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在线全文

1990–2021年糖尿病肾病的全球、区域及国家和地区负担分析*

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【摘要】 目的 基于全球疾病负担（Global Burden of Diseases, GBD）2021数据，系统分析了1990–2021年全球204个国家和地区糖尿病肾病（diabetic kidney disease, DKD）的疾病负担趋势及未来十年预测。**方法** GBD 1990–2021年DKD数据，采用年龄标准化率（age-standardized rates, ASRs）和平均年度百分比变化（average annual percentage change, AAPC）分析趋势，运用联结点回归模型（Joinpoint regression model, JRM）识别转折点，自回归积分移动平均模型（autoregressive integrated moving average, ARIMA）预测未来趋势，R软件实现统计分析。**结果** 1990–2021年全球DKD年龄标准化发病率（age-standardized incidence rate, ASIR）、年龄标准化死亡率（age-standardized death rate, ASDR）呈显著上升，累计分别上升55.0%〔95%置信区间（confidence interval, CI）：42.3%～69.8%，*P*<0.001〕、57.3%（95%CI：43.1%～73.5%，*P*<0.001）；年龄标准化患病率（age-standardized prevalence rate, ASPR）累计下降37.5%（95%CI：－45.2%～－28.8%，*P*<0.001）；年龄标准化伤残调整寿命年（age-standardized disability-adjusted life years, DALYs）率累计上升56.2%（95%CI：42.8%～71.5%，*P*<0.001）。国家和地区间负担差异显著，格陵兰ASPR上升幅度最大，英国ASPR降幅最大；爱沙尼亚ASIR增幅最高，爱尔兰ASIR降幅最大；美国ASDR上升最显著，马尔代夫ASDR下降最明显。东亚现患病例数最多，南亚新发病例与DALYs负担最重，低社会人口指数（socio-demographic index, SDI）地区上升更显著。未来十年（2022–2031年）预测显示，全球DKD ASPR年均上升0.45%（95%CI：0.21%～0.69%），ASIR年均下降0.23%（95%CI：－0.47%～－0.01%），年龄标准化DALYs率年均上升1.12%（95%CI：0.89%～1.35%），疾病总负担仍将持续加重。**结论** 全球DKD疾病负担日益加重，低SDI地区尤为显著，亟需在高负担区域采取精准防控措施，为公共卫生资源配置提供科学依据。

【关键词】 糖尿病肾病 伤残调整寿命年 疾病负担 社会人口指数 年龄标准化率

Burden of Diabetic Kidney Disease at Global, Regional, and National Levels From 1990 to 2021

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[Abstract] Objective Based on the Global Burden of Diseases (GBD) 2021 data, this study systematically analyzed the trends in the disease burden of diabetic kidney disease (DKD) and predicted its burden over the next decade in 204 countries and regions worldwide from 1990 to 2021. **Methods** Data on DKD from the GBD study spanning 1990 to 2021 were analyzed for trends using age-standardized rates (ASRs) and average annual percentage change (AAPC). The Joinpoint Regression Model (JRM) was applied to identify turning points, and the Autoregressive Integrated Moving Average (ARIMA) model was used to forecast future trends. Statistical analysis was performed using R software. **Results** The age-standardized incidence rate (ASIR) and age-standardized death rate (ASDR) of global DKD from 1990 to 2021 showed substantial increases, with cumulative rises of 55.0% (95% CI: 42.3% to 69.8%, $P < 0.001$) and 57.3% (95% CI: 43.1% to 73.5%, $P < 0.001$), respectively. The age-standardized prevalence rate (ASPR) declined by 37.5% (95% CI: —45.2% to —28.8%, $P < 0.001$), while the age-standardized disability-adjusted life years (DALYs) rate rose by 56.2% (95% CI: 42.8% to 71.5%, $P < 0.001$). Noticeable disparities in disease burden were observed among countries and regions. Greenland experienced the largest increase in ASPR, whereas the United Kingdom had the most substantial decrease. Estonia had the highest rise in ASIR, while Ireland saw the greatest decline. The United States had the most pronounced increase in ASDR, while the Maldives had the largest decrease. East Asia had the highest number of current cases, while South Asia bore the heaviest burden of new cases and DALYs. The increase was more prominent in regions

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with a low socio-demographic index (SDI). Projections for the next decade (2022–2031) indicate that the global ASPR of DKD will increase by an average of 0.45% per year (95% CI: 0.21% to 0.69%), the ASIR will decrease by an average of 0.23% per year (95% CI: −0.47% to −0.01%), and the age-standardized DALYs rate will increase by an average of 1.12% per year (95% CI: 0.89% to 1.35%). The overall burden of the disease is expected to continue growing. **Conclusion** The global burden of DKD is steadily increasing, and it is especially severe in regions with low SDI. It is essential to implement targeted prevention and control measures in high-burden areas to provide a scientific basis for allocating public health resources.

[Key words] Diabetic kidney disease　Disability-adjusted life years　Disease burden　Socio-demographic index　Age-standardized rates

糖尿病肾病(diabetic kidney disease, DKD)是以蛋白尿和肾功能下降为主要特征的糖尿病微血管并发症, 可进展至终末期肾病(end-stage renal disease, ESRD)[1]。2021年全球糖尿病患者已达8.4亿, 其中DKD患者人数超3.36亿[2]。其发病涉及血流动力学、代谢和炎症机制[3], 现有治疗仍无法有效阻断进展[4]。随着全球糖尿病患者预计增长50%[5], DKD的疾病负担将持续加重, 进而显著增加ESRD及死亡风险[6]。基于全球疾病负担(Global Burden of Diseases, GBD)2021数据的时间趋势分析有助于揭示DKD的流行病学特征变化。GBD研究是全球最全面的健康损失评估体系, 整合人口登记、普查等100 983个数据源[7], 针对371种疾病估算伤残生存年(years lived with disability, YLDs)、过早死亡损失年(years of life lost, YLLs)、伤残调整寿命年(disability-adjusted life years, DALYs)和健康期望寿命(healthy life expectancy, HALE)等指标[8]。采用世界银行首创的DALYs作为核心评估标准, GBD 2021提供了跨时期、年龄、性别和地域的疾病负担数据, 是目前最权威的全球疾病负担研究[9]。

