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Past and Future Trends in the Intestinal Nematode Infections, 1990-2046: A Forecasting Study Based on the Global Burden of Disease

Zhang-zhou Shen[1#], Hou-Qiang Luo[2#], Fen Wang[3], Qin-qin Feng[3]

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ABSTRACT

Background: Intestinal nematode infections are a neglected tropical diseases (NTD) that impose a significant global burden. We report the latest estimates of the global, regional and national burden of intestinal nematode infections from 1990 to 2021, aiming to provide a reference for the development of effective prevention and control strategies worldwide.

Methods: Based on the 2021 global burden of disease study, data on intestinal nematode infections were analyzed by gender, age, year and SDI region and country. Age-standardized rates were used for comparisons between different groups. The EAPC analysis was employed to assess the temporal trends of the disease burden and ARIMA and ES models were used to predict the disease burden from 2022 to 2046.

Result: Compared with 1990, the global burden of intestinal nematode infections declined in 2021, with reductions in prevalence, DALYs and deaths. The age-standardized mortality rate (EAPC: -5.12, 95% CI: -5.2 -5.04), age-standardized DALYs rate (EAPC: -5.65, 95% CI: -5.78 -5.53) and age-standardized prevalence rate (EAPC: -3.59, 95% CI: -3.68 -3.51) all showed downward trend. The predictions based on both ARIMA and ES models indicated that the global burden of intestinal nematode infections is likely continue to decline over the next 25 years. Inspite of this progress, the infection rate remains high in certain African countries and regions. Hence, it is necessary to continuously strengthen prevention and control policies to maintain the downward trend of the disease burden.

Key words: EAPC, ES, Intestinal nematode infections, National burden, SDI region.

INTRODUCTION

Intestinal nematodes (including *Ascaris lumbricoides*, hookworms, *Trichuris trichiura*, *Enterobius vermicularis* and *Strongyloides stercoralis*) are a significant category of parasitic diseases that impose a heavy disease burden worldwide, especially in developing countries (Schuster and Chiodini, 2001; Pisarski, 2019; Pawar *et al.*, 2026). These infections are mainly transmitted orally (such as *A. lumbricoides, T. trichiura, E. vermicularis*) through food/water contaminated with their infective stages (L3 larvae) or skin contact (such as hookworm larvae) and undergo an internal migration before develop into adults in the intestines) (Dorny *et al.*, 2009; Kajero *et al.*, 2022; Ghamdi *et al.*, 2024). Studies have shown that the global infection is substantial with an estimated 599 million people infected with hookworms and 266 million people with *T. trichiura*, causing approximately 20,000 deaths annually and imposing a significant disability adjusted life years (DALYs), estimating 1.817 million DALYs due to hookworms, 1.006 million due to *T. trichiura* and 0.97 million due to *E. vermicularis*) (Pisarski, 2019; Tu *et al.*, 2019; Song *et al.*, 2026), particularly in Southeast Asia and sub-Saharan Africa (Wurthwein *et al.*, 2001; Arhin and Asante-Darko, 2023). In general, these infections present with common symptoms such as abdominal pain, diarrhoea and malnutrition; although, species-specific manifestations are also prominent. For instance, hook worm infections cause chronic blood loss and iron deficiency anemia, whereas *E. vermicularis* is associated with perianal itching (Bair *et al.*, 2004; Brooker, 2010; Al-Eodawee *et al.*, 2024). In summary, intestinal nematode infections remain a major public health concern.

[1]Hubei Key Laboratory for Kidney Disease Pathogenesis and Intervention, Hubei Provincial Engineering Research Center of Immunotherapy Drugs for Renal Tumors, Hubei Polytechnic University, Medical School, Huangshi 435003, Hubei, China.
[2]College of Animal Science, Wenzhou Vocational College of Science and Technology, Wenzhou 325006, Hubei, China.
[3]Department of Obstetrics, Huangshi Maternity and Children's Health Hospital, Affiliated Maternity and Children's Health Hospital of Hubei Polytechnic University, Huangshi 435003, Hubei, China.
[#] These authors contributed equally to this work.

