

中国脑卒中及亚型疾病负担趋势分析与预测研究

李航¹, 冯梓柚², 张宇³, 张维⁴, 袁磊⁵, 朱梦兰³

1. 广州中医药大学第二附属医院胰胆肛肠科, 广东 广州 510120; 2. 广州中医药大学护理学院; 3. 中国人民解放军 32265 部队; 4. 广州中医药大学第二附属医院急诊科; 5. 海军军医大学卫生勤务学系健康管理学教研室

摘要:目的 分析中国脑卒中及亚型的疾病负担趋势。方法 基于全球疾病负担数据采用描述性统计分析、Joinpoint 回归模型来探究变化趋势, 并应用贝叶斯年龄-时期-队列模型预测至 2036 年的疾病负担。结果 1990—2021 年, 中国脑卒中发病人数增长 142.65%, 但标化发病率下降 9.78%, 死亡率下降 43.01%。亚型分析显示, 缺血性脑卒中发病率显著上升 35.72%, 而蛛网膜下腔出血死亡率降幅达 82.70%。2021 年男性发病率性别比升至 1.73, 女性 DALY 率降幅超男性 16 个百分点, 较 1990 年性别差异持续扩大。年龄分布呈现双峰特征, 75~79 岁人群发病率最高 (2 005.45/10 万), 55~59 岁人群标化 DALY 率降幅最大, 较 1990 年增加 57.61%。归因分析表明, 高收缩压仍为首要危险因素, 标化死亡率 77.73/10 万, 但低体力活动相关死亡率近 20 年激增 222.54%。预测至 2036 年, 女性脑卒中标化发病率较 2021 年将逆势上升 5.26%, 男性死亡率下降 16.69%, 性别差异进一步加剧。结论 中国脑卒中防控取得显著成效, 但人口老龄化与危险因素演变带来新挑战。需针对缺血性卒中增长、青年发病年轻化及性别差异制定精准干预策略, 强化空气污染控制与代谢综合征管理, 完善区域化三级防治网络。

关键词:脑卒中; 疾病负担; 趋势分析; 贝叶斯年龄-时期-队列模型

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Analysis and forecast study on the trends of stroke and its subtypes disease burden in China

LI Hang*, FENG Zi-you, ZHANG Yu, ZHANG Wei, YUAN Lei, ZHU Meng-lan

* Department of Pancreas and Anorectal Medicine, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, Guangdong 510120, China

Abstract: Objective To analyze the disease burden trends of stroke and its subtypes in China. **Methods** Using data from the Global Burden of Disease Study, descriptive statistical analysis and Joinpoint regression models were employed to examine trends from 1990 to 2021, while the Bayesian age-period-cohort (BAPC) model was applied to predict disease burden up to 2036. **Results** From 1990 to 2021, the number of stroke cases in China increased by 142.65%, yet the standardized incidence rate decreased by 9.78%, and the mortality rate dropped by 43.01%. Subtype analysis revealed a significant increase of 35.72% in the incidence of ischemic stroke, while the mortality rate from subarachnoid hemorrhage declined by 82.70%. In 2021, the male-to-female ratio of incidence rose to 1.73, and the decrease in the Disability-Adjusted Life Years (DALYs) rate was 16 percentage points higher for women than for men, indicating a widening gender disparity compared to 1990. The age distribution exhibited a bimodal pattern, with the highest incidence rate observed in the 75-79 age group (2 005.45 per 100 000), and the largest decrease in standardized DALYs occurred in the 55-59 age group, increasing by 57.61% compared to 1990. Attributable risk analysis showed that high systolic blood pressure remains the primary risk factor, with a standardized mortality rate of 77.73 per 100 000. However, deaths associated with low physical activity have surged by 222.54% in the past two decades. By 2036, it is predicted that the standardized incidence of stroke among women will increase by 5.26% compared to 2021, while the mortality rate among men will decrease by 16.69%, further exacerbating gender disparities. **Conclusion** While China has achieved progress in stroke prevention, challenges persist due to population aging and evolving risk factors. Targeted interventions addressing the rise of ischemic stroke, younger-onset cases, and gender disparities are urgently needed, alongside enhanced air pollution control, metabolic syndrome management, and regionalized

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作者简介: 李航(1997—), 男, 本科, 护理师, 研究方向: 临床护理、脑卒中

通信作者: 朱梦兰, E-mail: 18594930939@163.com

tertiary prevention networks.

