factor or risk factors. DALY=disability-adjusted life-year. $PM_{2.5}$=particulate matter with a diameter of <25 μm. *Air pollution cluster includes ambient $PM_{2.5}$ pollution and household air pollution from solid fuels. †Tobacco smoke cluster includes smoking and second-hand smoking. ‡Dietary risks cluster includes diet high in sodium, diet low in fruits, diet low in vegetables, diet high in red meat, and diet low in whole grains, and alcohol consumption. §Behavioural risks cluster includes smoking (including second-hand smoking), dietary risks (diet high in sodium, diet low in fruits, diet low in vegetables, diet high in red meat, diet low in whole grains, and alcohol consumption), and low physical activity. ¶Environmental risks cluster includes air pollution cluster, low ambient temperature, high ambient temperature, and lead exposure. ‖Metabolic risks cluster includes high body-mass index, high fasting plasma glucose, high LDL cholesterol, high systolic blood pressure, and kidney dysfunction.

Table 2: **Stroke-related DALYs (absolute numbers and percentages) associated with risk factors and their clusters in 2019, for all ages and both sexes**

proportion of stroke-related DALYs was observed in the World Bank low-income to upper-middle-income groups (ranging from 85·9% [95% UI 83·2–88·6] in the World bank low-income group to 87·3% [84·4–89·9] in the World Bank upper-middle-income group). From 1990 to 2019, there was an increase in the total number of stroke-related DALYs due to high BMI, high fasting plasma glucose, high LDL cholesterol, kidney dysfunction, a diet high in red meat, alcohol consumption, and second-hand smoking, but a decrease in DALYs due to smoking and a diet low in fruits and vegetables (appendix figure S15). There were also moderate variations in the ranking of risk factors by pathological types of stroke (figure 4; appendix figures S16–18). In 2019, the five leading specific risk factors contributing to stroke death and disability combined (DALYs) were high systolic blood pressure (79·6 million [67·7–90·8] attributable DALYs; 55·5% [48·2–62·0] of all stroke DALYs]), high BMI (34·9 million [22·3–48·6]; [24·3% [15·7–33·2]), high fasting plasma glucose (28·9 million [19·8–41·5]; 20·2% [13·8–29·1]), ambient particulate matter pollution (28·7 million [23·4–33·4]; 20·1% [16·6–23·0]), and smoking (25·3 million [22·6–28·2]; 17·6% [16·4–19·0]; table 2, figure 5). For risk factors by pathological type of stroke and changes in risk factor rankings from 1990 to 2019 by GBD regions, see the appendix (section 4.3 and figures S19–26).

Discussion

In 2019, stroke remained the second-leading Level 3 cause of death and the third-leading Level 3 cause of death and disability combined in the world, and its burden (in terms of the absolute number of cases) increased substantially from 1990 to 2019. Our findings indicate that the bulk of the global stroke burden (86·0% [95% UI 85·9–86·9] of deaths and 89·0% [88·9–89·3] of DALYs) is in lower-income and lower-middle-income countries. Globally, over the past three decades, the total number of stroke-related DALYs due to risk factors increased substantially (by 33·5 million, from 91·5 million in 1990 to 125 million in 2019), with diverging trends in World Bank high-income countries and low-income to upper-middle-income countries: a relatively small decrease in the high-income group and large increases in the low-income to upper-middle income groups. The large increase in the global burden of stroke was probably not only due to population growth and ageing but also because of the substantial increase in exposure to several important risk factors such as high BMI, ambient particulate matter pollution, high fasting plasma glucose, high systolic blood pressure, alcohol consumption, low physical activity, kidney dysfunction, and high temperature (appendix figure S26).[7,14] This study is also the first systematic analysis to determine the effect of non-optimal temperature on



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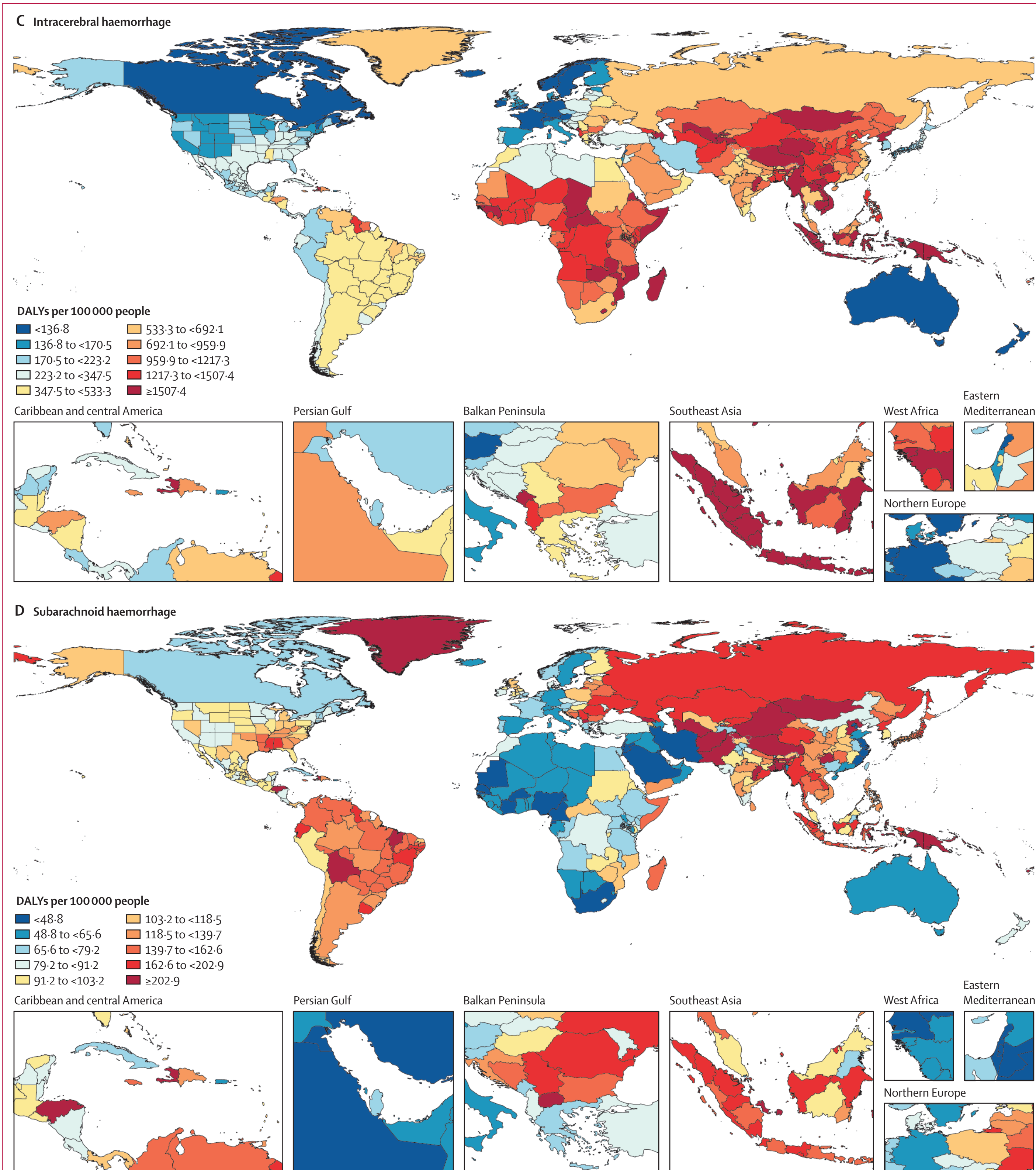

