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RESEARCH

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A global analysis of the burden of ischemic heart disease attributable to diet low in ω-3 fatty acids between 1990 and 2021

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Abstract

Aim Ischemic heart disease (IHD) is a major contributor to global mortality and disability, imposing a significant health and economic burden on patients and society. Despite existing treatment options including medications and surgeries, their effectiveness remains limited, with issues such as suboptimal treatment outcomes and high recurrence rates. This study aims to investigate the relationship between low dietary intake of ω-3 fatty acids and the burden of IHD, hoping to provide new insights into the prevention and treatment of IHD.

Method Using the Global Burden of Disease (GBD) 2021 dataset, we examined the impact of low ω-3 dietary intake on the burden of ischemic heart disease (IHD) between 1990 and 2021globally, regionally, temporally. The Joinpoint regression model was applied to analyze the trend of IHD burden attributed to low ω-3 dietary intake over time.

Results In 2021, the global IHD-related Disability-Adjusted Life Years (DALYs) and deaths caused by a low ω-3 diet was 15,511,020(95% UI: 3,098,820 to 25,946,110) and 627,340 (95% UI: 119,540 to 1,082,740), accounting for 8.23% (95% UI: 1.64–13.52%) of all IHD-related DALYs and 6.97% (95% UI: 1.33–11.76%) of all IHD deaths, respectively. From 1990 to 2021, there was a significant upward trend in DALYs and deaths, but age-standardized DALYs and death rates showed a declining trend. Regional analysis indicated that the burden of IHD was highest in South Asia and lowest in High-Income Asia Pacific regions. At the national level, India, China, the United States, and Pakistan had a higher burden of IHD. Furthermore, as the Socio-Demographic Index (SDI) increased, the burden of IHD caused by a low ω-3 diet gradually decreased.

Conclusion This study untangles a significant association between a low ω-3 diet and the burden of IHD, emphasizing the importance of promoting healthy eating habits globally. Future research should further explore the impact of dietary changes on the burden of IHD and develop targeted public health policies to reduce the burden of IHD.

Keywords IHD, Diet low in ω-3 fatty acids, Disease burden

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Introduction

Ischemic heart disease (IHD) is one of the leading causes of death and disability worldwide, posing a significant health and economic burden on patients and society [1]. According to the World Health Organization, IHD causes millions of deaths annually and consumes vast medical resources. Although existing treatments, such as pharmacological therapy, surgical procedures and Percutaneous Coronary Intervention (PCI) have provided some relief, their efficacy remains suboptimal, with high recurrence rates [2]. Therefore, exploring novel preventive and therapeutic strategies is crucial to alleviate the burden of IHD.

In recent years, the role of dietary factors in the onset and progression of IHD has garnered increasing attention. ω-3 fatty acids, as essential polyunsaturated fatty acids, have been proven to exhibit anti-inflammatory, anti-thrombotic, and lipid-improving properties [3]. However, the association between low dietary intake of ω-3 fatty acids and increased IHD risk has not been fully investigated. Previous studies suggest that a low ω-3 diet may be linked to the development of cardiovascular diseases [4], but these studies are often limited to small samples or specific regions [5], lacking a systematic global evaluation. Thus, a comprehensive assessment of the impact of a low ω-3 diet on the burden of IHD bears significant scientific importance and public health value.

Currently, research on the relationship between a low ω-3 diet and IHD still has some gaps. Firstly, most studies fail to fully consider the influence of regional differences and socio-economic development levels on dietary patterns and the burden of IHD globally. Secondly, there is a lack of analysis on temporal trends, which cannot reflect the long-term impact of a low ω-3 diet on the burden of IHD. Furthermore, existing research often relies on single data sources or methodologies, which may introduce certain biases and limitations [6]. Therefore, employing more comprehensive and reliable datasets and analytical methods to evaluate the relationship between a low ω-3 diet and the burden of IHD represents an important direction in the current research field [7].

This study leverages the Global Burden of Disease (GBD) 2021 dataset and employs a systematic analysis methodology to examine the impact of low ω-3 dietary intake on IHD burden. The GBD dataset encompasses data on diseases, injuries, and risk factors globally, featuring a wide range of data sources and high reliability. By leveraging this dataset, our study can deeply analyze the impact of a low ω-3 diet on the burden of IHD from global, regional, and national perspectives, and explore its variations across different socio-demographic index (SDI) regions and temporal trends [8]. Additionally, this study integrates advanced statistical models and sensitivity analyses to enhance the accuracy and robustness of the results [9, 10].