Keywords: Stroke; Disease burden; Trend analysis; Prediction

脑卒中分为缺血性和出血性两种类型,是由于脑部血管狭窄、阻塞或破裂导致的脑血管病变,其主要临床特征为突然发生的神经功能障碍^[1-2]。脑卒中以其高发病率、高致残率、高致死率、复发风险高以及并发症多的特点,对中国而言构成了重大公共健康挑战^[3-4]。截至 2021 年,脑卒中是中国造成死亡的主要原因之一,标化死亡率达到 138.03/10 万人^[5],同时也是心血管病人群常见的合并症^[6]。随着人口老龄化的加剧、预期寿命的延长、城市化进程的加速,以及生活方式的变迁,加之医疗保健体系所遭遇的挑战,中国脑卒中的发病率呈现出明显的增长趋势^[7-8],且不同卒中亚型的差异加剧了中国的卒中负担复杂性^[9]。本研究通过识别和分析不同卒中亚型的流行病学特征,以期展示了我国脑卒中现状与防治重点。

1 资料与方法

1.1 数据来源 提取 2021 版全球疾病负担 (Global Burden of Disease, GBD) 数据库 (<https://vizhub.healthdata.org/gbd-results/>) 中国脑卒中疾病负担及危险因素相关数据。脑卒中相关的数据来源于全国卫生服务调查、死因监测系统、慢性病及其危险因素的监测项目,及已发表的学术文献和官方报告^[10]。研究对象为 ≥20 岁人群,按 5 岁年龄组分层;2022—2036 年分年龄/性别人口预测数据源自联合国《世界人口展望 2022》,标准人口结构采用 WHO 2000—2025 年全球标准人口^[11]。

1.2 观察指标 选取发病率、患病率、死亡率以及伤残调整寿命年 (Disability - Adjusted Life Years, DALY) 作为关键指标,并计算这些指标的 95% 不确定性区间 (Uncertainty Interval, UI)。DALY = 新发病例数 × 疾病严重程度权重 × 病程年数 + (预期寿命 -

死亡年龄)

1.3 统计学分析 使用 R 4.3.1 进行数据处理与统计分析。使用 Joinpoint 5.2.0 计算标化发病率与 DALY 率的平均年度变化百分比 (Average Annual Percentage Change, AAPC) 及分段年度百分比变化 (Annual Percentage Change, APC),检验标准为 $\alpha = 0.05$ ^[12]。构建贝叶斯年龄 - 时期 - 队列 (Bayesian Age - Period - Cohort, BAPC) 模型,预测 2022—2036 年 ≥20 岁人群脑卒中发病与死亡趋势。模型表达式:

$$\log_{\lambda_{ij}} = \alpha + \mu_i + \beta_j + \gamma_k$$

其中 α 为截距, μ_i 为年龄效应; β_j 为时期效应; γ_k 为队列效应^[13]。通过 R - INLA 包实现贝叶斯统计推断。参数估计的 95% 可信区间不包含零值,视为差异具有统计学意义。

2 结果

2.1 总体疾病负担与亚型差异 1990—2021 年,中国脑卒中发病人数增幅达 142.65%,标化发病率降幅为 9.78%。同期死亡人数增长 69.32%,但标化死亡率显著降低 43.01%。亚型分析显示,缺血性脑卒中标化发病率上升 35.72%,而蛛网膜下腔出血标化死亡率下降 82.70% (表 1)。