Corresponding Author: Qin-qin Feng, Department of Obstetrics, Huangshi Maternity and Children's Health Hospital, Affiliated Maternity and Children's Health Hospital of Hubei Polytechnic University, Huangshi 435003, Hubei, China.
Email: fqq20200710@163.com

ORCIDs: 0000-0002-0946-0922, 0000-0002-2990-6012, 0009-0005-9779-7435, 0009-0009-0280-1067

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MATERIALS AND METHODS

Data sources and population characteristics

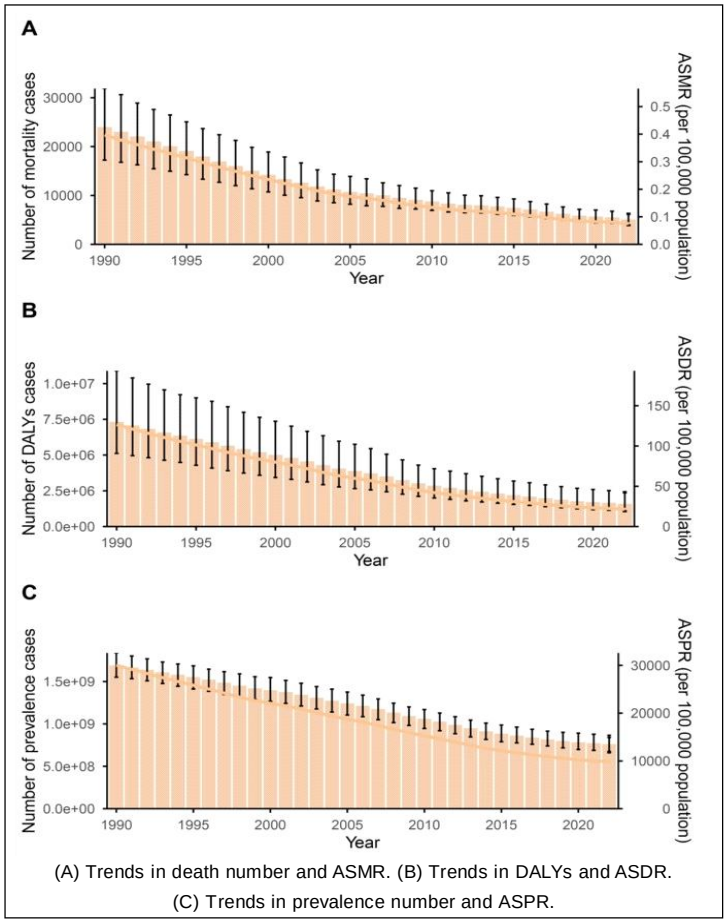
This secondary data analysis was carried out at the Medical School of Hubei Polytechnic University (Huangshi, Hubei, China), where all data processing, statistical analyses and forecasting modeling were performed. All data used in this study were extracted from the Global Burden of Disease (GBD) database (available at https://vizhub.healthdata.org/gbd-results/), covering the period from 1990 to 2021. The dataset comprised the number of deaths, DALYs and incident cases attributed to intestinal nematode infections worldwide, together with the corresponding age standardized rates (ASRs). These estimates spanned over 200 countries and territories, were aggregated into 46 GBD regions and were stratified by sex, five Socio demographic Index (SDI) quintiles and twenty distinct age groups. This comprehensive stratification allowed for detailed temporal and demographic analyses of the global burden of intestinal nematode infections over three decades.