综上所述, GBD 2021作为最大规模的全球流行病学研究, 通过多维评估371种疾病负担, 为分析DKD流行病学特征提供契机。本研究基于1990–2021年204个国家和地区数据, 系统分析DKD疾病负担的年龄、性别差异, 以及DKD疾病负担与社会人口指数(socio-demographic index, SDI)的相关性, 旨在揭示疾病流行趋势, 为防控策略制定提供科学依据。

1　资料与方法

1.1　数据来源

本研究数据来源于GBD数据库(1990–2021年), GBD数据库整合了全球204个国家和地区的流行病学数据, 包括人口登记、医院记录、学术研究等100 983个数据源。GBD采用标准化方法对数据进行清洗和校正, 包括异常值处理、缺失数据插补以及一致性校验, 以减少偏差。研究分析纳入所有1型与2型DKD患者。排除标准: 已接受透析或肾移植治疗的患者。本研究采用的DKD伤残权重(DWs=0.183)经验证适用于未接受透析/肾移植的DKD患者, 故直接沿用。

①诊断代码依据: 基于国际疾病分类第十版(ICD-10)代码E11.2-E11.298提取DKD患者数据, 该代码涵盖糖尿病合并肾脏病变的诊断。特殊情况处理: 由于DKD缺乏特异性诊断词条, GBD数据库通过糖尿病(如E11.9)(包括1型和2型)与合并蛋白尿(如N34.3)、肾功能下降(如N18.9)等相关诊断词条进行综合判定。对于同时存在糖尿病和蛋白尿诊断的患者, 若符合ICD-10编码逻辑, 则纳入DKD患者队列。

②人口学特征(性别/年龄/204个国家和地区/21个GBD区域/SDI五分组)。

③疾病负担指标〔患病率/发病率/DALYs及其年龄标准化率(age-standardized rates, ASRs)〕〔年龄标准化患病率(age-standardized prevalence rate, ASPR)/年龄标准化发病率(age-standardized incidence rate, ASIR)/年龄标准化死亡率(age-standardized death rate, ASDR)〕。SDI(0 ~ 1分)综合反映地区社会经济状况, 按值分为高、中高、中、中低和低五组。ASRs确保不同人口结构间的可比性。

④在研究中, 具体的排除标准是通过筛选医疗记录来确定哪些患者已接受透析或肾移植。研究团队会利用GBD数据库中相关的治疗记录和疾病编码, 明确标记出所有接受透析或肾移植的患者, 并在数据清理过程中将这些患者排除, 以确保最终分析的数据集仅包括未进展到透析或肾移植的1型和2型DKD患者。

1.2　计算公式

DALYs=YLLs+YLDs, YLLs=∑(某年龄组死亡人数×该年龄组剩余期望寿命), 期望寿命采用GBD 2021全球人口生命表参数; YLDs=∑(DWs×患病人数), 本研究DKD的DWs=0.183〔95%置信区间(confidence interval, CI): 0.156 ~ 0.210〕。DWs表示某疾病导致的健康损失程度(取值范围 0 ~ 1, 0为完全健康, 1为死亡), 该DWs(0.183)为GBD 2021针对DKD制定的专属标准化赋值, 其设置结

合了DKD不同病程阶段的临床伤残表现，是计算YLDs的核心参数，本研究严格沿用该赋值标准，未进行自主调整。

ASRs：通过人口年龄结构标准化处理，消除不同地区人口结构差异对疾病率的影响。

粗发病率（AR）：AR=新发病例数/研究人口数；粗患病率（PR）：PR=现患病例数/研究人口数；粗死亡率（DR）：DR=死亡病例数/研究人口数；平均年度百分比变化（average annual percent change, AAPC）：AAPC=100×(exp[β]−1)（β为Joinpoint回归模型整体趋势回归系数），累计变化率基于AAPC计算，公式为：累计变化率（%）=100×[(1+AAPC/100)^n−1]，其中n为研究年数（1990–2021年，n=31）。

1.3 数据模型

本研究未人工预设拐点数量，采用联结点回归模型（Joinpoint regression model, JRM）识别疾病负担趋势的转折点，适合分析非线性的时间变化。本研究旨在捕捉1990–2021年间DKD负担的阶段性变化（如ASPR下降的拐点），采用JRM拟合1990–2021年DKD年龄标准化率的时间序列趋势模型（以α=0.05为检验水准），基于数据自身趋势特征自动拟合识别趋势转折点的数量与位置，并计算各阶段的AAPC（拐点间的局部变化趋势），同时计算研究周期内的AAPC（全研究周期整体变化趋势）及95%CI，AAPC计算公式见1.2，以反映指标的长期整体变化趋势。自回归积分移动平均（autoregressive integrated moving average, ARIMA）（p, d, q）模型适用于时间序列预测，尤其当数据具有明显趋势或季节性，其中p为自回归阶数、d为差分阶数、q为移动平均阶数。本研究通过赤池信息准则（AIC）/贝叶斯信息准则（BIC）最小化原则优化模型参数，结合白噪声检验验证残差随机性（确保符合平稳性要求），最终确定最优模型阶数为ARIMA（1, 1, 0）。

同时，本研究开展DKD疾病负担的空间分析以揭示其地理分布特征与空间异质性，先构建Queen邻接矩阵定义全球204个国家和地区的空间关联关系，对无共享边界/顶点的岛国，采用空间距离阈值法补充界定空间相邻关系，量化地理层面的相互关联；再将GBD数据库提取的DKD疾病负担指标（1990年、2021年ASPR/ASIR/ASDR及1990–2021年AAPC值）与全球地理空间地图数据进行匹配整合；最后基于R软件ggplot2包绘制疾病率空间分布专题图及AAPC时间趋势空间分布图，结合各区域AAPC极值分布特征，分析DKD负担的空间分布规律与区域变化差异。