***Figure 3:* Age-standardised stroke-related DALYs attributable to all risk factors combined, for both sexes, 2019**
(A) All strokes. (B) Ischaemic stroke. (C) Intracerebral haemorrhage. (D) Subarachnoid haemorrhage. DALY=disability-adjusted life-year.

A All strokes

	Global	Central Asia	Central Europe	Eastern Europe	High-income Asia Pacific	Australasia	High-income North America	Southern Latin America	Western Europe	Andean Latin America	Caribbean	Central Latin America	Tropical Latin America	North Africa and Middle East	South Asia	East Asia	Oceania	Southeast Asia	Central sub-Saharan Africa	Eastern sub-Saharan Africa	Southern sub-Saharan Africa	Western sub-Saharan Africa
High systolic blood pressure	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
High body-mass index	2	2	2	2	2	4	2	2	2	2	2	2	2	2	4	5	4	2	4	3	2	3
High fasting plasma glucose	3	3	3	5	3	3	3	3	3	4	3	3	3	3	2	6	2	3	3	4	3	4
Ambient particulate matter pollution	4	4	6	7	13	5	12	6	9	3	6	4	7	4	3	2	12	5	5	9	4	5
Smoking	5	5	4	3	6	2	4	4	4	8	4	6	4	6	6	3	5	4	8	7	5	9
Diet high in sodium	6	10	5	12	14	7	11	10	12	9	14	8	8	17	10	4	8	7	14	5	14	11
Household air pollution from solid fuels	7	14	16	19	20	19	20	19	19	11	5	10	15	14	5	12	3	6	2	2	8	2
High LDL cholesterol	8	8	7	4	5	6	6	9	5	5	7	7	6	5	11	8	11	9	10	12	7	8
Kidney dysfunction	9	9	11	8	8	11	8	11	10	7	8	5	9	7	9	11	7	8	9	10	9	7
Diet low in fruits	10	11	12	11	9	8	10	13	11	13	12	11	13	13	7	13	6	11	6	6	6	6
Diet high in red meat	11	7	9	9	4	10	5	5	6	6	13	9	5	15	19	7	10	14	15	14	11	14
Low temperature	12	6	8	6	10	9	7	8	7	10	19	15	19	8	17	9	15	20	16	15	12	20
Alcohol use	13	12	10	10	7	12	9	7	8	15	9	13	10	20	15	10	14	13	11	11	10	10
Lead exposure	14	17	18	18	16	17	18	17	18	16	11	12	16	10	8	14	17	16	12	13	15	13
Second-hand smoke	16	15	13	14	18	14	16	14	17	18	17	17	17	12	14	15	13	15	18	16	16	16
Diet low in vegetables	17	19	19	17	15	18	14	15	16	12	10	14	11	18	12	19	9	12	7	8	13	12
Diet low in whole grains	18	13	14	13	17	16	15	16	15	17	18	18	18	9	18	16	16	17	17	18	19	17
Low physical activity	19	18	17	16	12	15	17	18	14	19	16	19	12	11	20	18	18	18	19	20	17	18
High temperature	20	20	20	20	19	20	19	20	20	20	20	20	20	19	16	20	20	19	20	19	20	15