Construction of prediction models

We fitted two complementary time-series models to forecast the burden of intestinal nematode infections from 2022 to 2046. An ARIMA model was selected using the auto.arima() function in R (v4.3.0) with the Akaike Information Criterion (AICc). An Exponential Smoothing (ES) model was simultaneously fitted using the ets() function, with smoothing parameters optimized *via* AICc. For both models, data from 1990 to 2016 served as the training set, while data from 2017 to 2021 were used as the validation set. Prediction accuracy was assessed using root mean square error (RMSE) and mean absolute error (MAE). Final predictions for 2022-2046 were generated by averaging the point estimates from both models to enhance robustness. All analyses were performed using R software (version 4.3.0) with the forecast package.

Methods for analyzing disease trends

First, annual reports were generated for the number of deaths, DALYs, prevalence and age standardized rates attributable to global intestinal nematode infections in both 1990 and 2021, allowing an analysis of the disease's temporal trajectory. Second, we examined changes in the disease burden between 1990 and 2021 across multiple demographic and geographic dimensions, including age, sex, socio demographic index (SDI) quintiles, GBD regions and individual countries. To quantify these temporal trends, a linear regression model was fitted to estimate the estimated annual percentage change (EAPC) for each



(A) Trends in death number and ASMR. (B) Trends in DALYs and ASDR. (C) Trends in prevalence number and ASPR.

Fig 1: Global trends in the disease burden of intestinal nematode infection from 1990 to 2021.

burden indicator. The resulting EAPC values served as metrics for evaluating the direction and magnitude of changes over the three decade study period. Statistical significance was determined using a threshold of $p<0.05$. All stages of data processing including data acquisition, cleaning, stratification, statistical analysis and graphical visualization were carried out using R software (version 4.3.0).

RESULTS AND DISCUSSION

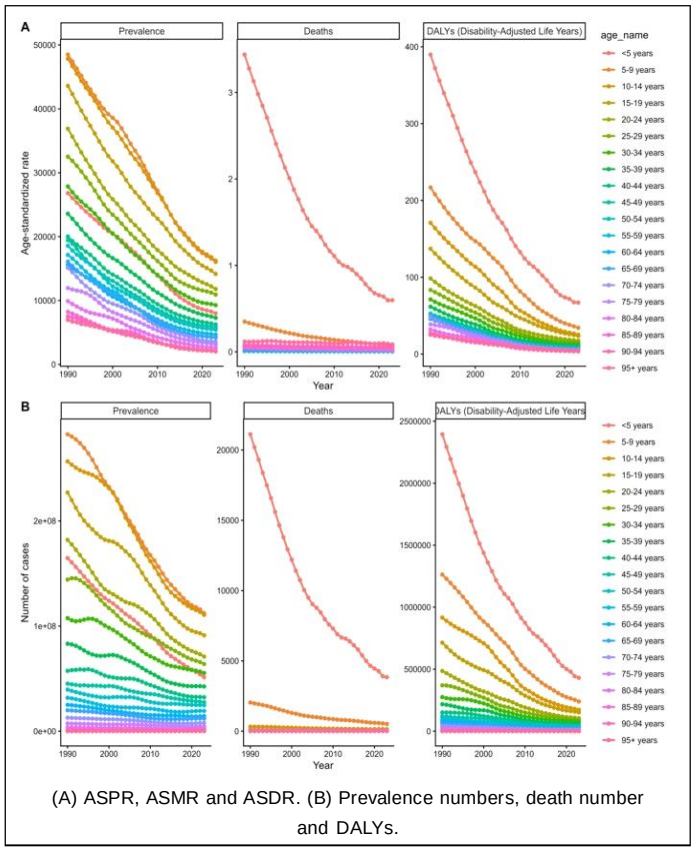
Analysis of global intestinal nematode infections trends (1990-2021)