Joinpoint 回归分析表明,脑卒中标化发病率 AAPC 为 -0.37% (95% CI: -0.45% ~ -0.29%),其中缺血性脑卒中呈上升趋势,脑内出血和蛛网膜下腔出血呈下降趋势。脑卒中标化 DALY 率 AAPC 为 -1.93% (95% CI: -2.07% ~ -1.80%),其中蛛网膜下腔出血降速最快。分段分析显示,2004—2007 年为脑卒中标化 DALY 率下降最显著阶段 (APC = -5.44%, $P < 0.001$) (表 2, 图 1)。

表 1 1990—2021 年中国卒中及亚型疾病负担情况
Table 1 1990—2021 Burden of Stroke and Subtypes in China

类型	人数(95% UI) (万)			变化率(%)
	1990 年	2021 年		
发病				
脑卒中	168.58 (150.69 ~ 189.72)	409.05 (359.38 ~ 469.98)		142.65
缺血性脑卒中	76.12 (62.14 ~ 93.77)	277.21 (229.57 ~ 331.92)		264.17
脑内出血	77.40 (64.47 ~ 89.62)	117.33 (100.40 ~ 133.05)		51.59
蛛网膜下腔出血	15.06 (12.87 ~ 17.69)	14.51 (12.54 ~ 16.90)		-3.60
患病				
脑卒中	1 073.11 (1 000.31 ~ 1 154.26)	2 633.54 (2 415.5 ~ 2 862.56)		145.41
缺血性脑卒中	657.72 (587.54 ~ 726.24)	2 080.39 (1 861.59 ~ 2 299.55)		216.30
脑内出血	311.50 (276.43 ~ 351.83)	438.52 (389.21 ~ 490.66)		40.78

(续表)

类型	人数(95% UI) (万)		
	1990 年	2021 年	变化率(%)
蛛网膜下腔出血	110.45(96.17 ~ 124.26)	132.33(117.61 ~ 148.41)	19.80
DALY			
脑卒中	3 800.34(3 342.83 ~ 4 284.35)	5 319.07(4 510.87 ~ 6 195.8)	39.96
缺血性脑卒中	992.61(851.01 ~ 1 165.62)	2 343.04(1 991.89 ~ 2 693.39)	136.05
脑内出血	2 277.91(1 963.05 ~ 2 651.08)	2 746.37(2 283.92 ~ 3 267.67)	20.57
蛛网膜下腔出血	529.81(279.1 ~ 680.63)	229.65(172.74 ~ 284.74)	-56.65
死亡			
脑卒中	153.06(133.49 ~ 172.15)	259.16(217.94 ~ 303.27)	69.32
缺血性脑卒中	42.80(36.23 ~ 50.64)	117.70(98.69 ~ 137.27)	175.01
脑内出血	91.30(78.44 ~ 106.45)	132.29(110.8 ~ 156.77)	44.89
蛛网膜下腔出血	18.96(9.08 ~ 24.9)	9.18(6.67 ~ 11.62)	-51.58
类型	标准率(95% UI) (1/10 万)		
	1990 年	2021 年	变化率(%)
发病			
脑卒中	226.94(202.92 ~ 252.80)	204.75(181.03 ~ 231.50)	-9.78
缺血性脑卒中	100.05(81.52 ~ 120.91)	135.79(113.25 ~ 159.83)	35.72
脑内出血	108.93(91.66 ~ 124.93)	61.15(52.98 ~ 69.06)	-43.86
蛛网膜下腔出血	17.96(15.37 ~ 21.12)	7.81(6.88 ~ 8.95)	-56.51
患病			
脑卒中	1 167.42(1 082.04 ~ 1 262.59)	1 301.42(1 200.61 ~ 1 405.73)	11.48
缺血性脑卒中	759.20(675.25 ~ 850.31)	1 018.82(918.5 ~ 1 123.35)	34.20
脑内出血	308.41(274.49 ~ 348.29)	222.11(200.09 ~ 246.48)	-27.98
蛛网膜下腔出血	107.89(94.6 ~ 121.79)	68.88(61.53 ~ 76.90)	-36.16
DALY			
脑卒中	4 834.79(4 242.58 ~ 5 418.84)	2 648.02(2 253.39 ~ 3 076.95)	-45.23
缺血性脑卒中	1 387.93(1 188.74 ~ 1 621.40)	1 180.98(1 009.7 ~ 1 356.67)	-14.91
脑内出血	2 830.02(2 441.76 ~ 3 281.07)	1 351.55(1 129.11 ~ 1 600.86)	-52.24
蛛网膜下腔出血	616.84(315.45 ~ 799.17)	115.49(86.86 ~ 142.50)	-81.28
死亡			
脑卒中	242.18(213.83 ~ 272.66)	138.03(116.69 ~ 160.32)	-43.01
缺血性脑卒中	75.22(64.48 ~ 88.23)	64.47(54.03 ~ 74.82)	-14.29
脑内出血	139.67(121.09 ~ 162.03)	68.84(57.61 ~ 81.17)	-50.71
蛛网膜下腔出血	27.29(12.81 ~ 36.07)	4.72(3.45 ~ 5.95)	-82.70