Methods

Overview

Data for this analysis were obtained from the GBD 2021 dataset, available at GBD Results(https://vizhub.healthdata.org/gbd-results/). The GBD dataset provides compreh ensive insights into the burden of 369 diseases and injuries and 87 risk factors across 204 countries and regions from 1990 to 2021. It serves as a critical resource for understanding global health trends, including mortality, disability, and risk factors. In this study, we focused on evaluating the impact of low ω-3 fatty acid intake on IHD burden, measured in terms of deaths and DALYs [11], along with corresponding age-standardized rates. In the GBD study, the globe is divided into 21 regions based on geographical location. Additionally, the study categorizes countries into five development tiers using the SDI [12].

Estimation methods

The primary dietary data used in the GBD 2021 study was sourced from nutritional surveys, specifically the 24-hour dietary recall method [13]. Moreover, the GBD study characterizes a diet low in ω-3 fatty acids as one where the intake of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) is less than 250 mg/day, specifically termed as insufficient seafood ω-3 fatty acid intake [14]. The GBD employs detailed methodologies, described elsewhere, to quantify the disease burden attributable to specific risk factors. In essence, the GBD 2021 utilized a comprehensive literature review and meta-analysis to determine the relative risk (RR) of IHD associated with low ω-3 fatty acid intake. The Population Attributable Fraction (PAF) was subsequently applied to assess the proportion of harm attributable to this dietary factor [15]. The PAF is a crucial metric in epidemiology and disease burden studies, serving to quantify the contribution of a specific exposure factor (such as inadequate intake of ω-3 fatty acids in the diet) to the burden of a particular disease (like IHD). Specifically, PAF illustrates the theoretical proportion of disease burden that could be reduced if the exposure level in the population were lowered to an ideal state (for instance, achieving adequate ω-3 fatty acid intake) compared to the actual disease burden. The burden of IHD deaths and DALYs resulting from low ω-3 fatty acid intake was then calculated by applying the PAF to the total IHD deaths and DALYs.

Statistical analysis

We present detailed data on IHD deaths and DALYs attributed to low ω-3 fatty acid intake in global diets, including 95% uncertainty intervals (UI). These findings are stratified by age, sex, geographical region, and specific countries. For trend analysis, we utilized Joinpoint 4.9.1.0 software to compute the Average Annual Percent Change (AAPC) of both the crude and age-standardized death and DALY rates, along with their 95% confidence intervals (CI) [16]. An AAPC greater than zero signifies an increasing trend, whereas a negative value indicates a decreasing trend. All data analyses were conducted using R software, with statistical significance set at a *P*-value of less than 0.05.

Results

The burden of IHD caused by low ω-3 fatty acid in global diet in 2021

In 2021, a low ω-3 fatty acid diet was associated with 15,511,020 (95% UI, 3,098,820 to 25,946,110) DALYs and 627,340 (95% UI: 119,540 to 1,082,740) IHD deaths globally. These figures accounted for 8.23% (95% UI: 1.64–13.52%) of all IHD-related DALYs and 6.97% (95% UI: 1.33–11.76%) of all IHD deaths, respectively (see Table 1). From 1990 to 2021, there was a significant upward trend in the number of IHD-related DALYs (AAPC of 0.58%; 95% CI: 0.53–0.60%) and deaths (AAPC: 0.74%; 95% CI: 0.71–0.77%) due to low ω-3 fatty acid intake. The corresponding age-standardized DALY rate declined from 322.93 per 100,000 people in 1990 (95% UI: 65.76 to 533.31) to 181.07 per 100,000 people in 2021 (95% UI: 36.18 to 302.84), with an AAPC of -1.83% (95% CI: -1.86% to -1.80%). Similarly, the death rate also declined significantly (AAPC: -1.96%; 95% CI: -2.00% to -1.93%), reaching 7.49 per 100,000 people in 2021 (95% UI: 1.42 to 12.95).

Overall, the age-standardized DALY and death rates (per 100,000) due to IHD caused by low ω-3 fatty acid intake were higher in males compared to females. Specifically, the rates for males were 216.38 (95% UI: 43.59 to 363.53) and 8.48 (95% UI: 1.58 to 14.68), respectively, while those for females were 146.53 (95% UI: 29.19 to 244.66) and 6.53 (95% UI: 1.25 to 11.22), respectively. Both death and DALY rates showed an upward trend with increasing age (see Fig. 1). Similarly, the total number of DALYs and deaths due to IHD caused by low ω-3 fatty acid intake was higher in males (8,874,950, 95% UI: 1,805,700 to 14,856,280 and 324,880, 95% UI: 61,560 to 559,600, respectively) than in females (6,636,070, 95% UI: 1,316,900 to 11,123,600 and 302,460, 95% UI: 57,910 to 520,770, respectively). Before the age of 75–79, males experienced more IHD deaths and DALYs due to low ω-3 fatty acid intake than females, but this pattern reversed afterward (see Fig. 1).