In 2021, the number of deaths related to intestinal nematode infections was 5,529 (95% UI: 4,323-6,774), with a corresponding ASMR of 0.08 per 100,000 people (95% UI: 0.06-0.10) (Fig 1A). The DALYs totaled 1,660,593, giving an ASDR of 22.43 per 100,000 (Fig 1B). The prevalence number was 773,734,280, with an ASPR of 10,037.02 per 100,000 (Fig 1C). During this period, all three burden indicators showed a consistent downward trend (Fig 1). Compared with 1990 levels, the number of deaths decreased by 77.0% (from 24,015), DALYs by 77.3% (from 7,324,965) and prevalent cases by 54.3% (from 1,692,2 10,617). The estimated annual percentage changes (EAPCs) were -5.12 (95% CI: -5.20 to -5.04) for deaths, -5.65 (95% CI: -5.78 to -5.53) for DALYs and -3.59 (95% CI: -3.68 to -3.51) for prevalence, confirming a steady global reduction trend in the intestinal nematode infections over the three decades.

Subgroup analysis by age, gender, SDI, GBD and country in 2021

Across all age groups, the disease burden indicators, (the number of deaths, DALYs, ASMR and ASDR) peaked in the 0-5y age group and declined thereafter with increasing age. The highest prevalence and ASPR were observed in the 5-9 and 10-14 year age groups. In 2021, children aged <5 years group experienced 4,275 deaths (ASMR: 0.64) and 479,992 DALYs (ASDR: 71.87). The 5-9 y group had the highest prevalence with 117,969,072 cases (ASPR: 16,992.46) followed by the 10-14 y group with115,307,285 cases (ASPR: 17,207.82). In contrast, the ≥95 y age group had the lowest disease burden with only 6 deaths and 273 DALYs. With regard to the gender, the disease burden indicators were comparable between females and males, with only minor variation in the number of deaths, DALYs, prevalence cases and ASRs.

Across SDI regions, in the low SDI region presented the highest disease burden indicators. In 2021, the low SDI region recorded 3,944 deaths (ASMR: 0.18), 930,815 DALYs (ASDR: 47.30) and 261,268,855 prevalent cases (ASPR: 14,391.15), which were substantially higher than the corresponding estimates in high SDI region and the high-middle SDI region.



(A) ASPR, ASMR and ASDR. (B) Prevalence numbers, death number and DALYs.

Fig 2: The trend of intestinal nematode infection in age subgroups from 1990 to 2021.

At the regional level, Central Africa recorded highest ASMR (0.37), whereas Oceania had the highest ASDR (143.98) and ASPR (41,834.54) in 2021. However, the highest disease burden was noticed in World Bank Sub-Saharan Africa region that recorded 4,189 deaths and 867,465 DALYs, while World Bank Lower Middle Income region had the highest prevalence 363,930,749 cases). Among the GBD regions, Eastern Sub-Saharan Africa recorded 1,192 deaths and 328,794 DALYs, while Southeast Asia recorded 894 deaths and 335,001 DALYs. At the national level, intestinal nematode infections were widely distributed in 2021 globally, with casesreported from Africa, Asia and the Americas. The highest ASMR (0.99) and ASDR (238.48) was noticed in the Central African Republic while Peru recorded the highest ASPR (50,931.9). Nigeria had the highest number of deaths (1,065) and DALYs (173,304), while India reported the highest prevalence (116,071,255, cases). Other high-burden countries included the Democratic Republic of the Congo, Ethiopia and Indonesia. In contrast, many high-income countries (*e.g.*, United States, Germany, Japan) reported negligible deaths and prevalent cases, with GBD estimates rounding to zero.