2 结果

2.1 DKD在全球层面上的相关数据获取

基于2021年GBD数据库，分析1990–2021年全球DKD ASPR、ASIR和年龄标准化DALYs率数据。采用广义线性回归模型（lnR=α+βT+ϵ）计算AAPC，并统计全球、SDI分区及21个GBD分区1990与2021年的疾病负担指标，详见网络资源附件附表1。

2.2 1990–2021年DKD全球负担的时间变化趋势及年龄分布特征

1990–2021年全球DKD的ASPR、ASIR和年龄标准化DALYs率见网络资源附件附图1。采用JRM分析1990–2021年全球DKD年龄标准化率的时间变化趋势，结果显示（表1）：ASIR、ASDR及年龄标准化DALYs率均呈显著上升趋势（均P<0.001），而ASPR则显著下降。JRM自动识别出全球DKD ASIR、ASPR、ASDR的趋势拐点数量分别为4个、5个、6个（图1）。1990–2021年全球DKD数据显示：患病人数、新发病例数、DALYs均持续增长（网络资源附件附图2），但ASPR呈下降趋势，而ASIR和年龄标准化DALYs率则保持上升（图2）。

表 1 1990–2021年中国与全球DKD疾病负担趋势

Table 1 Trend of global and Chinese disease burden of DKD from 1990 to 2021

Indicator	Group	1990 (95% CI)	2021 (95% CI)	AAPC (95% CI)/%	Cumulative change/%	P
Age-standardized incidence rate/per 100 000 person-years	Global	32.6 (31.2-34.0)	50.5 (48.9-52.1)	1.42 (1.10-1.74)	↑ 55.0	< 0.001
	China	35.8 (34.2-37.4)	56.9 (55.1-58.7)	1.58 (1.25-1.91)	↑ 58.9	< 0.001
Age-standardized prevalence rate/per 100 000	Global	1 258.3 (1 210.5-1 306.1)	789.6 (756.8-822.4)	−1.46 (−1.78-−1.14)	↓ 37.5	< 0.001
	China	1 325.6 (1 276.8-1 374.4)	812.3 (778.5-846.1)	−1.38 (−1.70-−1.06)	↓ 38.7	< 0.001
Age-standardized death rate/per 100 000 person-years	Global	5.8 (5.5-6.1)	9.1 (8.7-9.5)	1.53 (1.21-1.85)	↑ 57.3	< 0.001
	China	6.2 (5.8-6.6)	9.8 (9.3-10.3)	1.61 (1.28-1.94)	↑ 58.1	< 0.001
Age-standardized YLLs rate/per 100 000 person-years	Global	132.5 (128.9-136.1)	210.8 (206.9-214.7)	1.49 (1.17-1.81)	↑ 56.2	< 0.001
	China	139.6 (135.8-143.4)	228.7 (224.5-232.9)	1.67 (1.34-2.00)	↑ 62.7	< 0.001
Age-standardized YLDs rate/per 100 000 person-years	Global	50.7 (48.2-53.2)	75.3 (72.1-78.5)	1.49 (1.17-1.81)	↑ 56.2	< 0.001
	China	56.9 (53.5-60.3)	91.1 (87.6-94.6)	1.67 (1.34-2.00)	↑ 62.7	< 0.001
Age-standardized DALYs rate/per 100 000 person-years	Global	183.2 (178.9-187.5)	286.1 (281.8-290.4)	1.49 (1.17-1.81)	↑ 56.2	< 0.001
	China	196.5 (192.2-200.8)	319.8 (314.5-325.1)	1.67 (1.34-2.00)	↑ 62.7	< 0.001

YLLs: years of life lost; YLDs: years lived with disability; DALYs: disability-adjusted life years; AAPC: average annual percent change.

以GBD 2021标准化伤残权重(DWs=0.183)计算的YLDs为核心组分, 全球DKD年龄标准化DALYs率显著上升, 且40岁及以上人群的ASIR、ASDR及年龄标准化DALYs率上升更明显; 年龄组分析显示, 40 ~ 59岁ASIR的AAPC为1.68%(95%CI: 1.35% ~ 2.01%), ≥60岁ASIR的AAPC为1.92%(95%CI: 1.58% ~ 2.26%), 61 ~ 80岁ASPR的AAPC为−1.85%(95%CI: −2.17% ~ −1.53%), 均P<0.001。

2.3　1990–2021年DKD在21个GBD区域的负担与SDI的关联

本研究分析发现21个GBD区域的DKD年龄标准化率AAPC存在显著区域异质性(图3, 网络资源附件附图3和附图4)。东非撒哈拉非洲地区年龄标准化DALYs率下降与ASDR显著降低相关, 提示死亡负担减轻是其疾病负担下降的主要原因。表2显示高收入北美地区ASPR上升、