注: DALY; 伤残调整寿命年。

表 2 1990—2021 年脑卒中及亚型平均年度变化(%)

Table 2 Average Annual Percentage Change in Stroke and Subtypes from 1990 to 2021 (%)

类别	时间	标化发病率(95% CI)	时间	标化 DALY 率(95% CI)	
脑卒中	APC	1990—1995	0.94(0.79 ~ 1.10) ^a	1990—1998	-1.48(-1.60 ~ -1.35) ^a
	APC	1995—2000	-0.77(-0.98 ~ -0.57) ^a	1998—2004	0.27(0.07 ~ 0.48) ^a
		2000—2006	-0.14(-0.29 ~ 0.01)	2004—2007	-5.44(-6.20 ~ -4.68) ^a
		2006—2014	-1.90(-1.99 ~ -1.81) ^a	2007—2010	-1.69(-2.56 ~ -0.82) ^a
		2014—2019	1.44(1.21 ~ 1.67) ^a	2010—2015	-3.64(-3.97 ~ -3.31) ^a
		2019—2021	-1.61(-2.38 ~ -0.84) ^a	2015—2021	-1.61(-1.88 ~ -1.34) ^a
	AAPC		-0.37(-0.45 ~ -0.29) ^a		-1.93(-2.07 ~ -1.80) ^a
缺血性卒中	APC	1990—1994	1.66(1.37 ~ 1.94) ^a	1990—1998	-0.37(-0.57 ~ -0.18) ^a
		1994—2000	0.31(0.12 ~ 0.49) ^a	1998—2004	2.18(1.90 ~ 2.47) ^a
		2000—2007	1.65(1.51 ~ 1.80) ^a	2004—2007	-4.10(-5.11 ~ -3.08) ^a
		2007—2015	0.18(0.07 ~ 0.29) ^a	2007—2010	0.29(-0.88 ~ 1.48)
		2015—2019	2.44(2.04 ~ 2.84) ^a	2010—2015	-1.85(-2.28 ~ -1.41) ^a
		2019—2021	-0.54(-1.34 ~ 0.26)	2015—2021	-0.88(-1.19 ~ -0.57) ^a
	AAPC		0.97(0.88 ~ 1.06) ^a		-0.53(-0.70 ~ -0.35) ^a
脑内出血	APC	1990—1995	0.36(0.17 ~ 0.55) ^a	1990—1998	-1.53(-1.69 ~ -1.37) ^a
		1995—2005	-0.98(-1.06 ~ -0.91) ^a	1998—2004	0.95(0.72 ~ 1.19) ^a
		2005—2014	-4.71(-4.79 ~ -4.63) ^a	2004—2007	-6.01(-6.72 ~ -5.29) ^a