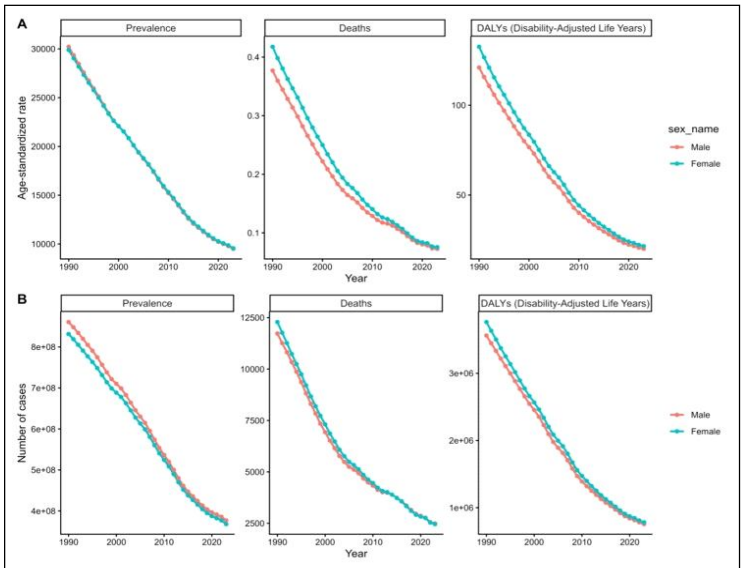
Trend analysis and prediction of disease burden

From 1990 to 2021, all disease burden indicators showed an overall reduction trend across age, gender and SDI groups (Fig 2-4). Age-wise analyses showed that marked reductions in ASMR occured in children aged <5 years (EAPC: -5.38), whereas the smallest decline was noticed in individuals aged ≥95 years (EAPC: -0.83). The greatest decease in DALYs occurred in the 50-54 years age group (EAPC: -6.13). Similar reducing trend was observed in both males and females. Across SDI quintiles, the low SDI region experienced the largest reduction in ASMR (EAPC: -6.22), while the middle SDI region recorded the smallest decline (EAPC: -4.23).

At the regional and national levels, disease burden indicators decreased in most of the GBD regions and countries between 1990 and 2021 (Fig 5). East Asia experienced the grestest reduction in ASDR (EAPC: -11.16), whereas Oceania showed the smallest decline (EAPC: -1.79). Burkina Faso (and Ethiopia experienced the most rapid reduction in ASMR, while increasing trends were observed in a few countries and territories such as Zimbabwe and Vanuatu.

Forecast for 2022-2026 generated employing the ARIMA model indicated a gradual reduction in tASMR, ASDR, ASPR, number of deaths, DALYs and prevalence (Figure 6A-C). Similar trends were obtained using the ES model (Fig 6D-F). However, the ARIMA model projected a substantially greater decline in the disease burden indicators, whereas the ES model predicted a more gradual decrease over the same projection period.

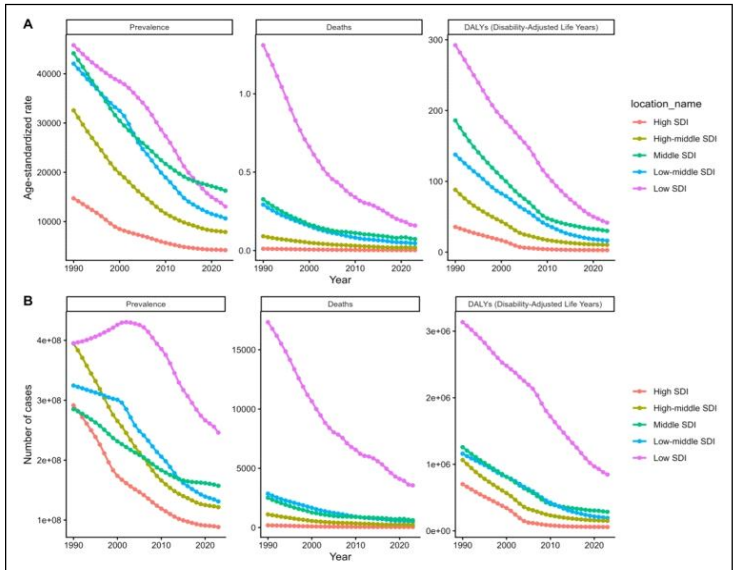
Utilizing the latest GBD 2021 data, the present study assessed the global burden of intestinal nematode infections from 1990 to 2021 and predicted the disease burden for the period from 2022 to 2046 using ARIMA and ES models. Both models predicted continued reduction in disease burden over the next two decades, supporting the reliability of future burden estimates and providing scientific evidence to inform long-term public health policy planning. This reduction in the global burden of intestinal nematode infections is compatible with earlier studies disclosing considerable development progress in the control of neglected tropical diseases. The reduction in the disease burden may be attributable to multiple factors, including enhanced garbage and sewage treatment, promotion of sanitary toilets and tap water, interruption of transmission



(A) ASPR, ASMR and ASDR. (B) Prevalence numbers, death number and DALYs.

