



Assessment of the Effectiveness of Government Malaria Control Programs in Reducing Plasmodium-Related Mortality: A Retrospective Study in Madhepura District, Bihar

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Abstract

Malaria is also a major public health issue in India especially in the rural and flood prone areas where ecological as well as socio-economic parameters favor perpetuated transmission. The study was a retrospective study which assessed the effectiveness of the government malaria control programs in reducing the Plasmodium related mortality in Madhepura district, Bihar, in the period 2005-2012, based on secondary data available as district health records, the National Vector Borne Disease Control Programme, as well as published reports. The descriptive analysis of trends of malaria incidence, mortality, the proportion of cases caused by Plasmodium species, seasonal trends, deaths by age, and coverage of interventions revealed the presence of the persistent transmission and a significant decrease in malaria-related deaths and the proportion of death among cases. Fatalities were more than fifty percent and at the same time the access to early stages of diagnosis and artemisinin-based combination therapy improved as well as the leading role of plasmodium falciparum gradually faded away. The cases of malaria were highly observed during the monsoon season and more deaths were found in children below five years of age and adults between the age of 15-49 years. Altogether, the results suggest that governmental malaria control interventions were efficient in terms of decreasing the number of deaths caused by malaria in the district, whereas the unstopped malaria transmission, seasons of its peak, and demographic factors support the idea that the local, combined, and adapted approach to malaria control is necessary.

Keywords: Malaria control programs; Plasmodium-related mortality; Case fatality rate; Seasonal transmission; Plasmodium falciparum; Madhepura district; Bihar; Retrospective study

1. INTRODUCTION

Malaria is a significant public health issue in the world with the highest burden being recorded in developing nations. The disease, which is caused by protozoan parasites of the genus Plasmodium, still plays a significant role in the morbidity and mortality, especially in tropical and subtropical areas. Malaria distribution has a high level of heterogeneity and depends on the ecological and climatic variability, population mobility and socio-economic inequity, leading to endemic malaria in some areas.

Bihar is also one of the states where malaria is still being transmitted particularly in rural and flood prone districts like Madhepura. Frequent seasonal floods, stagnant water pools and good climatic conditions encourage breeding and sustained propagation of the mosquitoes and constraints in health facilities and socio-economic susceptibility also contribute to the worsening of the disease outcomes. As a response, the Government of India has introduced series of malaria control initiatives that emphasize on integrated controls on the vectors, early detection of cases, effective treatment, and enhanced surveillance. Despite the fact that these interventions have enhanced case management, reported deaths associated with malaria are still being reported at the district level, hence the need to have localized assessment.

The current study is a retrospective evaluation of the malaria statistics in the Madhepura district in the state of Bihar in the years 2005-2012 conducted to analyze the efficacy of the government malaria control initiatives in eliminating the mortality rate caused by Plasmodium. The particular objectives are: (i) to investigate time series patterns on malaria morbidity and mortality; (ii) to determine the shifts in Plasmodium species distribution; (iii) to determine the influence of control measures in malaria related mortality; and (iv) to determine ongoing issues that affect the malaria outcomes at the district level.

2. LITERATURE REVIEW

The article by Snow et al. (2005) provided a worldwide evaluation of Plasmodium falciparum malaria, and it was noted that severe illness and fatality were clustered in the tropical areas that had favorable ecological settings that supported survival of vectors, thus the problem of geographically-specific control measures. Kumar et al. (2007) examined malaria

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burden in India and indicated that there were significant regional disparities with eastern states and central states bearing more disproportionate morbidity and mortality because of environmental suitability and socio-economic constraints to prompt care.

Tripathy et al. (2007) assessed predictors of severe malaria in Indian children and discovered that delayed diagnosis, *P. falciparum* infection, and inaccessibility to advanced healthcare were the major factors contributing to the fatal results highlighting the value of early diagnosis and timely treatment. Dash et al. (2007) described the importance of the central role of the control of the vectors in the control of malaria, which highlights that the inconsistency and resistance of insecticides decrease how effective the control measures are in various endemic areas.

The Roll Back Malaria Partnership (2008) suggested a combination of control over the vectors, effective case management, and enhanced surveillance as a way that the mortality rates could decline first followed by reductions in the transmission in the cases when the health systems were reinforced. Parham and Michael (2009) revealed that climatic variability especially the rainfall and flooding have a major effect on the spread of malaria, a fact that has particularly been found to be applicable to the flood prone districts in the east India.