B Ischaemic stroke

	Global	Central Asia	Central Europe	Eastern Europe	High-income Asia Pacific	Australasia	High-income North America	Southern Latin America	Western Europe	Andean Latin America	Caribbean	Central Latin America	Tropical Latin America	North Africa and Middle East	South Asia	East Asia	Oceania	Southeast Asia	Central sub-Saharan Africa	Eastern sub-Saharan Africa	Southern sub-Saharan Africa	Western sub-Saharan Africa
High systolic blood pressure	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
High fasting plasma glucose	2	2	2	5	4	3	2	2	2	3	2	2	2	2	2	6	2	2	3	3	2	3
High LDL cholesterol	3	4	4	3	2	2	4	3	3	4	3	3	3	5	4	3	4	3	4	4	4	4
Ambient particulate matter pollution	4	5	7	8	13	5	11	7	8	5	6	5	9	4	3	2	12	5	6	9	5	6
High body-mass index	5	3	3	2	3	6	3	4	4	2	4	4	4	3	6	7	5	6	5	5	3	5
Smoking	6	6	5	4	6	4	5	5	5	9	5	7	5	7	7	4	6	4	9	7	6	11
Diet high in sodium	7	11	6	11	16	7	10	10	13	7	13	8	10	17	11	5	8	8	15	6	15	10
Kidney dysfunction	8	8	9	7	7	8	7	9	9	6	7	6	8	6	8	9	7	9	7	8	7	7
Household air pollution from solid fuels	9	14	17	19	20	19	20	19	19	10	8	10	15	14	5	11	3	7	2	2	8	2
Diet high in red meat	10	10	10	9	5	10	6	6	6	11	12	9	6	13	19	8	11	16	16	15	10	15
Low temperature	11	7	8	6	9	9	8	8	7	8	19	14	18	10	18	10	16	19	17	14	11	20
Diet low in whole grains	12	9	11	10	10	13	9	11	11	12	10	12	11	8	12	13	10	12	10	11	13	8
Diet low in fruits	13	12	12	12	11	11	12	13	14	15	14	13	16	15	10	14	9	11	8	10	9	9
Lead exposure	14	17	18	18	14	17	17	18	17	17	11	11	13	11	9	12	17	17	13	12	16	12
Low physical activity	15	13	13	13	8	12	13	16	10	16	9	16	7	9	14	16	13	13	12	16	12	13
Second-hand smoke	16	15	15	16	19	16	18	15	18	18	17	18	17	12	16	15	15	14	18	18	17	17
Alcohol use	18	18	14	14	15	15	15	14	12	20	18	19	19	20	20	17	20	18	20	19	18	18
Diet low in vegetables	19	19	19	17	17	18	16	17	16	14	15	15	14	19	15	19	14	15	11	13	14	14
High temperature	20	20	20	20	18	20	19	20	20	19	20	20	20	18	17	20	19	20	19	20	20	16

(Figure 4 continues on next page)

stroke burden. The greater age-standardised burden of stroke in World Bank low-income to upper-middle-income countries than in the high-income countries might also relate to poorer acute health care for stroke,[15] poorer stroke awareness,[16] and greater prevalence or effect of some risk factors (eg, tobacco use, poor diet, diabetes, hypertension, cardiovascular disease, rheumatic heart disease, dyslipidaemia, and obesity) in low-income countries than in upper-middle-income countries,[17,18] which highlights the inadequacy of primary prevention efforts in these settings.

For the first time, we have presented the global, regional, and national burden of stroke and its risk factors by its major pathological types. Although ischaemic

C Intracerebral haemorrhage

	Global	Central Asia	Central Europe	Eastern Europe	High-income Asia Pacific	Australasia	High-income North America	Southern Latin America	Western Europe	Andean Latin America	Caribbean	Central Latin America	Tropical Latin America	North Africa and Middle East	South Asia	East Asia	Oceania	Southeast Asia	Central sub-Saharan Africa	Eastern sub-Saharan Africa	Southern sub-Saharan Africa	Western sub-Saharan Africa
High systolic blood pressure	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
High body-mass index	2	2	2	2	2	3	2	2	2	1	2	2	2	2	4	5	4	2	3	3	2	2
Ambient particulate matter pollution	3	4	7	6	11	6	11	7	8	3	6	4	7	3	3	2	12	5	6	10	4	5
High fasting plasma glucose	4	3	4	5	4	5	3	4	3	4	3	3	3	4	2	6	3	4	4	4	3	4
Smoking	5	5	3	3	5	2	4	3	4	8	5	6	4	5	7	3	5	3	8	7	5	8
Diet high in sodium	6	11	6	11	12	7	10	9	11	10	13	8	8	15	10	4	8	7	13	6	13	11
Household air pollution from solid fuels	7	12	14	16	17	16	17	16	16	13	4	11	13	10	5	11	2	6	2	2	8	3
Alcohol use	8	8	5	4	3	4	5	5	5	5	7	7	6	17	12	7	13	11	9	8	6	7
Diet low in fruits	9	10	11	10	8	8	9	12	10	11	10	10	11	8	6	12	6	9	5	5	7	6
Kidney dysfunction	10	9	10	9	7	9	8	10	9	6	8	5	9	6	8	10	7	8	10	11	10	9
Diet high in red meat	11	7	8	8	6	11	6	6	6	7	12	9	5	12	17	8	10	13	14	13	9	13
Low temperature	12	6	9	7	9	10	7	8	7	12	16	14	16	7	15	9	14	16	15	14	12	17
Lead exposure	13	15	15	15	14	14	15	15	15	15	11	13	15	9	9	13	15	15	11	12	15	12
Second-hand smoke	15	13	12	12	15	13	14	13	14	16	15	16	14	11	14	14	11	14	16	15	14	15
Diet low in vegetables	16	16	16	14	13	15	13	14	13	9	9	12	10	13	11	16	9	12	7	9	11	10
High temperature	17	17	17	17	16	17	16	17	17	17	17	17	17	16	16	17	17	17	17	17	17	14

