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Projected Burden of *Ascaris lumbricoides* Infection Globally and in Afghanistan: Trends, Disparities, and Implications for Control up to 2040

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ABSTRACT

Background: *Ascaris lumbricoides* remains one of the most common soil-transmitted helminths (STHs) worldwide and mostly affects low-income and conflict-affected populations. Global efforts at control have reduced the prevalence in many parts of the world, but substantial inequalities persist. We aimed to project the age-standardized prevalence rates (ASPR) of *A. lumbricoides* globally and in Afghanistan for the period 2023-2040, emphasizing temporal trends and sex-based disparities.
Methods: We used cubic spline regression models to analyze sex-stratified ASPR data from the Global Burden of Disease Study 2023 (1990–2023), forecasting prevalence through 2040 with 95% confidence intervals (CIs) for all estimates.
Results: The ASPR of *A. lumbricoides* in 2023 at a global level was 4319.6 per 100,000 populations, while Afghanistan showed a burden threefold higher, with 12,962.8 per 100,000. In 2040, the global ASPR would decline by 29.6% to 3040.6 per 100,000, whereas Afghanistan's ASPR would decrease only by 21.0% to 10,243.5 per 100,000 and remain 3.4 times above the global average. Females consistently showed higher ASPRs than males both at global and national levels, a trend expected to continue to the year 2040.
Conclusions: Afghanistan is predicted to continue to have extreme levels of ascariasis, with high and inequitable burdens of disease despite continued global progress. These findings underscore serious limitations of aggregate global indicators and the need for precision public-health strategies in high-burden settings that address structural determinants such as conflict, poverty, inadequate sanitation, and gender inequality.

Keywords: *Ascaris lumbricoides;* Age-standardized prevalence rate; Soil-transmitted helminths; Forecasting; Afghanistan; Global burden of disease

Introduction

Ascariasis in human populations is one of the most successful neglected tropical diseases (NTDs) worldwide [1]. *Ascaris lumbricoides* is an intestinal nematode parasite that belongs to soil-transmitted helminths (STHs) [2]. It infects humans by ingesting embryonated eggs from contaminated soil, water, or food and is commonly linked to poor sanitation and hygiene and socioeconomic conditions. The eggs have a high degree of environmental survival and can easily live in a warmer and more humid environment [3].

Approximately 731.8 million people (95% CI: 682–783) were infected with *Ascaris* worldwide in 2021 based on extrapolation to the 2020 human population [3]. Although ascariasis is often asymptomatic, moderate to heavy worm burdens in children have been linked to malnutrition, impaired growth and physical development, and intestinal obstruction. Heavy infections are also associated with adverse effects on nutrient absorption and have been proposed to affect cognitive development and educational outcomes, particularly among school-age children [4, 5]. Ascariasis is most intense in children aged 5–15 years and exhibits an overdispersed distribution, where the majority of individuals carry light infections while a small fraction experience heavy infections [3]. There is evidence suggesting a relationship between *Ascaris* infection and impaired cognitive function, though the mechanisms behind this association remain poorly defined [6].

Despite advances in mass drug administration (MDA) and improvements in socioeconomic conditions, STH infections persist in many low-income and conflict-affected countries, reflecting deep-seated inequities in health access and infrastructure [7]. Control and elimination of *A. lumbricoides* primarily depend on MDA with a small repertoire of anthelmintic agents. Although these interventions have successfully lowered infection prevalence and intensity in many endemic settings, the underlying transmission dynamics remain inadequately characterized. Moreover, reinfection frequently occurs after treatment is discontinued, largely because protective immunity does not develop following infection [8].

Afghanistan continue to report substantial prevalence of *A. lumbricoides*, particularly among children living in rural areas, informal settlements, and conflict-affected regions where health service coverage and sanitation infrastructure remain inadequate [9]. In contrast, Iran has experienced a notable decline in STH prevalence over recent decades, largely attributed to improvements in socioeconomic conditions, urbanization, health education, and sanitation coverage, although residual transmission persists in disadvantaged and rural communities [10, 11]. These inter- and intra-country disparities underscore the influence of structural determinants on ascariasis transmission. Long-term projections of *A. lumbricoides* burden are essential for guiding national and regional control strategies. Population growth, rapid urbanization, climate variability, migration, and unequal implementation of control programs may substantially influence future transmission dynamics. While global burden studies have demonstrated declining age-standardized prevalence and disability-adjusted life years (DALYs) attributable to STH infections, absolute numbers of infected individuals may remain high in endemic regions without sustained and equitable interventions [12–15]. However, country-specific projections extending to 2040 remain limited, particularly for politically and socioeconomically diverse settings such as Afghanistan.