The burden of IHD caused by low ω-3 fatty acids in the diet by region

The results are presented in Fig. 2. Among the 21 regions examined, South Asia had the highest number of ω-3 related IHD DALYs (6226.49, 95% UI: 1284.36 to 10237.06) and deaths (214.32, 95% UI: 35.90, 424.32) due to low ω-3 fatty acids in the diet. In contrast, the High-Income Asia Pacific region recorded the lowest number of DALYs (2.23, 95% UI: 0.37, 5.27) and deaths (0.15, 95% UI: 0.02, 0.37) due to low ω-3 fatty acid intake. When considering age-standardized rates per 100,000 population, Central Asia had the highest DALYs (678.40, 95% UI: 134.21, 1146.58) and death rates (32.79, 95% UI: 6.23, 56.68), followed by North Africa and South Asia.

Figure 3 illustrates the temporal patterns of the IHD burden associated with low ω-3 fatty acids in the diet across various regions. Notably, there was a significant increase in DALYs and deaths in 12 and 13 regions, respectively. Sub-Saharan Central Africa showed the most pronounced increase, with an AAPC of 2.68% (95% CI: 2.62%, 2.75%) for DALYs and 2.71% (95% CI: 2.65%, 2.78%) for deaths. Between 1990 and 2021, almost all regions, except for Sub-Saharan Africa, exhibited a downward trend in age-standardized DALY and death rates related to low ω-3 fatty acid diets. Sub-Saharan Africa

Table 1 Burden of IHD attributable to diet low in ω-3 in different SDI quintiles in 2021

	DALY		Death	
	Number AAPC(%)	**Rate (per 100,000 population) AAPC(%)**	**Number AAPC(%)**	**Rate(per 100,000 population) AAPC(%)**
Global	15,511,020(3,098,820 – 25,946,110) 0.58(0.54,0.60)	181.07(36.18,302.84) -1.83(-1.86, -1.80)	627,340(119,540-1,082,740) 0.74(0.71,0.77)	7.49(1.42,12.95) -1.96(-2.00, -1.93)
Low SDI	1,909,740(409,530-3,115,470) 2.01(1.98,2.05)	336.68(70.3,559.69) -0.64(-0.69, -0.60)	65,210(13,450 – 109,240) 2.10(2.06,2.14)	13.93(2.77,23.84) -0.50(-0.55,-0.45)
Low-middle SDI	5,101,650(1,029,860-8,327,590) 1.52(1.49,1.55)	329.24(65.51,541.47) -1.11(-1.15, -1.07)	178,270(34,900 – 297,390) 1.78(1.74,1.83)	13.01(2.51,21.92) -0.99(-1.04,-0.95)
Middle SDI	4,821,650(964,070 – 8,042,550) 0.97(0.95,0.99)	179.79(35.43,302.41) -1.88(-1.90, -1.85)	194,450(36,790 – 338,120) 1.48(1.46,1.51)	7.95(1.49,13.94) -1.75(-1.79,-1.72)
High-middle SDI	2,304,570(460,290-4,001,670) -0.81(-0.90, -0.73)	120.59(24.32,208.46) -3.02(-3.13, -2.88)	118,540(22,450 – 213,000) -0.21(-0.29,-0.13)	6.2(1.18,11.12) -2.79(-2.87,-2.71)
High SDI	1,357,900(262,560-2,387,430) -1.58(-1.62, -1.55)	71.57(14.26,123.19) -3.38(-3.41, -3.34)	70,160(12,960 – 127,780) -1.48(-1.52,-1.44)	3.14(0.59,5.63) -3.76(-3.80,-3.72)