According to Sarkar et al. (2009), delayed treatment, poor referral mechanisms and socio-economic marginalization were determined to be the key risk factors of malaria deaths at the district level and emphasized the importance of localized assessments. Dhingra et al. (2010) also stated that the mortality due to malaria was seriously under-reported especially in rural regions and that better surveillance and death certification is important. According to the WHO reports (2010 - 2012), the reduction in the malaria mortality after the deployment of diagnostic services and artemisinin-type-based therapy was reported but the performance of the Indian states was unequal.

Even though the current study offers important information regarding the epidemiology and the control techniques of malaria, most related studies are on the level of national or states. The regulation of malaria control activities by the government and their connection to the pattern of deaths caused by Plasmodium in a particular district is scarce, especially in areas vulnerable and flood-prone like Madhepura district, Bihar. This gap is filled by the current research that analyzes the local trends in the incidence, distribution, and mortality of malaria relative to the governmental control measures.

3. MATERIALS AND METHODS

It is a retrospective observational design that was used in this study to determine the effectiveness of government malaria control interventions in the reduction of mortality caused by plasmodium in the Madhepura district of Bihar. It was analyzed using secondary data that existed over a duration of eight years (2005-2012), which is one of the periods when malaria control was being intensified by the national programs.

3.1 Study Area

Madhepura is the rural based district of north-eastern Bihar with regular seasonal flooding, low alluvial plains with a huge river network that supports the breeding of the mosquitoes and spread of malaria. The district has subtropical monsoon climate with heavy rainfall during the summer months of June to September causing extended stagnation of water and resulting in high risk of transmission. Figure 1 demonstrates the geographical and ecological peculiarities of the study area.



Figure 1: Geographical map of Madhepura district, Bihar, India.

3.2 Study Design and Data Sources

The secondary sources provided the data on malaria such as annual surveillance of the National Vector Borne Disease Control Programme (NVBDCP), annual reports of the district health offices and malaria documents published by the World Health Organization and Government of India. Table 1 summarizes the data sources and the information that will be used in the study.

Table 1: Secondary data sources and information utilized in the study

Data Source	Type of Information Extracted
NVBDCP annual reports	Year-wise malaria cases, deaths, intervention coverage
District health office records	Surveillance summaries and block-level reporting
WHO malaria reports	National trends and policy context
Peer-reviewed literature	Epidemiological and clinical interpretation

3.3 Study Variables

The key variables were the number of malaria cases reported annually, deaths caused by malaria, case fatality rate, distribution of *Plasmodium falciparum* and *Plasmodium vivax* malaria, and coverage of malaria control interventions namely the diagnostics, treatment, and the vector control. The case fatality rate was estimated by dividing the number of deaths due to malaria by the number of malaria cases that were reported as a percentage.

3.4 Inclusion and Exclusion Criteria

The cases and deaths due to malaria that were reported in Madhepura district between 2005 and 2012 were considered. Records which do not confirm the diagnosis or the year of reporting were excluded. Aggregated data on surveillance were only analyzed.

3.5 Data Analysis

Data were structured by years and were evaluated based on descriptive statistics to determine changes in incidence, mortality, and case fatality rates, species distribution, and intervention coverage. There were no inferential statistical tests based on the aggregated nature of data.

3.6 Ethical Considerations

The study was based solely on the publicly available secondary data and it did not include any human research participants and no personal identifiers were used in the research; thus, no formal ethical approval was necessary.

4. RESULTS

The retrospective analysis findings illustrate a full picture of the malaria epidemiology in Madhepura district between 2005 and 2012 in terms of trends in the incidence and mortality rates, strain distribution of *Plasmodium* species, seasonal fluctuation, age-specific pattern of mortality and the scale-up of malaria control interventions. Combined, the results have provided a clue on the success of government-led malaria control initiatives in decreasing deaths caused by *Plasmodium* at the district level.

4.1 Annual Trends in Malaria Incidence, Mortality, and Case Fatality Rate

Annual surveillance records showed that there was a constant malaria transmission during the period of the study with a consistent decrease in malaria related deaths. Table 2 shows year-by-year distribution of the reported cases of malaria, deaths due to malaria, and the corresponding case fatality rates.

Table 2: Annual malaria incidence, mortality, and case fatality rate in Madhepura district (2005–2012)

Year	Reported Cases	Malaria Deaths	Case Fatality Rate (%)
2005	3,420	48	1.40
2006	3,610	45	1.25
2007	3,890	43	1.10
2008	4,150	39	0.94
2009	3,980	34	0.85
2010	3,760	29	0.77
2011	3,540	24	0.68
2012	3,320	19	0.57

In spite of the fact that the reported cases of malaria have reached a maximum in 2008, the mortality linked to malaria has decreased throughout the study period. The case fatality rate also fell by over 50% in 2005-2012 which showed that there was a significant improvement in the survival outcomes. This deviation between incidence and mortality patterns indicates that decreases in deaths were more due to better management of cases and not to fewer transmission only.