The current analysis endeavors to forecast the global and Afghanistan-specific burdens of *A. lumbricoides* infection until the year 2040, and in doing so, trends, inequalities, and their impact on control measures were investigated. Through the synthesis of burden projections and associated factors, we aimed to contribute toward informed, evidence-guided policymaking and the achievement of STH morbidity elimination, in conformity with global guidelines for neglected tropical diseases and Sustainable Development Goals.

Methods

Data Sources

To project future *A. lumbricoides* prevalence, age-standardized prevalence rates (ASPRs) were sourced from the Global Burden of Disease 2023 study (GBD 2023) through the Global Health Data Exchange (GHDx) (https://vizhub.healthdata.org/gbd-results/). Sex-specific data spanning 1990–2023 globally and for Afghanistan were retrieved and analyzed.

Modeling approach

Future trends in *A. lumbricoides* prevalence were estimated using a cubic spline regression model. The model was calibrated to observed data from 1990 to 2023 through a least-squares fitting approach to minimize residual error, and subsequently used to forecast ASPRs up to 2040. All estimates are presented with corresponding 95% confidence intervals (CIs). Statistical analyses and visualizations were conducted using R software (version 3.4.1).

Results

Global and national burden in 2023

In 2023, the global ASPR of *A. lumbricoides* was estimated at 4,319.6 per 100,000 population. Marked national heterogeneity was observed, with Afghanistan experiencing a substantially higher burden, approximately threefold greater than the global average, at 12,962.8 per 100,000. At both the global and national levels, prevalence was consistently higher among females than males (global: 4,360.8 vs. 4,282.1; Afghanistan: 13,067.5 vs. 12,863.2).

Projected trends and rates of decline to 2040

Model-based projections indicate a sustained decline in the global burden of ascariasis through 2040 (Table 1). The global ASPR is expected to decrease by 29.6%, from 4,319.6 in 2023 to 3,040.6 per 100,000 by 2040 (95% UI: 2,887.4–3,201.8). This projected reduction follows a substantial historical decline of 64.4% between 1990 and 2021, suggesting a long-term downward trend, although the rate of reduction is anticipated to slow in future decades.

Although Afghanistan is projected to follow the overall declining pattern, it is expected to remain a pronounced outlier. The national ASPR is forecast to decline by 21.0%, reaching 10,243.5 per 100,000 by 2040 (95% UI: 10,011.6–10,480.7). Notably, this level remains approximately 3.4 times higher than the projected global average for the same year. Moreover, the slower rate of decline in Afghanistan compared with the global trend (21.0% vs. 29.6% between 2023 and 2040) suggests that relative disparities may persist or slightly widen over time.

Sex-disaggregated projections and persistent inequality

Declining the prevalence is projected for both sexes at the global level and in Afghanistan; however, sex-based differences are expected to remain largely unchanged (Table 1). In Afghanistan, the ASPR among females is projected to reach 10,326.6 per 100,000 by 2040, compared with 10,165.3 per 100,000 among males, yielding a female-to-male prevalence ratio of approximately 1.016, consistent with estimates for 2023. These findings indicate that while overall prevalence is expected to decrease, underlying structural determinants contributing to higher prevalence among females are unlikely to be substantially mitigated under current trends. These trends are visually summarized in Figure 1, which illustrates the observed and projected ASPR from 1990 to 2040 globally and in Afghanistan.

Table 1: Projected age-standardized prevalence rate (ASPR) of *Ascaris lumbricoides* globally and in Afghanistan from 2024 to 2040.