D Subarachnoid haemorrhage

	Global	Central Asia	Central Europe	Eastern Europe	High-income Asia Pacific	Australasia	High-income North America	Southern Latin America	Western Europe	Andean Latin America	Caribbean	Central Latin America	Tropical Latin America	North Africa and Middle East	South Asia	East Asia	Oceania	Southeast Asia	Central sub-Saharan Africa	Eastern sub-Saharan Africa	Southern sub-Saharan Africa	Western sub-Saharan Africa
High systolic blood pressure	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
High body-mass index	2	2	2	2	2	2	1	2	2	1	2	2	2	2	2	3	2	2	3	3	2	2
Ambient particulate matter pollution	3	4	4	5	9	4	9	6	6	3	6	4	6	3	3	2	11	4	7	9	4	4
Smoking	4	5	3	3	3	3	3	3	3	9	5	5	3	5	7	5	5	3	8	7	7	7
High fasting plasma glucose	5	3	5	4	5	5	4	5	4	4	3	3	5	4	4	6	4	5	4	4	3	5
Diet high in sodium	6	9	6	9	10	6	8	8	9	11	12	7	8	14	9	4	9	7	11	8	10	9
Household air pollution from solid fuels	7	10	12	14	15	14	15	14	14	8	4	10	11	8	5	9	3	6	2	2	6	3
Diet low in fruits	8	8	9	7	6	7	6	9	8	7	7	8	9	7	6	10	6	8	5	5	5	6
Diet high in red meat	9	6	7	6	4	8	5	4	5	5	9	6	4	10	15	7	8	11	12	11	9	10
Low temperature	10	7	8	8	7	9	7	7	7	10	14	12	14	6	13	8	12	15	14	12	11	15
Lead exposure	12	13	13	13	13	13	13	13	13	13	10	11	13	9	8	11	13	13	9	10	13	11
Diet low in vegetables	13	14	14	12	11	12	11	12	12	6	8	9	7	12	10	14	7	10	6	6	8	8
Second-hand smoke	14	11	10	10	12	11	12	11	11	14	13	14	12	11	12	12	10	12	13	14	12	12
High temperature	15	15	15	15	14	15	14	15	15	15	15	15	15	15	14	15	15	14	15	15	15	13

***Figure 4:* Age-standardised stroke-related DALYs attributable to risk factors by 21 GBD regions, for both sexes, 2019**

(A) All strokes. (B) Ischaemic stroke. (C) Intracerebral haemorrhage. (D) Subarachnoid haemorrhage. Numbers show the ranking level (1=highest, 15=lowest) by the number of DALYs attributable to the corresponding risk factors. Red shows 1st ranking; light brown, 2nd and 3rd ranking; very light yellow, 4–7 ranking; very light blue, 8–13 ranking; and dark blue, 14–15 ranking. Diet low in whole grains, low physical activity, and high LDL cholesterol were not assessed for intracerebral haemorrhage. Diet low in whole grains, alcohol use, low physical activity, high LDL cholesterol, and kidney dysfunction were not assessed for subarachnoid haemorrhage. DALY=disability-adjusted life-year. GBD=Global Burden of Diseases, Injuries, and Risk Factors Study.

stroke continues to constitute the largest proportion of all new strokes (comprising 62·4% of all incident strokes in 2019), followed by intracerebral haemorrhage (27·9%), and subarachnoid haemorrhage (9·7%), the relative proportions of each pathological type varied substantially by income group. For example, a new stroke case was nearly twice as likely to be intracerebral haemorrhage in the World Bank low-income to upper-middle-income groups combined than in the high-income group (29·5% of all incident strokes in 2019 *vs* 15·8%), whereas a new stroke case was more than twice as likely to be subarachnoid haemorrhage in the World Bank high-income group than in the low-income to upper-middle-income groups combined (19·7% *vs* 7·9%). The increased risk of intracerebral haemorrhage in low-income and upper-middle-income countries might be related to the high relative clinical significance and population-attributable risk of hypertension in these countries.[18] Our finding that a greater proportion of incident strokes in low-income to upper-middle-income countries are intracerebral haemorrhages in males than in females (appendix figure F6.9) are in line with previous observations,[19,20] and might be explained by lower levels of awareness and control of hypertension in low-income