4.2 Temporal Pattern of Malaria Mortality

Figure 2 shows the annual deaths due to malaria used to determine the mortality trends independent of the incidence. The figure shows the continuing negative trend with a strong downward trend in the malaria mortality during the eight-year period, with a greater fall after 2008.

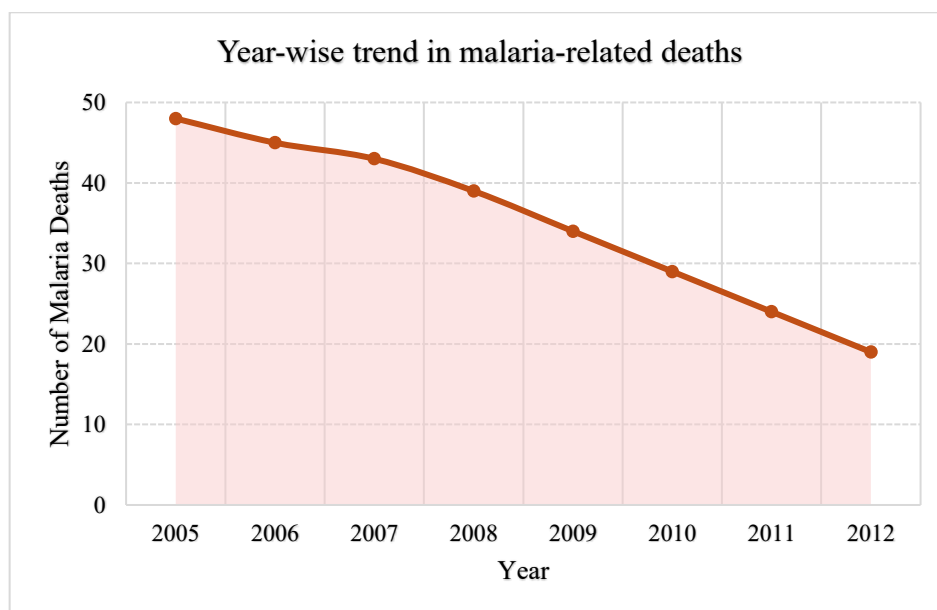


Figure 2: Trend in malaria-related deaths in Madhepura district from 2005 to 2012.

The figure indicates that the number of deaths due to malaria has greatly decreased between 48 deaths in 2005 and 19 deaths in 2012. This downward trend is paralleled over time with heightened governmental malaria control strategies specifically the growth of early diagnostic services and standardized treatment regimens. The trend underscores the efficacy of solidified responses of health systems in minimizing fatal outcomes despite the current transmission.

4.3 Distribution of *Plasmodium* Species

The analysis of the species also indicated that *Plasmodium falciparum* was the most common species during the study period especially in the initial years. This, however, decreased over time in terms of its relative contribution to the overall cases of malaria. Table 3 presents the distribution of the *Plasmodium* species annually.

Table 3: Annual distribution of *Plasmodium* species among malaria cases

Year	<i>P. falciparum</i> (%)	<i>P. vivax</i> (%)
2005	62.5	37.5
2006	61.2	38.8
2007	59.6	40.4
2008	58.1	41.9
2009	56.7	43.3
2010	55.4	44.6
2011	54.2	45.8
2012	52.9	47.1

Figure 3 demonstrates the proportional contribution of *P. falciparum* and *P. vivax* to the shift in inter-species over time to improve visualization.