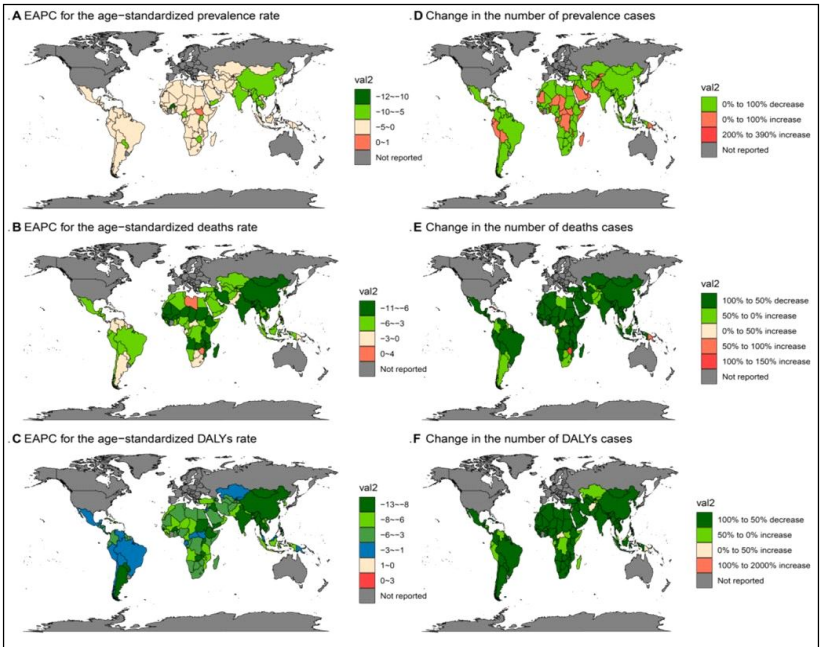
Fig 3: The trend of intestinal nematode infection in sex subgroups from 1990 to 2021.

routes (Cooper and Hollingsworth, 2018; Chen *et al.*, 2021) advanced diagnostic techniques and the widespread use of effective deworming drugs (Chai *et al.*, 2021; Jayakody *et al.*, 2022; Banas *et al.*, 2025). Furthermore, community based health education campaigns and school based deworming programs have played a critical role in breaking the cycle of re-infection, particularly among children in endemic areas. At the global level, the disease burden indicators of intestinal nematode infections in low SDI regions have significantly decreased, thanks to multi-dimensional interventions. This trend reflects the improvement in the medical and health sector investment, (Chen *et al.*, 2021), implementation of regular large-scale deworming campaigns and strengthened collaboration between national governments and international health organization (Hu *et al.*, 2018). These combined efforts have continuously reduced the infection indicators. Despite these achievements, the residual burden in low SDI regions