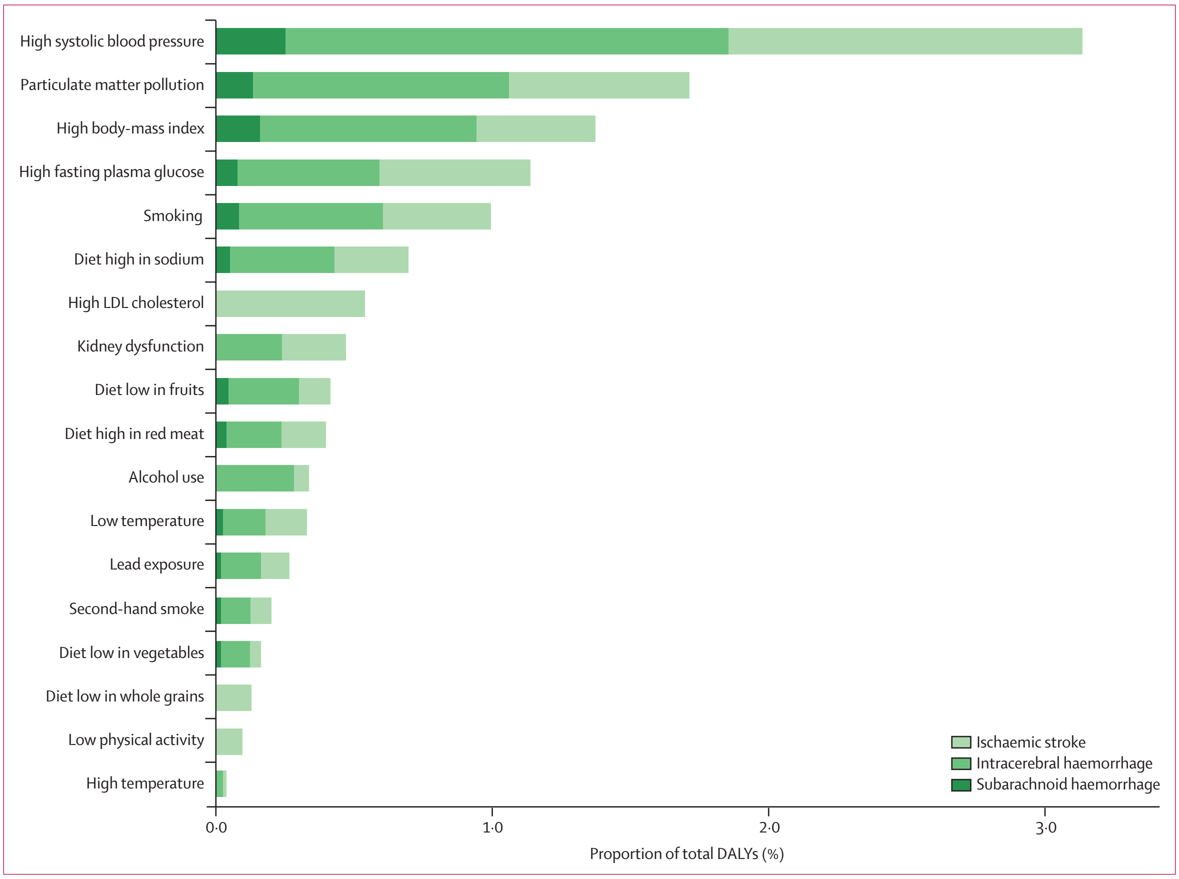

***Figure 5*: Proportion of DALYs attributable to risk factors by pathological type of stroke for both sexes combined, 2019**
Proportion of DALYs attributable to household air pollution from solid fuels are not shown in this figure. DALY=disability-adjusted life-year.

to upper-middle-income countries than in high-income countries,[18,21] as well as increased exposure to risk factors predisposing a higher proportion of males to intracerebral haemorrhage compared with females.[20,22] Our study also adds to the body of research on the incidence of subarachnoid haemorrhage; a previous systematic review of population-based studies of subarachnoid haemorrhage incidence by Etminan and colleagues[23] had similar findings to ours, as the authors used many of the same sources, but they only used crude incidence rates, which is perhaps why we found smaller between-country variations in the age-standardised incidence of subarachnoid haemorrhage (approximately a tenfold variation in our findings [appendix table s5] compared with a >20-fold variation in the systematic review).[23] The size of between-country variations we observed in age-standardised incidence, prevalence, and DALY rates of other pathological types of stroke and stroke overall were in line with previous observations.[2,3,19,20,24]

Despite the overall declines in age-standardised stroke incidence, prevalence, death, and DALY rates, three concerning trends have emerged. First, the greatest share of the global burden of stroke continues to be borne by low-income to upper-middle-income countries. The proportion of DALYs attributable to GBD-modelled risk factors was also particularly high in low-income to upper-middle-income countries. Second, the pace of the global decline in age-standardised stroke incidence, death, and DALY rates was noticeably slower over the past decade (2010–19) than in the previous decade (2000–09), and global age-standardised prevalence significantly increased from 2010 to 2019 (appendix figure 6.8). There was a significant increase in stroke prevalence and incidence rates in people younger than 70 years between 1990 and 2019 with even faster increases from 2010 to 2019 (appendix figure 6.7). A trend towards plateauing or increasing stroke incidence or mortality rates, or both, in middle-aged people was recently observed in the USA, European countries, Brazil, and China.[25–30] This trend might be a reflection of the increased exposure to some risk factors for stroke, such as elevated blood pressure, high BMI, and high fasting plasma glucose, across most countries.[31–33] In the USA, a worrisome trend observed in recent years (2017–18) is that awareness of hypertension in the population whose blood pressure is controlled is declining.[34] Third, most countries have not achieved sufficient declines in stroke incidence rates to offset the demographic force of population growth and ageing, resulting in overall increases in the number of incident, prevalent, fatal, and disabling strokes over time. A linear interpolation shows that if current trends continue, by 2050 there will be more than 200 million stroke survivors and almost 300 million DALYs, 25 million new strokes, and 13 million deaths from stroke annually.

This study was, to our knowledge, the first systematic analysis to provide estimates of the burden of stroke and its subtypes associated with non-optimal temperature (daily temperatures below or above the TMREL). Although previous studies have made ecological observations of the effects of ambient temperature on the risk of stroke, this study was the first to show the sizeable global effect of non-optimal temperature (primarily low temperature, at 8·36 million [95% UI 6·19–10·80] DALYs or a PAF of 5·8% [4·4–7·5]) on the burden of stroke and its pathological types (appendix tables T10b, T11b, and T12b). These findings were in line with a recent systematic review on ambient temperature and stroke occurrence.[35] Our estimates of geographical variations in the burden of stroke and its pathological types associated with non-optimal temperature and other risk factors suggest that country-specific and stroke type-specific priorities and strategies should be developed and implemented for reducing the burden of stroke in different geographical locations.

Our findings of the high proportion (87·0%) of age-standardised stroke-related DALYs associated with GBD risk factors are in line with previous observations[17,36] and highlight the potential to greatly reduce the stroke burden by addressing risk factor exposure. The increased contribution of certain metabolic risk factors in 2019 compared with 1990 (eg, an increase in the proportional contribution to stroke-related DALYs of 57·8% by high BMI and 40·3% by high fasting plasma glucose) and a decreasing contribution of certain environmental and occupational and behavioural risk factors to the stroke-related DALY burden over the same period (eg, a 38·2% decrease for household air pollution from solid fuels and a 6·1% decrease for a diet low in vegetables) might be related to a growing proportion of the global population reaching the final stages of the epidemiological transition, in which the risk burden has shifted towards metabolic risk factors and an increased proportion of the disease burden comes from stroke and other non-communicable diseases.[37] This observation also means that guidance on reducing the risk of stroke by targeting certain risk factors will need to change to reflect changes in the risk-attributable profile.