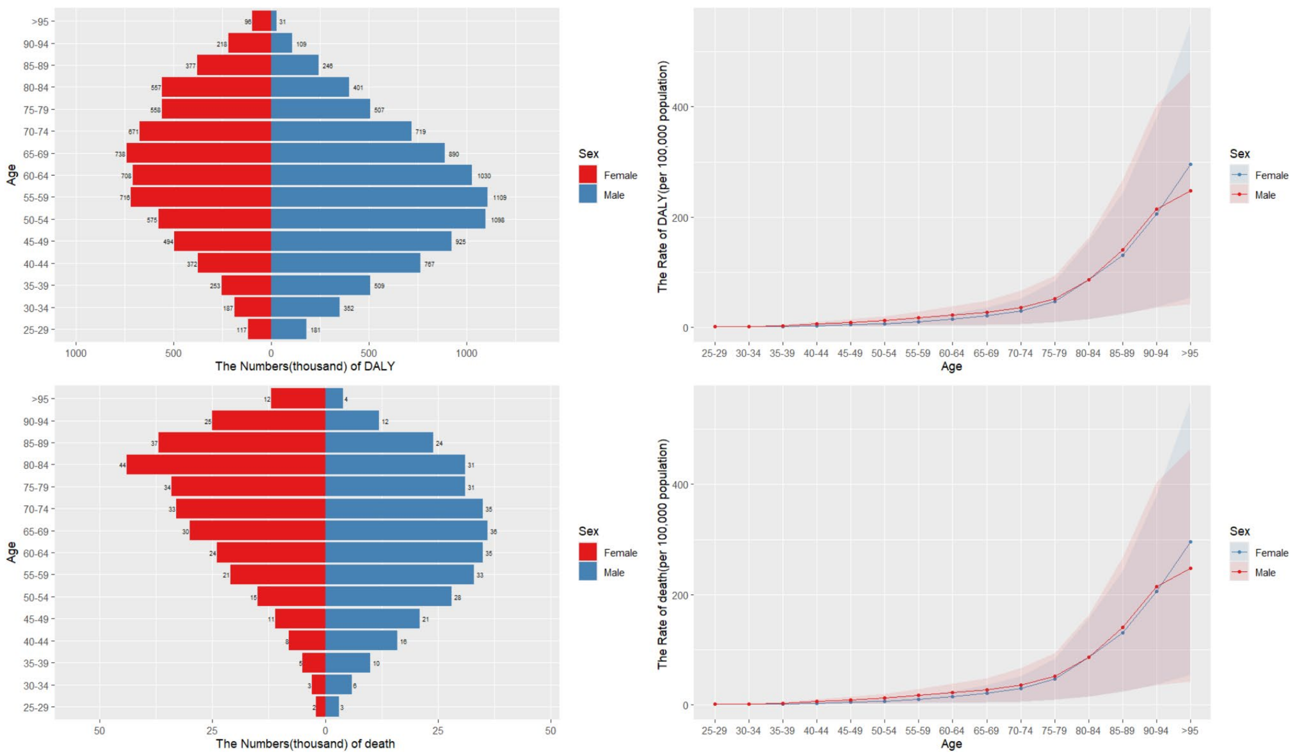

Fig. 1 Age-specific numbers and rates of IHD death and DALY attributable to diet low in ω-3 by gender, in 2021