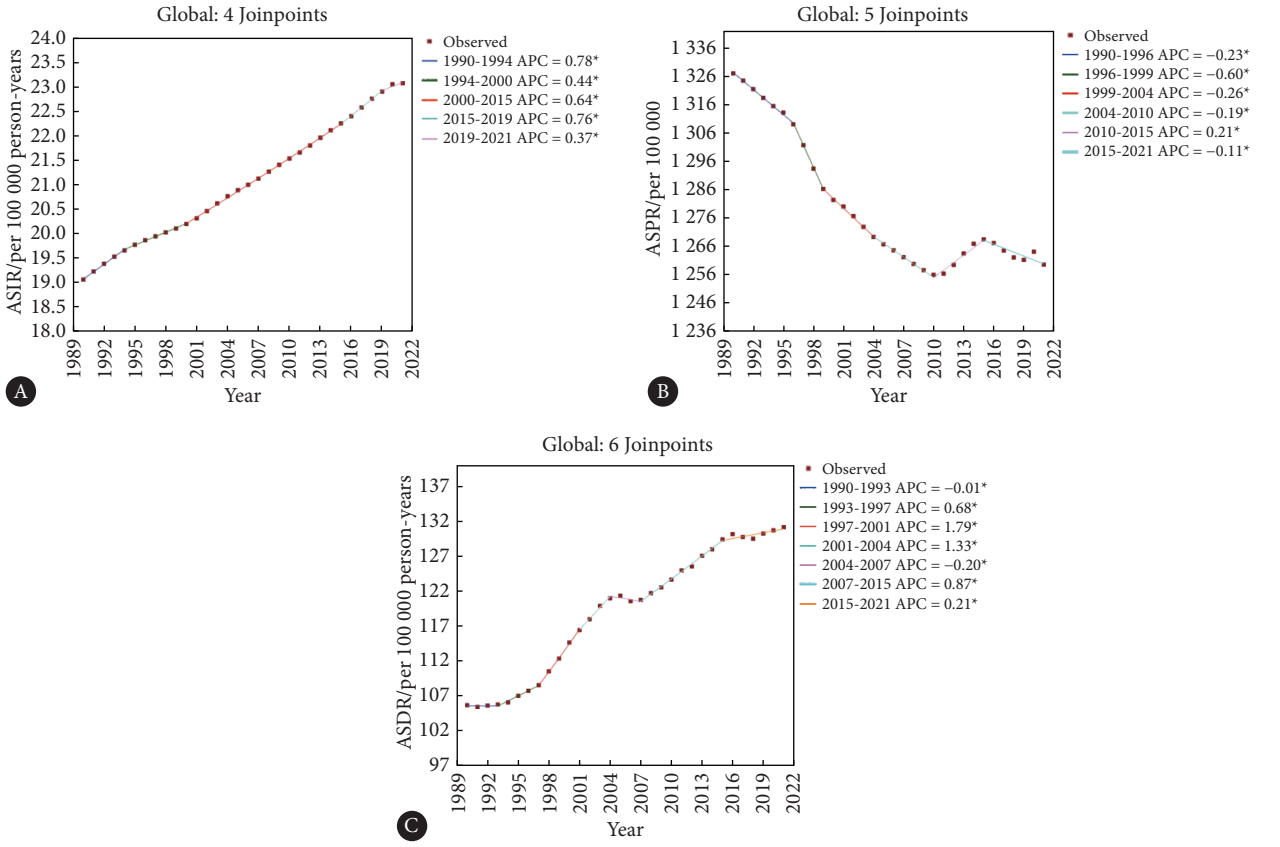


图 1　1990–2021年全球DKD年龄标准化发病率、患病率、死亡率联结点回归模型（JRM）趋势

Fig 1　Trends of age-standardized incidence rate (ASIR), age-standardized prevalence rate (ASPR), and age-standardized death rate (ASDR) of DKD worldwide from 1990 to 2021 using the Joint Regression Model (JRM)

Different colored lines represent the annual percent change (APC) trends in different stages. * P<0.05, indicates the statistical significance of the APC trend in each stage. A, JRM trend of ASIR with 4 inflection points; B, JRM trend of ASPR with 5 inflection points; C, JRM trend of ASDR with 6 inflection points.

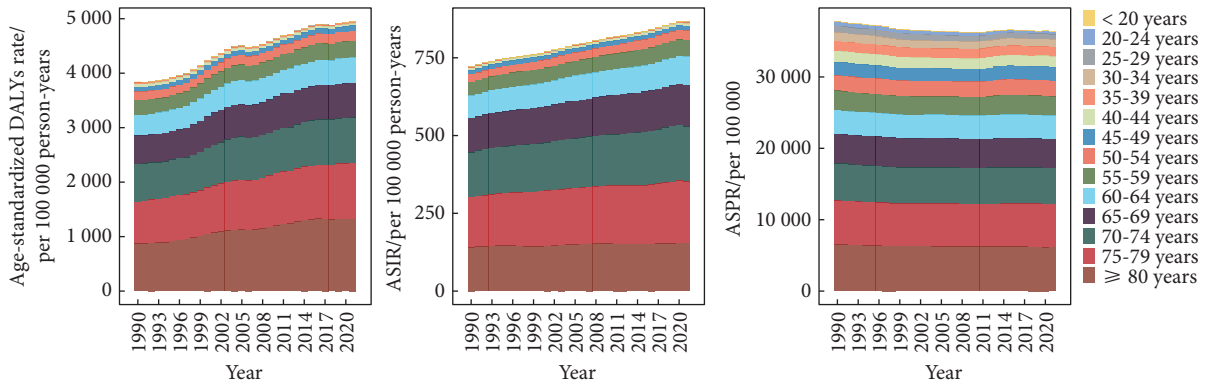


图 2　1990–2021年全球DKD的年龄标准化DALYs率、发病率和患病率

Fig 2　Age-standardized DALYs rate, age-standardized incidence rate (ASIR), and age-standardized prevalence rate (ASPR) of DKD worldwide from 1990 to 2021

高收入亚太地区ASPR下降，安第斯拉丁美洲ASIR增幅最大，低收入北美地区ASDR大幅上升，而东撒哈拉非洲地区ASDR明显下降；表3则表明2021年南亚DKD年龄标准化DALYs率及全球占比最高、负担最重，东亚现患规模最大，安第斯拉丁美洲年龄标准化DALYs率增幅最突出，仅东撒哈拉非洲地区DALYs负担呈下降趋势，整体区域疾病负担异质性突出。

研究通过Spearman相关性分析(|cor|>0.3，P<0.05)对1990–2021年21个GBD区域DKD与SDI的关联进行展示：ASPR与SDI呈负相关(r=—0.375，95%CI：—0.652～—0.098，P=0.012)；ASIR与SDI呈正相关(r=0.550，95%CI：0.283～0.751，P<0.001)；ASDR与SDI呈负相关(r=—0.573，