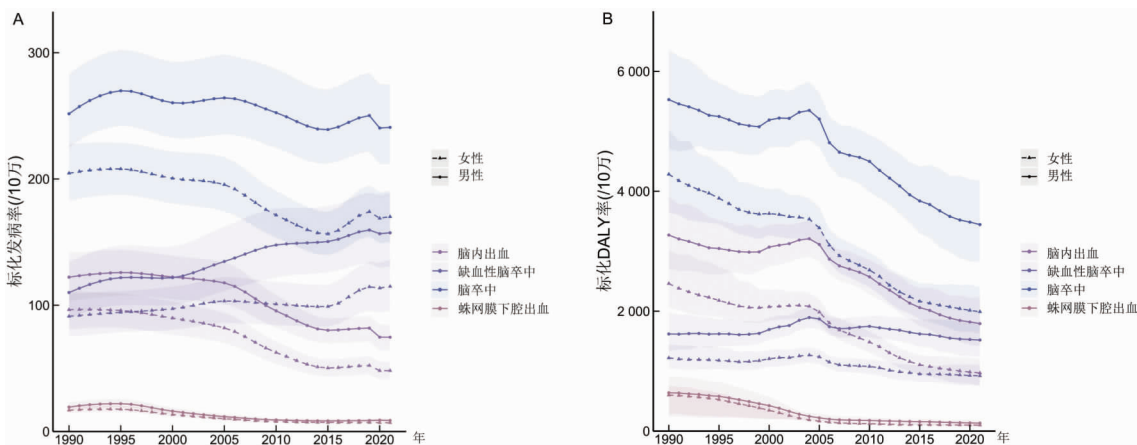
(续表)

类别	时间	标化发病率(95% CI)	时间	标化 DALY 率(95% CI)
蛛网膜下腔出血	2014—2019	0.25(0.02~0.48) ^a	2007—2010	-2.91(-3.74~-2.07) ^a
	2019—2021	-4.52(-5.25~-3.79) ^a	2010—2015	-5.04(-5.36~-4.73) ^a
	AAPC	-1.90(-1.97~-1.83) ^a	2015—2021	-2.23(-2.51~-1.95) ^a
	APC 1990—1993	2.92(2.01~3.84) ^a	1990—1995	-2.21(-3.22~-1.20) ^a
	APC 1993—1996	-0.45(-2.07~1.20)	1995—2000	-6.83(-8.04~-5.60) ^a
	APC 1996—2001	-6.71(-7.19~-6.23) ^a	2000—2004	-14.18(-15.25~-13.09) ^a
	APC 2001—2009	-5.57(-5.77~-5.37) ^a	2004—2007	-9.52(-11.22~-7.80) ^a
	APC 2009—2014	-2.28(-2.74~-1.81) ^a	2007—2021	-2.24(-2.36~-2.13) ^a
	2014—2021	0.31(0.11~0.51) ^a		
	AAPC	-2.63(-2.83~-2.43) ^a		-5.32(-5.64~-5.00) ^a

注:a: P<0.05;APC 为年度变化百分比;AAPC 为平均年度变化百分比。

2.2 性别与年龄分布特征 1990—2021 年期间,男性脑卒中标准化发病率始终高于女性,2021 年性别比升至 1.73。女性标化 DALY 率降幅达 53.52%,显著高于男性的 37.69%。亚型层面,男性缺血性脑卒中标准化发病率增幅为 42.99%,较女性高 17.04 个百分

点;蛛网膜下腔出血标化 DALY 率在男女性别中分别下降 79.13% 和 83.41% (图 1)。2021 年 75~79 岁人群脑卒中标准化发病率达 2 005.45/10 万,较 1990 年增长 5.87%;55~59 岁人群标化 DALY 率降幅最大(57.61%),提示中年干预成效显著(图 2)。



注: DALY: 伤残调整寿命年。

图 1 1990—2021 年中国脑卒中标准化发病率(A)和 DALY 率(B)变化趋势

Fig. 1 The trends in the standardized incidence rate (A) and DALY rate (B) of stroke in China from 1990 to 2021

2.3 1990—2021 年中国脑卒中相关风险因素的变化趋势 与 1990 年相比,2021 年脑卒中主要归因风险仍为高血压,标化死亡率 77.73/10 万,但其贡献度降低 33.57%。值得注意的是,低体力活动相关标化死亡率增长 222.54%,成为上升最快的风险因素(图 3A)。DALY 率分析显示,空气污染相关标化 DALY 率下降 65.02%,而高体质指数相关 DALY 率上升 50.62%(图 3B)。