Sex	*Country/region*	*2024*	*2025*	*2030*	*2035*	*2040*	*1990 vs. 2021*	*2023 vs. 2040*
Both	Global	4221.976(4174.82-4269.67)	4136.239(4080.34-4192.9)	3732.976(3636.89-3831.6)	3369.028(3240.69-3502.45)	3040.564(2887.44-3201.81)	-64.443	-29.610
	Afghanistan	12794.359(12730.84-12858.19)	12617.775(12541.94-12694.07)	11770.746(11635.54-11907.52)	10980.578(10793.25-11171.15)	10243.454(10011.61-10480.67)	-50.085	-20.978
Female	Global	4262.063(4215.13-4309.52)	4175.047(4119.42-4231.42)	3765.9(3670.33-3863.95)	3396.849(3269.26-3529.41)	3063.964(2911.8-3224.07)	-64.172	-29.739
	Afghanistan	12898.462(12834.78-12962.46)	12720.425(12644.39-12796.92)	11866.428(11730.86-12003.56)	11069.765(10881.94-11260.83)	10326.587(10094.12-10564.41)	-49.968	-20.975
Male	Global	4185.477(4138.09-4233.41)	4100.898(4044.72-4157.86)	3702.957(3606.35-3802.15)	3343.632(3214.55-3477.9)	3019.174(2865.09-3181.55)	-64.758	-29.492
	Afghanistan	12696.832(12634.14-12759.83)	12521.592(12446.74-12596.89)	11681.008(11547.55-11816)	10896.853(10711.96-11084.94)	10165.339(9936.49-10399.46)	-49.968	-20.973

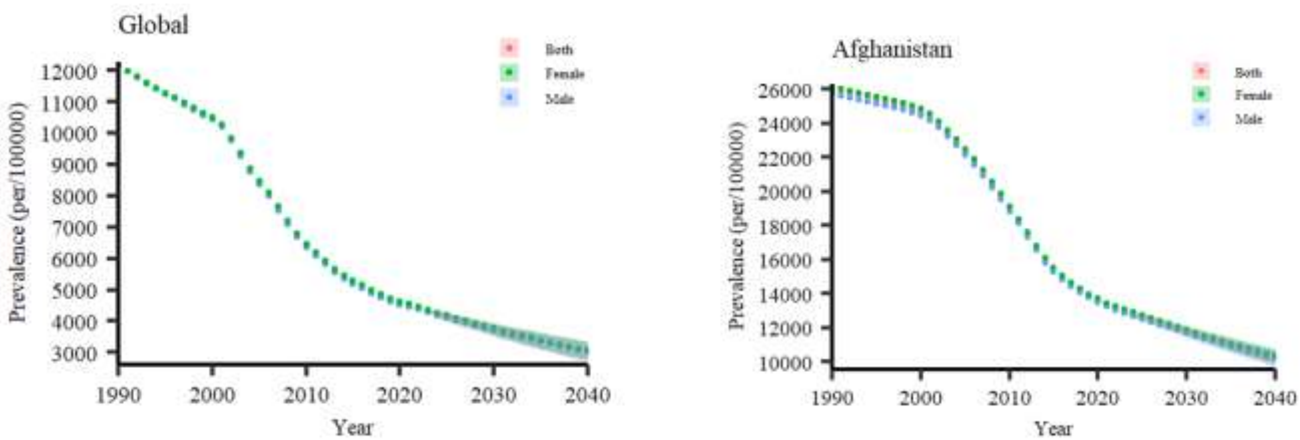

Figure 1: Observed and projected age-standardized prevalence rate (ASPR) of *Ascaris lumbricoides* globally and in Afghanistan in 1990-2040

Discussion

This study provides long-term estimates of *A. lumbricoides* prevalence up to 2040, which shows significantly different trajectories between global trends and those seen in Afghanistan. Afghanistan continues to be marked by a persistently high burden and a slower rate of decline, highlighting significant and persistent health disparities, even though a sustained decline in global ASPR is anticipated. The anticipated global decrease in ASPR between 2023 and 2040 is in line with earlier findings of sustained drops in STH infections, fueled by increased MDA, enhanced WASH, and more general socioeconomic development. These patterns show significant advancements at the population level and are consistent with the WHO NTD roadmap. But depending too much on global averages runs the risk of masking localized control failures [16–18]. Our findings demonstrate that aggregate success masks persistent hotspots where transmission remains intense and progress substantially lags.