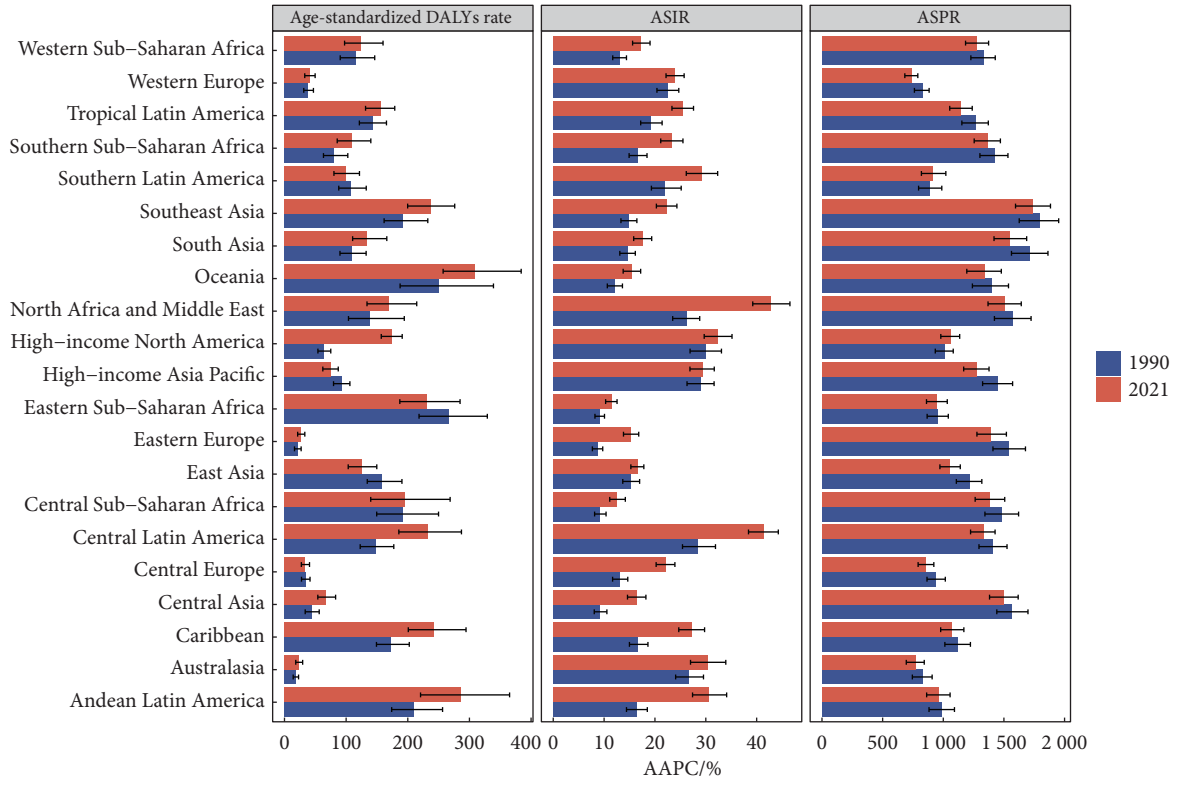


图 3 1990年和2021年在21个GBD区域的年龄标准化患病率、发病率和DALYs率AAPC的分布

Fig 3 Distribution of AAPC for age-standardized prevalence rate (ASPR), age-standardized incidence rate (ASIR), and age-standardized DALYs rate of DKD in 21 GBD regions, 1990 and 2021

表 2 部分GBD区域DKD主要指标变化趋势

Table 2 Trends in major indicators of DDKD in selected GBD regions

Indicator	Region	AAPC (95% CI)/%	Cumulative change/%	P
ASPR	High-income North America	0.35 (0.12-0.58)	↑ 11.8 (3.8-20.7)	0.003
ASPR	High-income Asia Pacific	—0.47 (—0.69-—0.25)	↓ 13.2 (—19.1-—6.8)	< 0.001
ASIR	Andean Latin America	2.31 (1.89-2.73)	↑ 102.5 (81.3-125.8)	< 0.001
ASDR	Low-income North America	3.66 (3.15-4.17)	↑ 201.3 (170.5-235.8)	< 0.001
ASDR	Eastern Sub-Saharan Africa	—0.69 (—1.02-—0.36)	↓ 19.1 (—27.2-—10.3)	< 0.001

ASPR: age-standardized prevalence rate; ASIR: age-standardized incidence rate; ASDR: age-standardized death rate; AAPC: average annual percentchange.

表 3 区域DALYs负担量化分析

Table 3 Quantitative analysis of the burden of regional DALYs

Region	2021 Age-standardized DALYs rate (95% CI)/per 100 000 person-years	Percentage of global DKD total DALYs (95% CI)/%	AAPC (95% CI)/%	Cumulative change (95% CI)/%	P
South Asia	361.5 (355.2-367.8)	32.6 (30.1-35.1)	1.85 (1.52-2.18)	↑ 78.3 (63.5-95.2)	< 0.001
East Asia	315.8 (310.3-321.3)	28.9 (26.4-31.4)	1.62 (1.29-1.95)	↑ 65.8 (51.2-82.5)	< 0.001
Andean Latin America	302.4 (295.6-309.2)	12.3 (10.1-14.5)	2.25 (1.83-2.67)	↑ 98.6 (78.3-121.5)	< 0.001
Eastern Sub-Saharan Africa	246.7 (240.1-253.3)	6.7 (5.2-8.2)	—0.65(—0.98-—0.32)	↓ 17.8 (—25.5-—9.5)	< 0.001

DALYs: disability-adjusted life years; AAPC: average annual percent change.