2.4 2022—2036 年脑卒中发病和死亡趋势预测 BAPC 模型预测结果显示,2022—2036 年,中国脑卒中发病率和死亡率呈现明显的性别差异,男性的标化发病率将下降到 235.41/10 万人,下降幅度为 3.69%,而女性的标化发病率预计上升至 184.75/10

万人,增长 5.26%;男性标化死亡率下降至 163.82/10 万人,降低 16.69%,女性的标化死亡率下降到 80.22/10 万人,降低 22.79%。亚型预测表明,至 2036 年,男性缺血性脑卒中标准化发病率比 2021 年下降 16.69%;而女性则上升 19.49%;脑出血与蛛网膜下腔出血病发病率性别差异显著,男性分别下降 18.98% 和 32.18%,女性降幅为 24.17% 和 5.11%(图 4)。

3 讨论

3.1 1990—2021 年中国卒中及亚型疾病负担趋势 本研究揭示 1990—2021 年中国脑卒中呈现“总量上升、标化率下降”的双重特征,这一矛盾现象与全球老

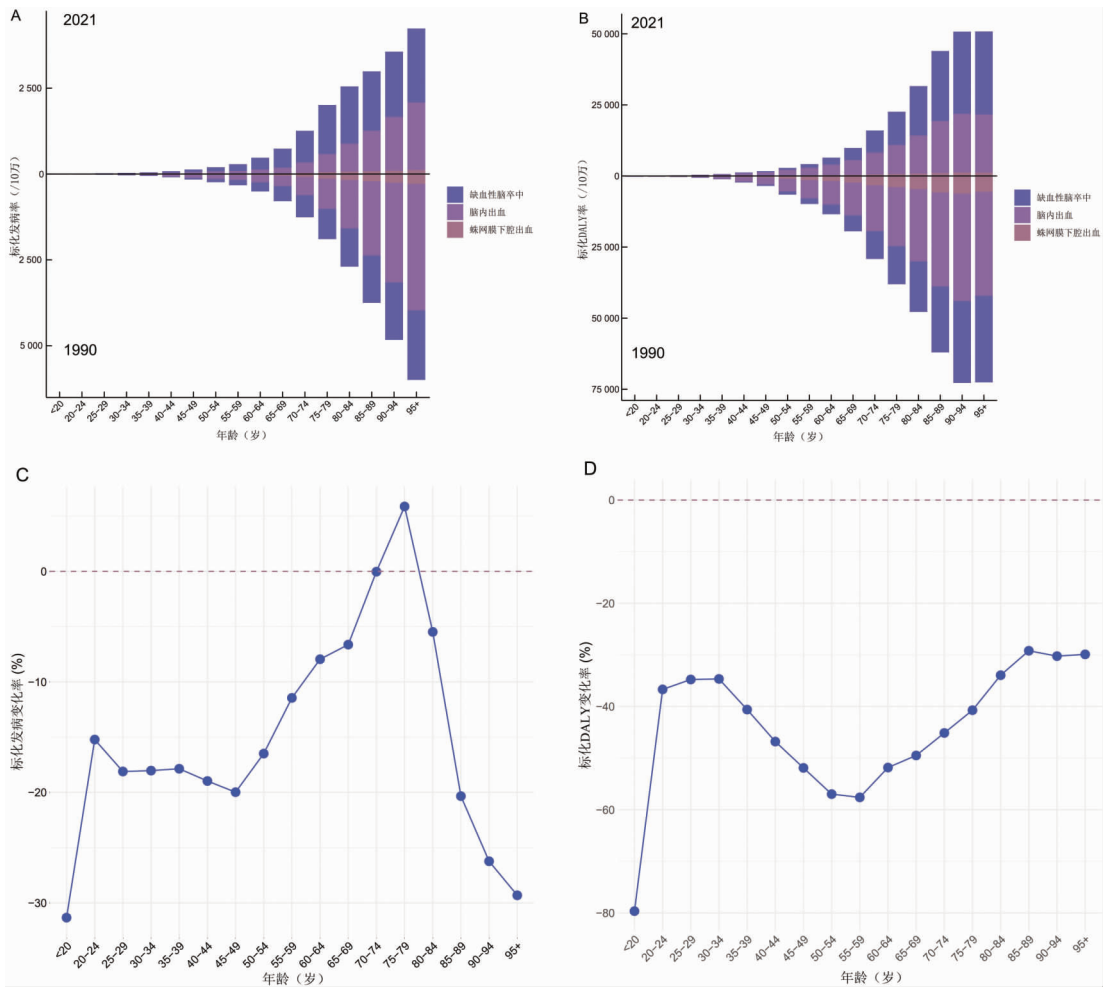
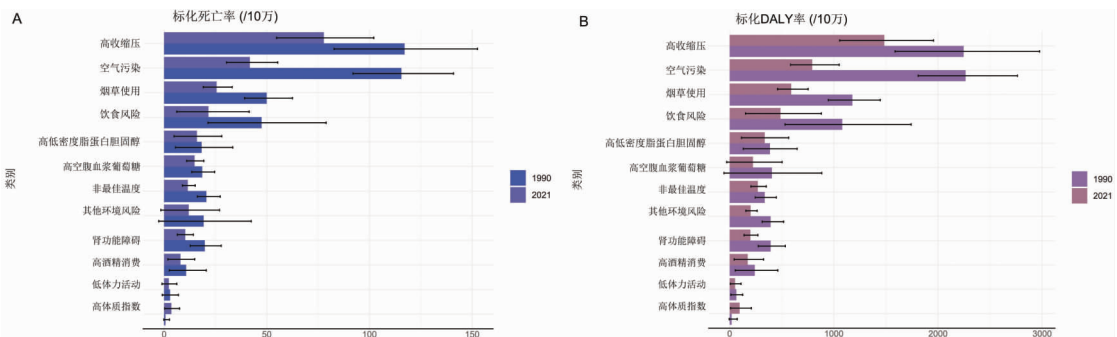