Our estimates of the global, regional, and national burden of stroke and its pathological types and risk factors are important for evidence-based health-care planning, priority setting, and resource allocation for stroke care, primary prevention, and research. The high and increasing stroke burden alongside stagnant or even increasing mortality rates from cardiovascular disease in some countries,[14] and increasing rates of exposure to many important stroke risk factors from 1990 to 2019,[7,14] suggest that current primary stroke prevention strategies and measures are not sufficient, and that efforts to implement population-wide primary prevention strategies more widely must be reinforced worldwide.[38] For every US$1 spent on prevention of stroke and cardiovascular disease, there is an estimated $10·9 return on investment.[39] Population-wide interventions for primary prevention of stroke and cardiovascular disease should include measures to reduce exposure to metabolic risk factors (eg, screening for and proper management of systolic blood pressure and weight), behavioural risk factors (eg, smoking cessation programmes and programmes to increase the accessibility and affordability of nutrient-rich foods), and environmental and occupational risk factors (eg, measures to reduce air pollution and lead exposure). The development and implementation of such population-level interventions, alongside efforts to reduce poverty and racial and socioeconomic inequities, through legislation, taxation, and other measures at the government level, must be the mainstream approach for reducing the risk of stroke, cardiovascular disease, and other non-communicable diseases, but the importance of primary prevention measures at the individual level should not be overlooked. In this respect, the emphasis should be on strategies that are appropriate for most people at risk of stroke and cardiovascular disease regardless of their level of risk exposure,[38] such as digital health technologies for affordable identification of people at increased risk of stroke and cardiovascular disease, universal health coverage, cheap and effective multidrug regimens (eg, polypills) for people at increased risk of cardiovascular disease, and involvement of health-care volunteers in primary prevention activities. For example, the World Stroke Organization recommends that all adults know their individual risk of having a stroke, their personal risk factors for stroke, and how to control these risk factors using the validated, internationally endorsed, and free Stroke Riskometer app, which is currently available in 19 languages for more than 70% of the global population.[40] A recent Cochrane systematic review showed the feasibility and potential effectiveness of several health promotion interventions targeting risk factors to achieve behavioural changes for primary prevention of cardiovascular disease in low-income to upper-middle-income countries.[41] Although knowledge of personal risk and management of behavioural risk factor activities is primarily the prerogative of individuals, health professionals have a responsibility to identify risk factors that require pharmacological and non-pharmacological treatment to reduce the chance of stroke occurrence (eg, elevated blood pressure, atrial fibrillation, diabetes, dyslipidaemia, or symptomatic carotid artery stenosis). Simple, inexpensive screening for cardiovascular disease risks (eg, elevated blood

For more on the **Stroke Riskometer & PreventS app** see https://nisan.aut.ac.nz/Stroke-Riskometer/

pressure, smoking, and overweight) by health professionals in low-income and middle-income settings or more accurate screening for high cardiovascular disease risks (including blood lipid tests) by health professionals in higher-income locations can help to identify people who might require prophylactic drug therapy, in conjunction with behavioural interventions.[40] However, health professionals often do not have enough time to conduct detailed assessments of behavioural risk factors or to develop individually tailored recommendations for primary prevention of stroke and cardiovascular disease. To ameliorate this problem, data on stroke risk and risk factors from individuals should be integrated with the electronic patient management systems of health service providers. A study in Finland suggests that the quality of stroke prevention by primary health-care professionals could be improved by developing digital clinical decision-making tools and by implementing inter-professional teamwork[42] (eg, the PreventS web app currently being developed in New Zealand). All of these measures should be facilitated by ongoing, culturally appropriate health education campaigns (including coordinated activities of non-governmental organisations) and inclusion of such health education information into standardised educational curricula at all levels.

In addition to primary stroke prevention efforts, appropriate secondary prevention efforts and adequate acute treatment and rehabilitation are essential to improve stroke outcomes. Our findings of large geographical variations in stroke prevalence, mortality, and disability are a reflection not only of geographical differences in stroke incidence but also of major inequities in acute stroke care and rehabilitation across countries.[43] Even in European countries, only 7·3% of all patients with acute ischaemic stroke receive intravenous thrombolysis and only 1·9% receive endovascular treatment, with the highest country-level rates being 20·6% for intravenous thrombolysis (in the Netherlands) and 5·6% for endovascular treatment (in Malta),[44] and one in three patients discontinues using one or more secondary stroke prevention drugs about 1 year after stroke.[45] Treatment rates are even lower in many low-income and middle-income countries.[21,43] To reduce inequalities in stroke care, a roadmap for delivering quality stroke care and various action plans[46,47] have been suggested, with emphasis on the importance of applying culturally appropriate and context-appropriate strategies. There is a pressing need to implement evidence-based guidelines for stroke management and to reduce the gap in stroke care between high-income countries and low-income and middle-income countries. Recent evidence suggests that delivering an adequate level of stroke care[48,49] and preventive interventions[49] in low-income and middle-income countries are feasible. Attention should be paid to developing the workforce for stroke care and setting up affordable and accessible rehabilitation facilities. Promising results[50] suggest that self-management could be used as an adjunct strategy for ongoing rehabilitation at home or in other settings. The importance of country-based ongoing stroke registries and stroke risk factors surveys, which are profoundly lacking in low-income and middle-income countries, should also be emphasised.