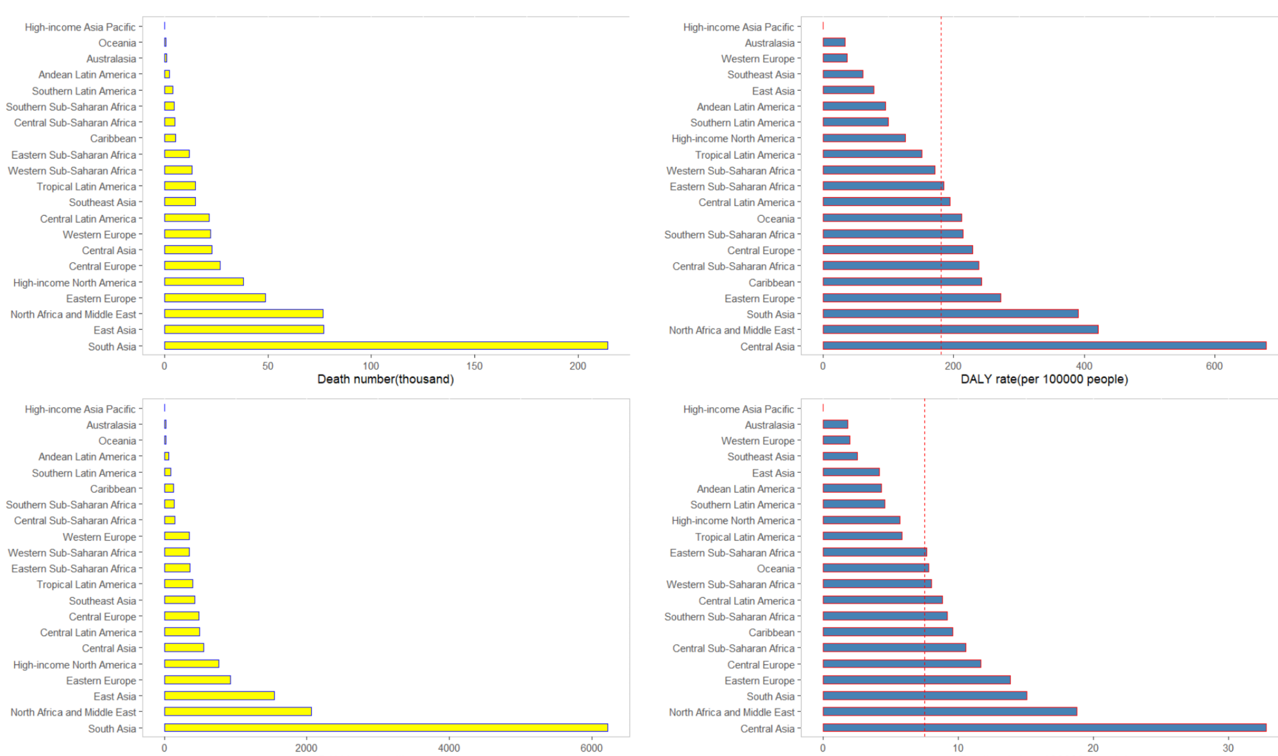

Fig. 2 Numbers and age-standardized rates of IHD death and DALY attributable to diet low in ω-3 among different regions in 2021

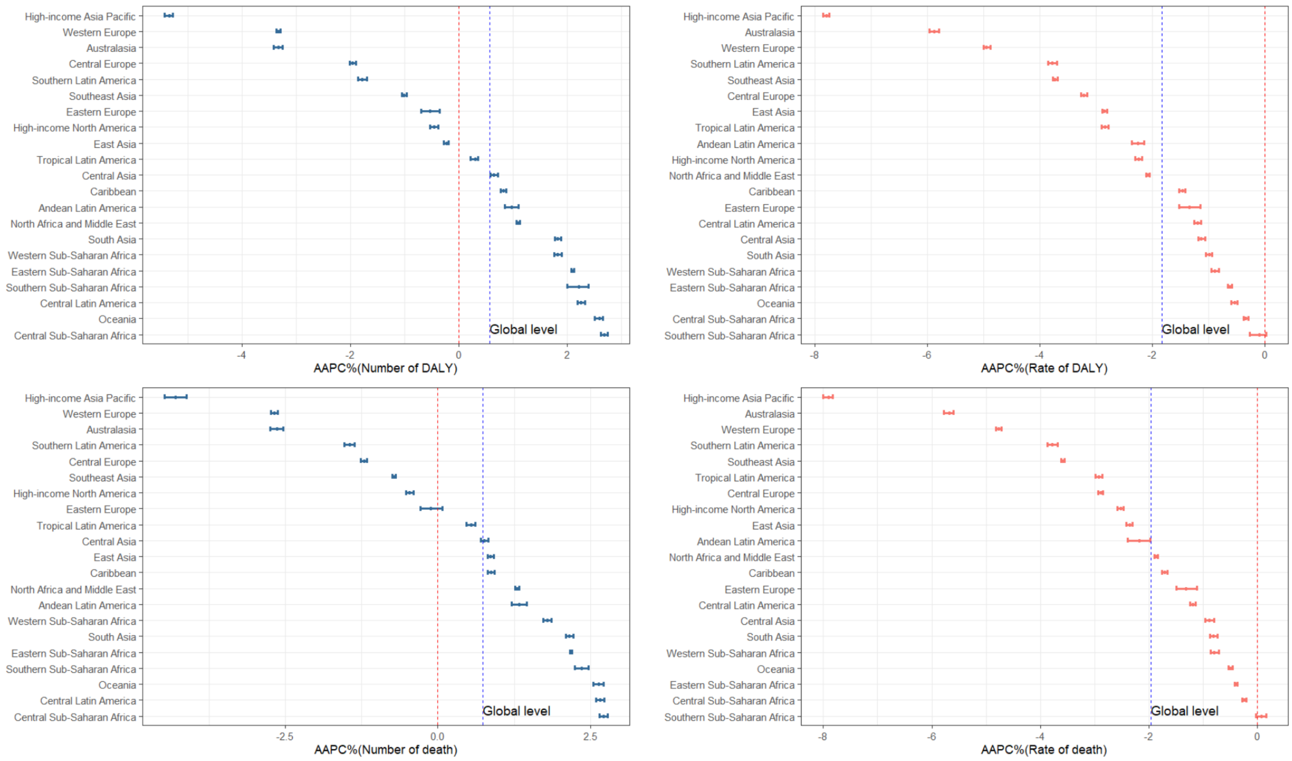

Fig. 3 Temporal trend of age-standardized rate of IHD death and DALY attributable to diet low in ω-3 from 1990 to 2021 among different regions