图 2 1990 年和 2021 年各年龄段发病率和标准化 DALY 率

Fig. 2 The incidence rates and standardized DALY rates for each age group in 1990 and 2021



注: DALY 为伤残调整寿命年。

图 3 1990 年和 2021 相关危险因素所致的标准化死亡率(A)和 DALY 率(B)

Fig. 3 The standardized mortality rate (A) and DALY rate (B) due to related risk factors in 1990 and 2021

龄化社会疾病负担演变规律一致^[14]。可能源于三重驱动机制:人口老龄化导致高危人群基数扩大;诊疗技术革新提升疾病检出灵敏度;三级预防体系降低年龄特异性风险^[15-16]。值得注意的是,缺血性脑卒中发病人数和标化发病率均上升;脑内出血和蛛网膜下腔出血均下降,提示需制定亚型特异性防控策略。缺

血性脑卒中发病率和死亡率随年龄增长而上升,但晚出生队列的风险较低^[17]。预测模型显示,除女性标化发病率外,其他指标均显著下降,提示健康政策和医疗服务改善的积极作用^[18]。

3.2 疾病负担的人群分布特征 脑卒中疾病负担存在显著的人口学梯度差异体现在两个方面。性别差

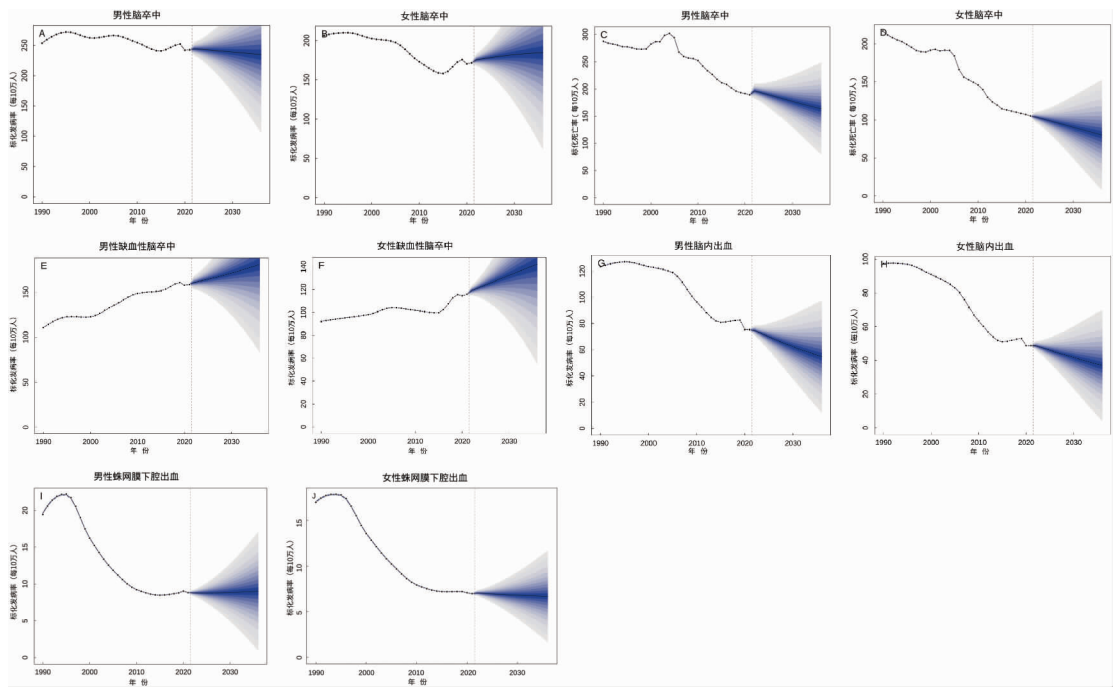


图 4 2022—2036 年脑卒中发病和死亡趋势预测

Fig. 4 Predicted Trends in Stroke Incidence and Mortality from 2022 to 2036