Although this study was, to our knowledge, the first and most comprehensive review of the global, regional, and national burden of stroke and its 19 specific risk factors by all three pathological types, it was not free from limitations common to all previous GBD estimates of stroke risk and risk factors,[2,3,11,36] particularly the absence of original, good-quality stroke epidemiological studies for most countries. We therefore were not able to include some important potential risk factors (eg, atrial fibrillation and substance abuse), or include different patterns in risk factor exposure (eg, different doses and types of alcohol consumption, pack-years of smoking) and doses of exposure, analyse stroke burden by ischaemic stroke subtypes, or do a decomposition analysis to attribute changes in stroke burden to changes in the population growth, ageing, and risk factors separately. Additionally, evidence for the selection of TMRELs for some risk factors was uncertain and based on non-experimental studies, although all TMRELs were discussed and approved by a team of risk epidemiologists and stroke experts. Despite these limitations, our results are broadly consistent with previous estimates from population-based and analytical epidemiological studies, thus supporting the validity of our results.

In summary, although strokes are largely preventable, as indicated by declining incidence rates globally, stroke remained the second-leading cause of death and third-leading cause of death and disability combined worldwide in 2019. Without wider implementation of population-wide primary stroke and cardiovascular disease prevention strategies, the burden of stroke is likely to continue growing, disproportionally affecting low-income and middle-income countries. As the 19 analysed risk factors for stroke are common for other major non-communicable diseases, appropriate control of these risk factors will also reduce the burden of coronary heart disease, vascular dementia, type 2 diabetes, and even some types of cancer. Further research on the frequency, outcomes, and determinants of stroke and its pathological types in different locations and over time is warranted. Such research could include identifying populations at highest risk as well as further investigating differences in stroke pathological types and their geographical patterns, all of which would be useful for more targeted prevention and treatment efforts. Closing the gaps between high-income countries and low-income and middle-income countries in the adaptation and implementation of internationally recognised guidelines and recommendations for reducing stroke morbidity and mortality, with an emphasis on primary prevention strategies, is crucial to addressing the global stroke burden.

Contributors

Please see the appendix (pp 7–10) for more detailed information about individual author contributions to the research, divided into the following categories: managing the estimation or publication process; writing the first draft of the manuscript; primary responsibility for applying analytical methods to produce estimates; primary responsibility for seeking, cataloguing, extracting, or cleaning data; designing or coding figures and tables; providing data or critical feedback on data sources; development of methods or computational machinery; providing critical feedback on methods or results; drafting the manuscript or revising it critically for important intellectual content; extracting, cleaning, or cataloguing data; designing or coding figures and tables; and managing the overall research enterprise. V L Feigin and G A Roth had access to and verified the data underlying this study. All authors had full access to all the data in the study, and V L Feigin had final responsibility for the decision to submit for publication.

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Data sharing

All data presented in the manuscript can be found on the Institute for Health Metrics and Evaluation GBD Compare and Viz Hub website at https://vizhub.healthdata.org/gbd-compare/#.

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References

1 Kyu HH, Abate D, Abate KH, et al. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1859–922.

2 Krishnamurthi RV, Ikeda T, Feigin VL. Global, regional and country-specific burden of ischaemic stroke, intracerebral haemorrhage and subarachnoid haemorrhage: a systematic analysis of the global burden of disease study 2017. *Neuroepidemiology* 2020; **54** (suppl 2)**:** 171–79.

3 Johnson CO, Nguyen M, Roth GA, et al. Global, regional, and national burden of stroke, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol* 2019; **18:** 439–58.

4 Johnson W, Onuma O, Owolabi M, Sachdev S. Stroke: a global response is needed. *Bull World Health Organ* 2016; **94:** 634A.

5 Stanaway JD, Afshin A, Gakidou E, et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1923–94.

6 Vos T, Lim SS, Abbafati C, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1204–22.

7 Murray CJL, Aravkin AY, Zheng P, et al. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1223–49.

8 Aho K, Harmsen P, Hatano S, Marquardsen J, Smirnov VE, Strasser T. Cerebrovascular disease in the community: results of a WHO collaborative study. *Bull World Health Organ* 1980; **58:** 113–30.

9 Roth GA, Abate D, Abate KH, et al. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1736–88.

10 Roth GA, Johnson CO, Nguyen G, et al. Methods for estimating the global burden of cerebrovascular diseases. *Neuroepidemiology* 2015; **45:** 146–51.

11 Stanaway JD, Afshin A, Gakidou E, et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1923–94.

12 Murray CJL, Lopez AD. Measuring the global burden of disease. *N Engl J Med* 2013; **369:** 448–57.

13 World Bank. World Bank Country and Lending Groups. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (accessed April 20, 2021).

14 Murray CJL, Abbafati C, Abbas KM, et al. Five insights from the Global Burden of Disease Study 2019. *Lancet* 2020; **396:** 1135–59.

15 Pandian JD, Kalkonde Y, Sebastian IA, Felix C, Urimubenshi G, Bosch J. Stroke systems of care in low-income and middle-income countries: challenges and opportunities. *Lancet* 2020; **396:** 1443–51.

16 Cossi MJ, Preux PM, Chabriat H, Gobron C, Houinato D. Knowledge of stroke among an urban population in Cotonou (Benin). *Neuroepidemiology* 2012; **38:** 172–78.

17 O'Donnell MJ, Chin SL, Rangarajan S, et al. Global and regional effects of potentially modifiable risk factors associated with acute stroke in 32 countries (INTERSTROKE): a case-control study. *Lancet* 2016; **388:** 761–75.

18 Owolabi MO, Sarfo F, Akinyemi R, et al. Dominant modifiable risk factors for stroke in Ghana and Nigeria (SIREN): a case-control study. *Lancet Glob Health* 2018; **6:** e436–46.

19 Feigin VL, Lawes CM, Bennett DA, Barker-Collo SL, Parag V. Worldwide stroke incidence and early case fatality reported in 56 population-based studies: a systematic review. *Lancet Neurol* 2009; **8:** 355–69.

20 An SJ, Kim TJ, Yoon B-W. Epidemiology, risk factors, and clinical features of intracerebral hemorrhage: an update. *J Stroke* 2017; **19:** 3–10.