showed no significant trend, specifically, the AAPC for DALYs was −0.09% (95% CI: -0.26%, 0.029%), and the AAPC for deaths was 0.06% (95% CI: -0.04%, 0.16%). Furthermore, Sub-Saharan Africa ranked fourth globally in terms of the increase in IHD deaths and DALYs caused by low ω-3 fatty acids in the diet.

The burden of IHD caused by low dietary ω-3 fatty acids, categorized by country

As illustrated in Fig. 4, India bears the heaviest burden of IHD DALYs (5066.23, with a 95% UI ranging from 1041.34 to 8314.56) and deaths (176.37, 95% UI: 34.86 to 296.21) due to low dietary ω-3 fatty acids, followed by China, the United States, and Pakistan. In terms of the age-standardized DALY rate per 100,000 population associated with a low ω-3 fatty acid diet, Afghanistan ranks first with 1178.89 (95% UI: 262.71 to 2021.11), preceded by the Syrian Arab Republic, Uzbekistan, Yemen, and Sudan. The Syrian Arab Republic also has the highest age-standardized mortality rate due to IHD caused by low dietary ω-3 fatty acids, with 48.99 per 100,000 population (95% UI: 10.49 to 84.47). Conversely, countries like Maldives, Japan, Guam, and Singapore have the lowest burden of IHD associated with a low ω-3 fatty acid diet (see Fig. 4).

Between 1990 and 2021, most countries experienced a decline in DALYs and mortality rates related to IHD associated with low dietary ω-3 fatty acids. However, there are exceptions: 26 countries showed an increase in DALY rates, and 31 countries had elevated mortality rates. Notably, Namibia experienced the largest increase in both DALY and mortality rates, with an AAPC of 5.48% (95% CI: 5.31–5.65%) and 5.52% (95% CI: 5.35–6.58%), respectively. In contrast, Malaysia showed the most significant decrease, with an AAPC of -16.18% (95% CI: -6.53% to -15.76%) for DALY and −14.77% (95% CI: -15.00% to -14.47%) for mortality.

The burden of IHD caused by low ω-3 fatty acids in diet across different SDI quintiles

Specifically, in 2021, the age-standardized DALYs rate and the death rate per 100,000 population reached their highest values in low SDI quintiles, at 336.68 (95% UI: 70.3 to 559.69) and 13.93 (95% UI: 2.77 to 23.84), respectively. Conversely, these rates were lowest in high SDI quintiles, with 71.57 (95% UI: 14.26 to 123.19) and 3.14 (95% UI: 0.59 to 5.63), respectively. From 1990 to 2021, the burden of IHD associated with a low ω-3 fatty acid diet, measured by age-standardized DALYs rate and death rate, decreased in all five SDI quintiles. However, the magnitude of this decrease gradually diminished from high to low SDI quintiles (Table 1).