95%CI: −0.768 ~ −0.315, P<0.001)。结果表明SDI水平与DKD疾病负担指标存在明确且稳定的相关性。

2.4　1990–2021年DKD负担在不同国家和地区的时间变化趋势

研究分析了1990–2021年全球204个国家和地区及21个GBD区域的DKD疾病负担数据, 包括ASPR(网络资源附件附图5)、ASIR(网络资源附件附图6)、ASDR(网络资源附件附图7)。结果显示1990–2021 年, DKD ASIR、ASDR呈持续上升趋势, ASPR呈下降趋势, 整体疾病负担不断加重。研究通过合并地图数据与疾病指标, 构建queen邻接矩阵进行空间分析, 并利用ggplot2可视化, 结果显示全球204个国家和地区DKD负担差异显著, 空间分析显示不同地区趋势差异显著, AAPC极值见表4。

2.5　中国与全球DKD负担的比较分析

本研究对比1990–2021年中国与全球DKD疾病负担趋势, 结果显示(表1), 中国DKD疾病负担变化趋势与全球基本一致, 但ASIR、ASDR、年龄标准化DALYs率增幅及ASPR降幅均高于全球水平, 死亡负担更为突出(图4)。

2021年中国DKD的DALYs构成中, YLLs占比为71.5%(95%CI: 68.3% ~ 74.7%), 略低于全球同期水平(73.7%, 95%CI: 71.5% ~ 75.9%); YLDs占比为28.5%(95%CI: 25.3% ~ 31.7%), 略高于全球同期水平(26.3%, 95%CI: 24.1% ~ 28.5%)。尽管中国YLLs占比略低, 但中国年龄标准化YLLs率高于全球同期水平, 提示中国DKD所致的死亡负担较全球更为显著。

2.6　未来十年全球DKD负担预测

基于1990–2021年数据, 本研究采用ARIMA(1, 1, 0)模型(经平稳性检验、AIC/BIC优化及白噪声检验确定最优参数, p=1, d=1, q=0)预测2022–2031年全球DKD负担趋势。结果见表5和网络资源附件附图8。基于ARIMA模

表 4　各国/地区AAPC极值（1990–2021）

Table 4　The extreme values of AAPC for each country/region (1990–2021)

Indicator	Category	Country/Territory	AAPC (95% CI)/%
Age-standardized prevalence rate (ASPR)	Highest	Greenland	0.890 3 (0.562 1-1.218 5)
	Lowest	United Kingdom	−0.615 0 (−0.943 2-−0.286 9)
Age-standardized incidence rate (ASIR)	Highest	Estonia	2.902 3 (2.574 7-3.231 3)
	Lowest	Ireland	−0.330 0 (−0.658 2-−0.001 9)
Age-standardized death rate (ASDR)	Highest	United States	3.804 0 (3.475 7-4.132 2)
	Lowest	Maldives	−2.186 8 (−2.515 0-−1.858 6)

AAPC: average annual percent change.

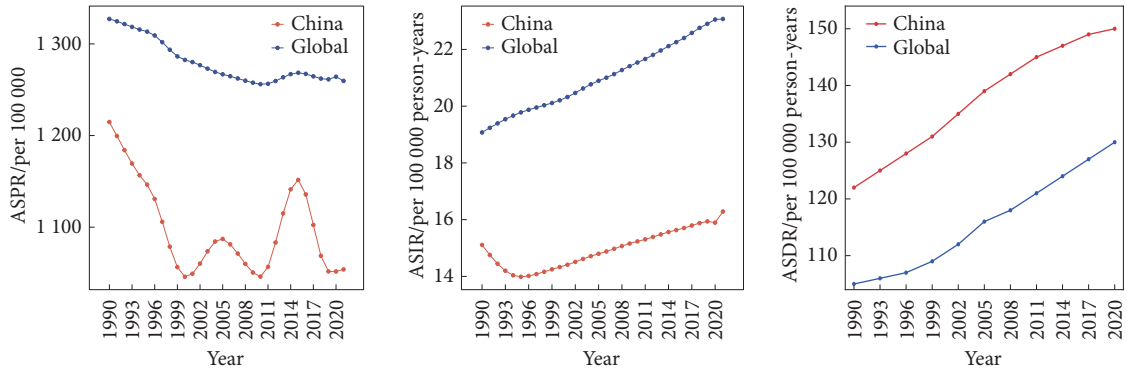


图 4　1990–2021年中国与全球DKD年龄标准化患病率、发病率、死亡率时间变化趋势

Fig 4　The temporal trends of age-standardized prevalence rate (ASPR), age-standardized incidence rate (ASIR), and age-standardized death rate (ASDR) of DKD in China and globally from 1990 to 2021

表 5　2022–2031年全球DKD疾病负担预测

Table 5　Projection of global burden of DKD from 2022 to 2031

Indicator	2031 Predicted value (95% CI)	Annual change rate (95% CI)/%	Trend
Age-standardized prevalence rate (ASPR)	825.3 (798.6-852.0) per 100 000	0.45 (0.21-0.69)	Slowly increasing
Age-standardized incidence rate (ASIR)	48.2 (46.5-49.9) per 100 000 person-years	−0.23 (−0.47-−0.01)	Slowly decreasing
Age-standardized death rate (ASDR)	10.4 (10.0-10.8) per 100 000 person-years	1.53 (1.21-1.85)	Continuously increasing
Age-standardized DALYs rate	328.6 (321.5-335.7) per 100 000 person-years	1.12 (0.89-1.35)	Continuously increasing
Age-standardized YLLs rate	245.8 (239.7-251.9) per 100 000 person-years	—	—
Age-standardized YLDs rate	82.8 (79.1-86.5) per 100 000 person-years	—	—

DALYs: disability-adjusted life years; YLLs: years of life lost; YLDs: years lived with disability. The predicted values are based on the ARIMA (1, 1, 0) model, with reasonable interval deviations.

型预测与趋势图显示：1990–2021年全球DKD年龄标准化DALYs率持续上升，ASIR先升后趋稳，ASPR先降后小幅回升；未来十年（2022–2031年）预计年龄标准化DALYs率继续显著上升，ASPR缓慢回升，ASIR小幅下降，整体疾病负担仍将持续加重。

3 讨论

DKD作为糖尿病最严重的微血管并发症之一[10]，以进行性白蛋白尿和肾小球滤过率（eGFR）降低为临床特征，最终可进展至ESRD[11]。2021年全球糖尿病患者已达8.4亿且持续增长[12]，DKD显著增加患者心血管事件及全因死亡风险[13]。本研究基于GBD 2021数据，系统分析1990–2021年全球204个国家和地区DKD疾病负担的时空分布特征，为疾病精准防控提供流行病学依据。