21 Owolabi M, Olowoyo P, Miranda JJ, et al. Gaps in hypertension guidelines in low- and middle-income versus high-income countries: a systematic review. *Hypertension* 2016; **68:** 1328–37.

22 Everett B, Zajacova A. Gender differences in hypertension and hypertension awareness among young adults. *Biodemogr Soc Biol* 2015; **61:** 1–17.

23 Etminan N, Chang HS, Hackenberg K, et al. Worldwide incidence of aneurysmal subarachnoid hemorrhage according to region, time period, blood pressure, and smoking prevalence in the population: a systematic review and meta-analysis. *JAMA Neurol* 2019; **76:** 588–97.

24 Thrift AG, Thayabaranathan T, Howard G, et al. Global stroke statistics. *Int J Stroke* 2017; **12:** 13–32.

25 Hall EW, Vaughan AS, Ritchey MD, Schieb L, Casper M. Stagnating national declines in stroke mortality mask widespread county-level increases, 2010–2016. *Stroke* 2019; **50:** 3355–59.

26 Shah R, Wilkins E, Nichols M, et al. Epidemiology report: trends in sex-specific cerebrovascular disease mortality in Europe based on WHO mortality data. *Eur Heart J* 2019; **40:** 755–64.

27 Cabral NL, Freire AT, Conforto AB, et al. Increase of stroke incidence in young adults in a middle-income country: a 10-year population-based study. *Stroke* 2017; **48:** 2925–30.

28 Ekker MS, Verhoeven JI, Vaartjes I, van Nieuwenhuizen KM, Klijn CJM, de Leeuw F-E. Stroke incidence in young adults according to age, subtype, sex, and time trends. *Neurology* 2019; **92:** e2444–54.

29 Béjot Y, Delpont B, Giroud M. Rising stroke incidence in young adults: more epidemiological evidence, more questions to be answered. *J Am Heart Assoc* 2016; **5:** e003661.

30 Wang W, Jiang B, Sun H, et al. Prevalence, incidence, and mortality of stroke in china: results from a nationwide population-based survey of 480 687 adults. *Circulation* 2017; **135:** 759–71.

31 Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care* 2004; **27:** 1047–53.

32 Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014; **384:** 766–81.

33 Forouzanfar MH, Liu P, Roth GA, et al. Global burden of hypertension and systolic blood pressure of at least 110 to 115 mm Hg, 1990–2015. *JAMA* 2017; **317:** 165–82.

34 Muntner P, Hardy ST, Fine LJ, et al. Trends in blood pressure control among US adults with hypertension, 1999–2000 to 2017–2018. *JAMA* 2020; **324:** 1190–200.

35 Wang X, Cao Y, Hong D, et al. Ambient temperature and stroke occurrence: a systematic review and meta-analysis. *Int J Environ Res Public Health* 2016; **13:** 698.

36 Feigin VL, Roth GA, Naghavi M, et al. Global burden of stroke and risk factors in 188 countries, during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet Neurol* 2016; **15:** 913–24.

37 Omran AR. The epidemiologic transition: a theory of the epidemiology of population change. 1971. *Milbank Q* 2005; **83:** 731–57.

38 Brainin M, Sliwa K. WSO and WHF joint position statement on population-wide prevention strategies. *Lancet* 2020; **396:** 533–34.

39 Bertram MY, Sweeny K, Lauer JA, et al. Investing in non-communicable diseases: an estimation of the return on investment for prevention and treatment services. *Lancet* 2018; **391:** 2071–78.

40 Brainin M, Feigin VL, Norrving B, Martins SCO, Hankey GJ, Hachinski V. Global prevention of stroke and dementia: the WSO Declaration. *Lancet Neurol* 2020; **19:** 487–88.

41 Uthman OA, Hartley L, Rees K, Taylor F, Ebrahim S, Clarke A. Multiple risk factor interventions for primary prevention of CVD in LMIC: aCochrane review. *Glob Heart* 2017; **12:** 199–208.

42 Patomella A-H, Mickols G, Asaba E, et al. General practitioners' reasoning on risk screening and primary prevention of stroke - a focus group study. *BMC Fam Pract* 2018; **19:** 190.

43 Pandian JD, William AG, Kate MP, et al. Strategies to improve stroke care services in low- and middle-income countries: a systematic review. *Neuroepidemiology* 2017; **49:** 45–61.

44 Aguiar de Sousa D, von Martial R, Abilleira S, et al. Access to and delivery of acute ischaemic stroke treatments: a survey of national scientific societies and stroke experts in 44 European countries. *Eur Stroke J* **4:** 13–28.

45 Ullberg T, Glader EL, Zia E, Petersson J, Eriksson M, Norrving B. Associations between ischemic stroke follow-up, socioeconomic status, and adherence to secondary preventive drugs in southern Sweden: observations from the Swedish Stroke Register (Riksstroke). *Neuroepidemiology* 2017; **48:** 32–38.

46 Norrving B, Barrick J, Davalos A, et al. Action plan for stroke in Europe 2018–2030. *Eur Stroke J* 2018; **3:** 309–36.

47 Lindsay P, Furie KL, Davis SM, Donnan GA, Norrving B. World Stroke Organization global stroke services guidelines and action plan. *Int J Stroke* 2014; **9** (suppl A100): 4–13.

48 Martins SO, Mont'Alverne F, Rebello LC, et al. Thrombectomy for stroke in the public health care system of Brazil. *N Engl J Med* 2020; **382:** 2316–26.

49 Yan LL, Li C, Chen J, et al. Prevention, management, and rehabilitation of stroke in low- and middle-income countries. *eNeurologicalSci* 2016; **2:** 21–30.

50 Parke HL, Epiphaniou E, Pearce G, et al. Self-management support interventions for stroke survivors: a systematic meta-review. *PLoS One* 2015; **10:** e0131448-e.