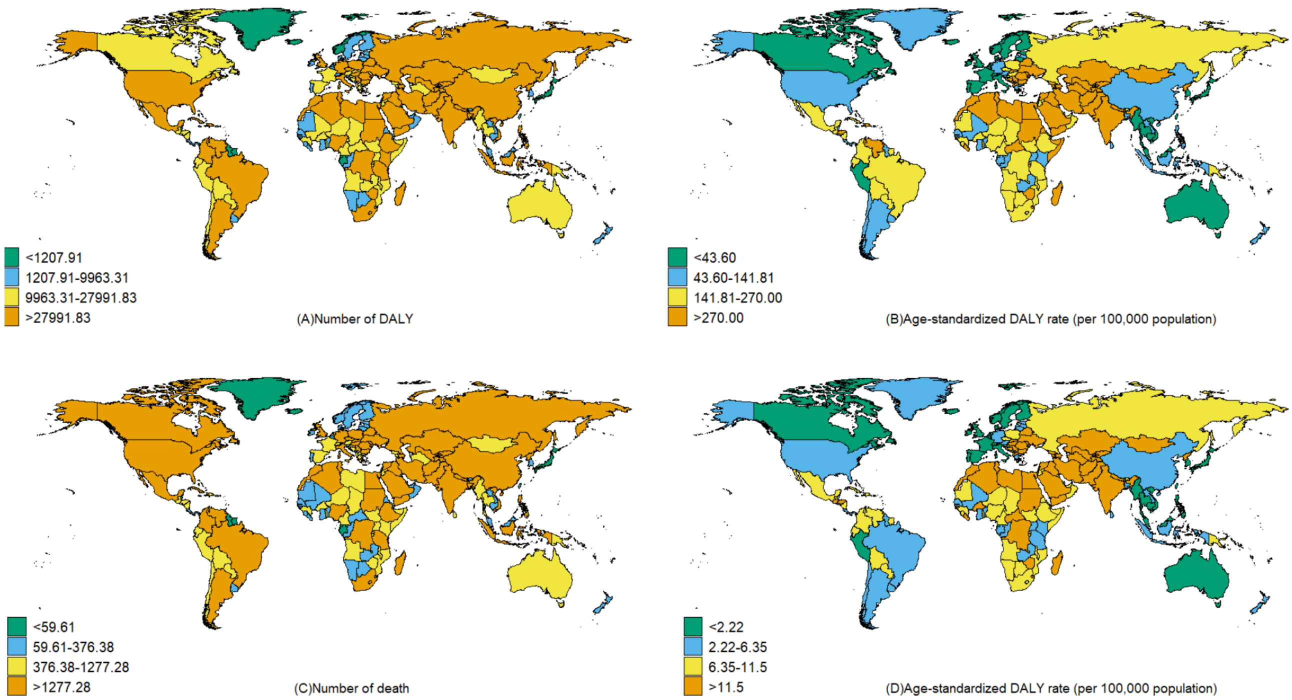

Fig. 4 Number and age-standardized IHD death and DALY rates of IHD attributable to diet low in ω-3 across countries in 2021

Discussion

In recent years, the role of dietary factors in the pathogenesis of IHD has garnered increasing attention, particularly the relationship between ω-3 fatty acid intake and IHD risk [17]. This study systematically evaluates the association between low dietary ω-3 fatty acid intake and the burden of IHD based on the GBD 2021 dataset. Through large-scale data analysis, we untangle the significant global impact of a low-ω-3 diet on the burden of IHD and explore its distribution characteristics across different regions, countries, and temporal trends. The following discussion delves into these key findings and their potential implications for public health policies.

Utilizing the GBD 2021 dataset, this study presents the first comprehensive assessment of the relationship between low dietary ω-3 fatty acid intake and the burden of IHD. In contrast to previous research [18], our study not only quantifies the global burden of IHD attributed to a low-ω-3 diet but also reveals its varying distribution across different regions, countries, and SDI levels. For instance, while some studies have reported an association between ω-3 fatty acids and cardiovascular diseases, they have not specifically analyzed its contribution to the burden of IHD [19]. Our research bridges this knowledge gap, providing detailed data on the global burden of IHD linked to a low-ω-3 diet. Furthermore, we find that despite a decline in age-standardized DALYs and mortality rates from 1990 to 2021, the overall burden of IHD shows an upward trend. This discovery offers a valuable basis for developing targeted public health policies.

Our research findings may have implications for clinical practice. Firstly, our data indicates that the burden of IHD due to a low ω-3 diet is highest in South Asia and lowest in high-income Asia Pacific regions. This discovery suggests that economic development level and dietary habits play a critical role in the burden of IHD [20]. Therefore, it is essential to develop differentiated health intervention measures based on the dietary structure and economic conditions of different regions. For instance, in regions with low SDI, dietary patterns can be improved by promoting foods rich in ω-3 fatty acids, such as fish and nuts [21], thereby reducing the burden of IHD. Additionally, our study also demonstrates that despite the overall increase in IHD burden, it is still possible to reduce its impact through measures like improving diet. This finding provides new ideas for future public health policy formulation, emphasizing the importance of a healthy diet in preventing IHD.