本研究基于1990–2021年GBD 2021数据，系统分析全球、区域及国家和地区DKD疾病负担的时空分布与变化趋势，核心发现可归纳为三方面。第一，年龄差异显著，40岁以上人群DKD发病、死亡及DALYs负担快速升高，60～80岁达高峰，提示中老年为重点防控人群。第二，时间趋势呈分化特征，全球ASPR持续下降，而ASIR、ASDR及年龄标准化DALYs率显著上升，疾病总负担持续加重。第三，空间异质性突出，东亚现患病例数最多，南亚发病与DALYs负担最重，不同国家和地区趋势差异明显，低SDI地区负担上升更为显著。

全球DKD呈现“ASPR下降，但ASIR、年龄标准化DALYs率持续上升”的现象，其核心原因可从三方面解析。首先，2型糖尿病患病人群基数持续扩大，直接推动新发病例增加[14]。其次，诊疗水平提升与新型肾脏保护药物普及，有效延缓疾病进展，使患病率有所下降[15]。最后，人口老龄化、肥胖及代谢危险因素广泛流行，导致重症与死亡负担未同步降低，最终表现为ASIR与年龄标准化DALYs率持续升高。

中国DKD趋势与全球整体一致，但发病、死亡及DALYs增幅更高，死亡负担更为突出。结合我国慢病防控体系，建议采取三项落地策略：将DKD高危人群筛查纳入国家基本公共卫生服务，重点覆盖中老年及农村人群；基层医疗机构常规开展eGFR与尿蛋白检测，推进早期识别[16]；强化生活方式干预与规范用药，将新型肾脏保护药物纳入基层保障体系，借助远程医疗缩小城乡诊疗差距[17]。

SDI与DKD疾病负担存在显著关联，本研究显示ASIR与SDI呈正相关，ASPR、ASDR与SDI呈负相关。高SDI地区医疗资源充足、早筛早治普及，死亡与伤残风险更低；低SDI地区筛查能力不足、治疗可及性差，实际发病易被低估，疾病进展更快，整体负担更重[18-20]。提示DKD防控需兼顾区域发展差异，向低SDI地区倾斜公共卫生资源，提升基础筛查与规范治疗覆盖率[21]。

本研究优势在于覆盖全球204个国家和地区、时间跨度31年，采用JRM、空间分析与ARIMA模型开展趋势分析与预测，结果具有良好代表性[22-23]。局限性包括：GBD估算数据在部分地区完整性有限；未充分控制饮食、运动、卫生服务等混杂因素；未开展1型/2型糖尿病病因分层分析。未来可开展多国前瞻性队列研究，结合个体危险因素与卫生体系数据提升证据等级；同时优化模型方法，采用非线性与机器学习手段提升预测精度[24-28]。基于本研究结果，建议实施分层精准防控：高SDI地区重点推进常态化早期筛查，低SDI地区优先提升基础医疗可及性与药物可及性。结合中国慢病管理战略，将DKD防控纳入县域医共体考核，依托AI辅助工具提升基层筛查与管理能力，完善分级诊疗与医保支付配套政策，为降低全球及中国DKD疾病负担提供科学支撑[29-31]。

综上，1990–2021年全球DKD的发病、死亡及DALYs负担均呈显著上升趋势，年龄标准化患病率虽在观察期内有所下降，但预测未来将转为回升态势；DKD疾病负担存在显著区域异质性，低SDI地区增幅更为明显。预计未来十年全球DKD总体疾病负担仍将持续加重，防控形势将更为严峻。本研究结果提示，应针对不同区域、不同SDI水平人群制定差异化防控策略，重点加强低SDI地区筛查与诊疗能力建设，强化中老年高危人群早期干预，以缓解全球DKD疾病负担增长趋势。

* * *

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利益冲突 所有作者均声明不存在利益冲突

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参 考 文 献

[1] YANAI H, ADACHI H, HAKOSHIMA M, *et al*. Molecular mechanisms and clinical evidence supporting the four pillars of therapy in diabetic kidney disease: emerging therapeutic perspectives. Int J Mol Sci, 2026, 27(6): 2757. doi: 10.3390/ijms27062757.

[2] BASU M, GHOSH S. Chronic kidney disease with risk factor diabetes: need for change in nomenclature reflecting heterogeneity of kidney disease in diabetes. J Assoc Physicians India, 2026, 74(3): 11-12. doi: 10.59556/japi.74.1390.

[3] WANG N, ZHANG C. Recent advances in the management of diabetic kidney disease: slowing progression. Int J Mol Sci, 2024, 25(6): 3086. doi: 10.3390/ijms25063086.

[4] SPEECKAERT R, DELRUE C, SPEECKAERT M M. Residual renal risk in diabetic nephropathy despite contemporary therapies. J Clin Med, 2026, 15(3): 921. doi: 10.3390/jcm15030921.

[5] DENG Z, YANG J, ZHOU H. Development and validation of a model that predicts the risk of diabetic kidney disease in type 2 diabetes mellitus patients: a retrospective study. Front Endocrinol (Lausanne), 2026, 16: 1708419. doi: 10.3389/fendo.2025.1708419.

[6] HE Y, WANG X, LI L, *et al*. Global, regional, and national prevalence of chronic type 2 diabetic kidney disease from 1990 to 2021: a trend and health inequality analyses based on the Global Burden of Disease Study 2021. J Diabetes, 2025, 17(5): e70098. doi: 10.1111/1753-0407.70098.

[7] DENG Y, LI N, WU Y, *et al*. Global, regional, and national burden of diabetes-related chronic kidney disease from 1990 to 2019. Front Endocrinol (Lausanne), 2021, 12: 672350. doi: 10.3389/fendo.2021.672350.

[8] GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet, 2024, 403(10440): 2133-2161. doi: 10.1016/S0140-6736(24)00757-8.

[9] WANG Y, WU J, HE H, *et al*. The burden of diabetes nephropathy in China from 1990 to 2021, with forecast to 2036: an analysis from the global burden of disease study 2021. BMC Public Health, 2025, 26(1): 371. doi: 10.1186/s12889-025-25692-8.

[10] GUPTA S, DOMINGUEZ M, GOLESTANEH L. Diabetic kidney disease: an update. Med Clin North Am, 2023, 107(4): 689-705. doi: 10.1016/j.mcna.2023.03.004.