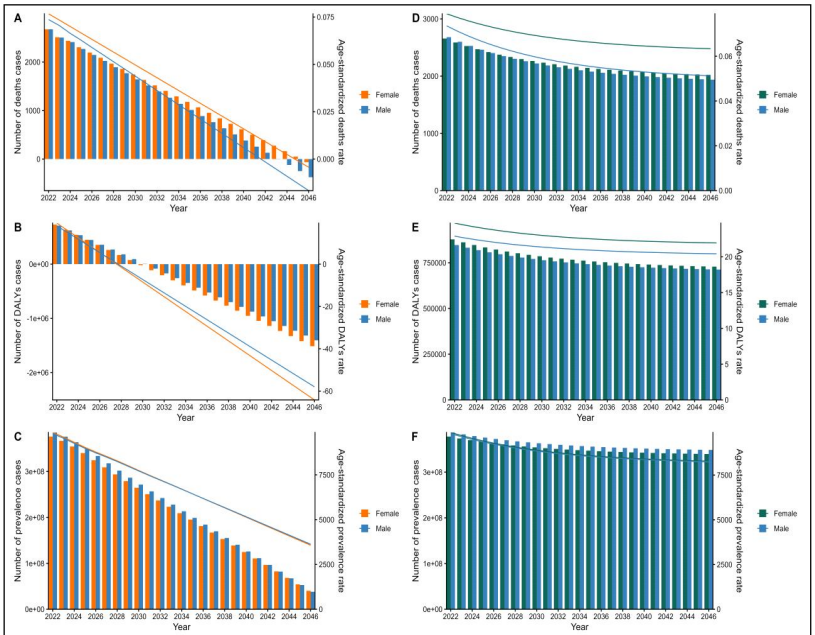
(A) ASPR, ASMR and ASDR. (B) Prevalence numbers, death number and DALYs.

Fig 4: The trend of intestinal nematode infection in SDI subgroups from 1990 to 2021.



(A) ASPR. (B) ASMR. (C) ASDR. (D) Prevalence number. (E) Deaths number. (F) DALYs.

Fig 5: The trend of intestinal nematode infection in national and regional subgroups from 1990 to 2021.



(A) death number and ASMR using the ARIMA model (D) and exponential smoothing model, (B) predicted trends in DALYs and ASDR using the ARIMA model (E) and exponential smoothing model, (C) predicted trends in prevalence number and ASPR using the ARIMA model (F) and exponential smoothing model.

Fig 6: Predicted trends of global intestinal nematode infection.

remains substantially higher than in other SDI quintiles, underscoring the need for sustained investment. Though, most countries and regions presented reducing trend, increasing trend in disease burden indicators were noticed in Southern Sub-Saharan Africa and Zimbabwe. This is likely to be due to the ecological conditions conducive for parasites transmission, weak health infrastructure, lack of public health education and insufficient understanding of the disease's pathogenic mechanism, making it difficult to establish effective prevention mechanisms. This result is consistent with previous research conclusions (Elliott *et al.*, 1999; Pullan *et al.*, 2010). Therefore, to achieve the goal of eliminating the public health threat of intestinal nematode infections globally, more investment and support should be provided to low SDI regions (Bergquist *et al.*, 2015). This study has the following limitations: 1. The GBD data mainly rely on the existing reports and underreporting or incomplete monitoring system, in resource limited areas may have resulted underestimation of disease burden (Hotez *et al.*, 2014). 2. Difference in diagnostic methods and reporting standards among countries may affect the comparability of data. 3. There is insufficient quantitative research on the long-term health impacts of intestinal nematode infections, such as impaired growth cognitive function impairment, *etc.* Moreover, the GBD estimates may not fully capture co infections with other parasites, which could modify disease severity and treatment outcomes. Future studies integrating multi pathogen surveillance would further improve the accuracy of global disease burden assessments.

CONCLUSION

In summary, the global burden of intestinal nematode infections declined between 1990 and 2021 across age groups, gender, SDI regions and most geographic regions. However, the disease burden remained disproportionately high in low SDI regions and increasing trends were observed in a few countries and regions. The results emphasize the need for sustained prevention and control strategies including surveillance, early diagnosis, effective treatment, improvements in water, sanitation and hygiene and public health education. By integrating global estimates on the prevalence of intestinal nematode infections, this study provides evidence to support the development of health policies and most effective resource allocation.

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Disclaimers

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Informed consent

All procedures for experiments were approved by the Committee of Hubei Polytechnic University.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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