Afghanistan's projected trajectory highlights a structural paradox: by 2040, its burden will still be more than three times the global average, despite a declining trend. The combination of ongoing conflict and severely limited infrastructure for health and sanitation is probably the cause of this ongoing excess. These circumstances limit WASH improvements, maintain environmental contamination, and compromise the efficacy and continuity of MDA programs. Furthermore, stopping transmission under conventional control methods is especially difficult when there is a sizable pre-existing reservoir of infection. Afghanistan is a prime example of how, despite overall progress, vulnerable settings may continue to be left out of gains in global health [19, 20].

It is noteworthy that women consistently have higher ASPRs both nationally and internationally [16, 21]. Gendered social and environmental exposures, such as domestic roles that increase contact with contaminated soil and water, as well as unequal access to healthcare and preventive interventions, are more likely to be the cause of this disparity than biological factors. Gender-specific vulnerabilities might not be adequately addressed by current STH control strategies, as indicated by the persistence of this gap in long-term projections [22]. Thus, sex-disaggregated burden estimates highlight the need for gender-responsive intervention design and serve as a crucial indicator of inequality [18, 23].

Together, these findings highlight the fact that uniform, one-size-fits-all strategies cannot be used to advance ascariasis control. In high-burden environments like Afghanistan, comprehensive approaches that go beyond routine deworming are needed to address the underlying structural causes of transmission. These include consistent funding for WASH infrastructure, gender-sensitive and community-based health education, and robust primary healthcare systems that could function in unstable environments. Subnational and sex-disaggregated data should be given priority in global monitoring frameworks to guarantee that enduring disparities are found and corrected. Therefore, a drastic change from standardized to precision public health approaches for STH control is required due to the divergent futures depicted in this modeling analysis.

Control measures must shift from the current emphasis on mass deworming medication administration to development-oriented measures for areas with a high burden, like Afghanistan. Deworming programs must be connected to development initiatives pertaining to the provision of clean drinking water, sanitary facilities, and gender-responsive hygiene practices. However, it is necessary to build robust primary health care systems that can withstand instability.

At an international level, however, it is impossible to define successfully what is to be measured with reference to averages. Monitoring and evaluation structures should therefore emphasize sub-national and sex disaggregated analysis to identify “hot spots” of disease transmission, and at the same time make sure that those most in need are also not left behind. World support and assistance must therefore be flexible and have a long-term perspective in full appreciation of the fact that the social and structural determinants of disease in a fragile state will pose a challenge for several decades to come, and not within the span of project implementation.

From a research and development perspective, there is a need for operational research to be conducted within affected and fragile environments with a view to identifying appropriate distribution strategies for mass drug administration and WASH. From a mixed-methods research perspective, there is a need to gain a deeper understanding of root causes associated with the disparity of suffering from and infected by diseases on a gender differential disparity perspective. There is a need to investigate more on mixed research studies.

A number of limitations should be taken into consideration when interpreting these results. Firstly, these projections are based on GBD projections limited by the availability and accuracy of data on primary surveillance. For example, in conflict zones such as Afghanistan, the lack of data might sometimes produce uncertain results. Secondly, the method of cubic spline regression models takes into consideration the continuation of the historical pattern but ignores possible future breaks, such as massive changes in politics and/or the development of new tools of control. Thirdly, these results are based on age-standardized calculation models that do not take into consideration the importance of intensity of infection as well as its relationship with reinfection and geographic diversity, which are essential factors in transmitting and causation of diseases. Fourthly, uncertainty levels increase when these calculations are performed on the long-term impact, emphasizing that these projections are only possible potential outcomes rather than specific predictions.

Conclusion

Although the estimated global burden of *A. lumbricoides* is set to further decline until 2040, this remains an extremely uneven process. Afghanistan is forecast to continue as an outlier with high burden and sex differences, which not only indicates the limitations of global measures of success but also the application of precise methods within such fragile and high-burden environments is necessary and necessary. Attaining fairness towards the reduction of ascariasis would necessitate continued integrated efforts towards overcoming the structural drivers such as conflict, poverty, poor sanitation, and gender disparity that continue contributing towards such continuing burdens. Otherwise, the global trend towards decline among STH infection may leave vulnerable populations behind.

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Conflicts of interest

The authors declare no competing interests.

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