异持续扩大,女性卒中风险随生命周期变化,年轻女性风险较高,中年降低,老年再次升高。女性 DALY 下降速率较男性快,可能与雌激素神经保护作用及男性吸烟暴露率更高相关^[19];年龄结构年轻化:20~59 岁组发病率年均下降 0.7%,但绝对病例数增长 35%,反映人口结构转型与危险因素年轻化叠加效应^[20]。40 岁以下患者占比已达 12.4%,远高于美国的 7.9%,且该群体中代谢综合征患病率显著高于老年组^[21]。

3.3 危险因素演变 中国脑卒中归因危险谱呈现“传统-新兴”双驱动特征:高收缩压、吸烟仍为最主要危险因素,但空气污染和饮食的影响强度持续上升^[22]。全球 77% 的卒中幸存者患有高血压,其中 1/3 未得到有效控制^[23]。中国自 2007 年起实施多项慢性病防控计划,逐渐改善高血压筛查和管理^[24]。烟草使用通过尼古丁和一氧化碳等成分加剧脑血管病变^[25]。PM_{2.5} 暴露与缺血性卒中的关联已在多中心研究中验证^[26]。我国钠摄入量仍超 WHO 标准的 2.1 倍,但尿钠/钾比下降提示干预措施初见成效^[27-28]。

3.4 精准防控的技术突破 近年卒中防治呈现三大技术革新:治疗时间窗拓展,血管内取栓联合替奈普酶将再通时间窗延长至 24 小时,并降低残疾率^[29];监测技术革新,可穿戴设备使房颤检出率提升 3.2 倍,对应卒中风险下降 29%^[30-31];风险预测升级,基于机器学习的多模态模型(整合腰围/身高比+动态

血压+焦虑量表)较传统 Framingham 评分提升预测效能^[32-34]。

3.5 研究局限性 本研究空间异质性分析不足,未量化医疗资源可及性对区域差异的影响,此外新兴危险因素未纳入分析。未来研究应构建“环境-临床-社会”多维度监测体系,重点评估分级诊疗政策对疾病负担的影响。

利益冲突声明 本研究不存在任何利益冲突

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