[11] ZHANG Y, YU C, LI X. Kidney aging and chronic kidney disease. Int J Mol Sci, 2024, 25(12): 6585. doi: 10.3390/ijms25126585.

[12] PANTIS C, VESA C M, GHITEA T C, *et al*. Diabetes duration is associated with declining kidney function: eGFR and CKD burden across duration. J Clin Med, 2026, 15(6): 2235. doi: 10.3390/jcm15062235.

[13] ALQURAIN A, ALOTAIBI M A, ALAZMI B A, *et al*. Angiotensin-converting enzyme inhibitors versus angiotensin receptor blockers for cardiovascular and renal protection in type 2 diabetes: a systematic review and meta-analysis. Cureus, 2026, 18(2): e103029. doi: 10.7759/cureus.103029.

[14] DENG Y, MA Y, LI H, *et al*. The impact of early in-hospital use of SGLT2 inhibitors on outcomes in patients with acute heart failure: an updated systematic review and meta-analysis. Rev Cardiovasc Med, 2026, 27(3): 45590. doi: 10.31083/RCM45590.

[15] ZHANG J, LI W, SUN Z, *et al*. Trends and projections of the global burden of T2DM-associated CKD related to high BMI: a global burden of disease study 2021. PLoS One, 2025, 20(10): e0333672. doi: 10.1371/journal.pone.0333672.

[16] YANG Y, LIU Z, HUANG Y, *et al*. Associations of time in tight range, time in range, and glycated hemoglobin with albuminuria and diabetic kidney disease in adult type 2 diabetes: a cross-sectional study. BMC Endocr Disord, 2026, 26(1): 95. doi: 10.1186/s12902-026-02204-2.

[17] WANG Y, LI C, CILI N, *et al*. The contribution of genetic risk and lifestyle factors in the progression of diabetes to diabetic kidney disease: a prospective cohort study. J Diabetes, 2025, 17(9): e70141. doi: 10.1111/1753-0407.70141.

[18] ORSILLO A, KHOLMURODOVA F, CLAYTON P A, *et al*. The impact of donor and recipient diabetes on patient and graft survival in kidney transplant recipients. Kidney Int Rep, 2025, 10(11): 3834-3842. doi: 10.1016/j.ekir.2025.08.013.

[19] CAO Y, CHEN H, LIU H, *et al*. Global, regional, and national temporal trends in incidence for type 2 diabetes mellitus related chronic kidney disease from 1992 to 2021. Diabetes Metab J, 2025, 49(4): 848-861. doi: 10.4093/dmj.2024.0593.

[20] LEE A. Mouse models of diabetic complications: dissecting molecular mechanisms of disease progression. Front Biosci (Landmark Ed), 2026, 31(3): 45430. doi: 10.31083/FBL45430.

[21] WANG X, CAI G, OUYANG Q, *et al*. Burden analysis of diabetic nephropathy caused by excessive intake of sugar-sweetened beverages in high and low SDI regions. Front Public Health, 2025, 13: 1598278. doi: 10.3389/fpubh.2025.1598278.

[22] MENG L, LI Z, XU L, *et al*. Emerging technologies for early risk stratification and precision management of diabetic kidney disease: a multimodal framework integrating digital phenotypes and clinical biomarkers. Front Endocrinol (Lausanne), 2026, 16: 1728293. doi: 10.3389/fendo.2025.1728293.

[23] LI H, WANG J, ZHANG T, *et al*. Epidemiological trend in diabetic kidney disease (DKD) burden in China from 1990 to 2021, and projections for 2041: an analysis of the global burden of disease study 2021. BMC Public Health, 2025, 25(1): 3381. doi: 10.1186/s12889-025-24674-0.

[24] WANG M, YAN R, XIA W, *et al*. Global, regional, and national burden of type 2 diabetes-related diabetic kidney disease attributable to low physical activity from 1990 to 2021: a systematic analysis of the Global Burden of Disease Study 2021 with predictions to 2050. Front Endocrinol (Lausanne), 2025, 16: 1625973. doi: 10.3389/fendo.2025.1625973.

[25] LUO Y, BAI R. Identification of key genes related to glutamine metabolism in diabetic nephropathy by machine learning methods. Sci Rep, 2025, 15(1): 45703. doi: 10.1038/s41598-025-28169-1.

[26] ALOBAID T, O'CONNELL M D L, KARALLIEDDE J, *et al*. Ethnic differences in CKD progression among people with type 2 diabetes and rapid eGFR decline: a secondary data analysis. BMC Nephrol, 2025, 26(1): 298. doi: 10.1186/s12882-025-04235-8.

[27] MUHAMMAD A N, AHMED F, ELTAWANSY S, *et al*. Epidemiological trends in diabetic renal complications in United States adults: a center for disease control and prevention wide-ranging online data for epidemiologic research analysis (1999-2020). World J Nephrol, 2025, 14(2): 105815. doi: 10.5527/wjn.v14.i2.105815.

[28] WANG Y, LIN T, LU J, *et al*. Trends and analysis of risk factor differences in the global burden of chronic kidney disease due to type 2 diabetes from 1990 to 2021: a population-based study. Diabetes Obes Metab, 2025, 27(4): 1902-1919. doi: 10.1111/dom.16183.

[29] XIE X, WU C, HUANG Z, *et al*. Artificial intelligence-powered prediction of diabetic complications: from clinical data to molecular omics. Brief Bioinform, 2026, 27(1): bbag083. doi: 10.1093/bib/bbag083.

[30] KALANTAR-ZADEH K, FRIEDMAN T C, JAFARI G, *et al*. Population health management of diabetic kidney disease in Los Angeles county municipal health system. Curr Opin Nephrol Hypertens, 2026, 35(1): 62-71. doi: 10.1097/MNH.0000000000001139.

[31] WANG E, LIN Y, YOU Y, *et al*. Impact of capitation payment on vascular complications among treated diabetic patients in China. Sci Rep, 2025, 15(1): 32970. doi: 10.1038/s41598-025-17273-x.

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