The Annual Percent Change (APC) is an indicator used to describe data trends within a single time period, assuming a constant rate of change during the study duration [22]. Calculated through simple linear regression, it is suitable for situations where data varies smoothly. However, when multiple trend inflection points exist within the data, APC might not accurately reflect the overall trend. Alternatively, the AAPC is a more complex statistical measure. Utilizing Joinpoint regression analysis, it identifies trend inflection points in the data, segmenting the entire timeline into multiple linear sections. The AAPC, which represents the weighted average of these linear segments, offers a more comprehensive reflection of data trends across different phases. Compared to APC, AAPC better captures the changing characteristics of complex data, particularly when multiple ascending or descending phases are present [23]. In this study, we opted for AAPC due to the possibility of multiple trend inflection points in IHD burden data between 1990 and 2021. Through AAPC, we can more precisely depict the long-term impact of a low ω-3 diet on IHD burden, taking into account varying characteristics across different stages. This provides us with more reliable statistical results, aiding in a more comprehensive understanding of the relationship between a low ω-3 diet and IHD burden [24].

Among high-income countries, taking the United States as an example, faces a heavier burden of IHD. Studies have shown that insufficient intake of ω-3 fatty acids in the high-income countries diet is one of the significant factors contributing to this heavy burden. Specifically, taking the United States as an example, Americans tend to have a higher intake of red meat and processed meat in their dietary habits [25], while their intake of fish and seafood rich in ω-3 fatty acids is relatively low. This unbalanced dietary structure leads to inadequate intake of ω-3 fatty acids, increasing the risk of IHD. Furthermore, low-income groups in the United States often find it difficult to access foods rich in ω-3 fatty acids [26], such as fresh fish and seafood, further exacerbating the burden of IHD. Intervention measures include: (1) Governments and public health institutions should conduct promotional activities to raise public awareness of the importance of ω-3 fatty acids [27], encouraging people to increase their intake of fish and seafood; (2) Policies should be formulated to support the development of the fishing and aquaculture industries, ensuring the supply and accessibility of fresh fish and seafood; (3) Communities should provide educational resources on healthy eating, especially for low-income groups, to help them access and prepare foods rich in ω-3 fatty acids.Low-income countries, particularly those in Sub-Saharan Africa and South Asia, bear a heavy burden of ischemic heart disease (IHD) due to inadequate dietary intake of omega-3 fatty acids. This situation can be improved through the following measures: (1) Data Monitoring and Research: Enhance global and regional health monitoring systems to collect data on the burden of IHD and its risk factors, providing a scientific basis for policymaking; (2) Technology Transfer and Support: Developed countries should offer technical and experiential support to resource-limited regions, assisting them in establishing effective public health interventions.The global analysis of the burden of ischemic heart disease caused by low ω-3 fatty acid content in the diet from 1990 to 2021 using the GBD database may provide comprehensive and systematic health data support for public health officials. This analysis could assist them in better formulating policies, optimizing resource allocation, evaluating intervention effects, and addressing the challenge posed by the increased burden of ischemic heart disease due to low ω-3 fatty acid content in the diet.

Nonetheless, this study has several limitations. First, although the GBD dataset is comprehensive and reliable, biases and uncertainties may still exist in its data sources, particularly in low SDI quintiles where data collection may be incomplete or inaccurate [28]. Second, the dietary assessment methods used in this study may have limitations. For example, we cannot entirely rule out the potential influence of other dietary factors on the burden of IHD [29]. Third, this study did not account for the contributions of other potential risk factors (e.g., smoking, hypertension) to IHD burden. Additionally, it is essential to acknowledge that IHD has a complex pathophysiology, making it unclear how much specific dietary interventions can improve its prevention and prognosis. Future research could validate our findings through large-scale, multi-center cohort studies and investigate the impact of other risk factors on IHD burden. Long-term follow-up studies could also provide a more comprehensive evaluation of the long-term effects of dietary interventions on IHD burden [30].

Conclusion

In summary, this study analyzed global disease burden data to untangle the significant impact of a low ω-3 diet on the burden of IHD, emphasizing its global distribution differences and temporal trends. The findings provide an important basis for formulating public health policies and promoting healthy eating. However, further research is still needed to overcome the existing limitations and explore more effective interventions to reduce the impact of a low ω-3 diet on the burden of IHD.

Abbreviations

IHD	Ischemic heart disease
GBD	Global Burden of Disease
DALYs	the global IHD-related Disability-Adjusted Life Years
SDI	Socio-Demographic Index

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Author contributions

Conceptualization, J.X. and T.P.; methodology, J.X., T.P. and L.K.; software, J.X. and T.P.; validation, L.K. and N.W.; formal analysis, J.X. and T.P.; investigation, J.X. and T.P.; resources, J.X., T.P. and L.K.; data curation, N.W.; writing-original draft preparation, J.X., T.P. and L.K.; writing-review and editing, N.W.; visualization, N.W.; supervision, J.X.; project administration, J.X.; funding acquisition, J.X. All authors have read and agreed to the published version of the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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