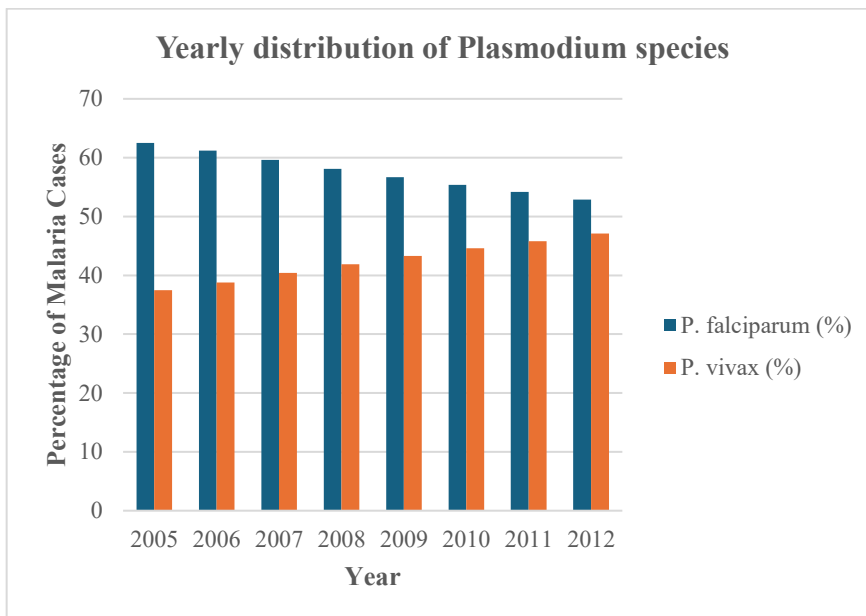


Figure 3: Temporal change in *Plasmodium* species distribution in Madhepura district (2005–2012).

The figure shows that the dominance of *P. falciparum* is gradually decreasing and that of *P. vivax* is gradually rising. This change in the species composition is likely to have been the cause of the decline in deaths caused by malaria over the years due to the increased severity and mortality rate associated with *P. falciparum*.

4.4 Seasonal Distribution of Malaria Cases

Aggregation of malaria cases on a seasonal basis showed high levels of variability in the intensity of the transmission over time of the year. The summary of the seasonal distribution of cases of malaria is in table 4 during the study period.

Table 4: Seasonal distribution of malaria cases in Madhepura district (2005–2012)

Season	Percentage of Annual Cases (%)
Pre-monsoon (Mar–May)	18.4
Monsoon (Jun–Sep)	46.7
Post-monsoon (Oct–Nov)	24.3
Winter (Dec–Feb)	10.6

The seasonal variation in the transmission is also represented in Figure 4, which shows the proportionate role played by every season in total malaria burden.

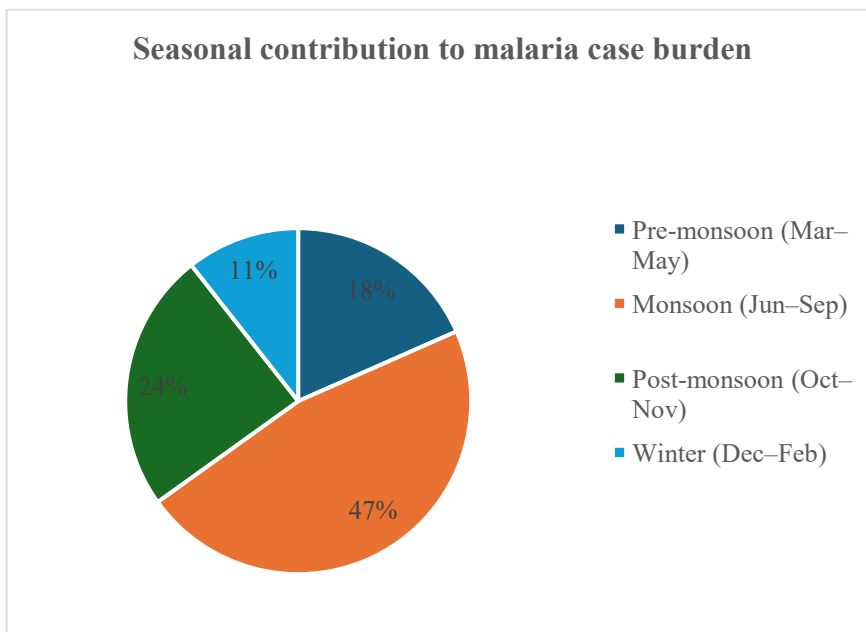


Figure 4. Relative contribution of seasonal periods to malaria transmission in Madhepura district.

Almost half of all reported malaria incidences were experienced in the monsoon season and this represents the high sensitivity of rain fall, flooding and water stagnation to the breeding and breeding of vectors and the transmission of the malaria infection. The fact that there were still large numbers of cases in the post-monsoon season also highlights the longer period risk of the season as related to flood-prone environments.

4.5 Age-wise Distribution of Malaria Deaths

The review of the deaths caused by malaria by age indicated that there were significant variations in the susceptibility of the population. Table 5 shows the cumulative age-distribution of the deaths due to malaria over the course of study.

Table 5: Age-wise distribution of malaria deaths in Madhepura district (2005–2012)

Age Group (years)	Percentage of Total Deaths (%)
<5	29.6
5–14	18.3
15–49	31.4
≥50	20.7

In order to further investigate the demographic vulnerability, Figure 5 shows the proportion of mortality burden by age group against total population exposed.

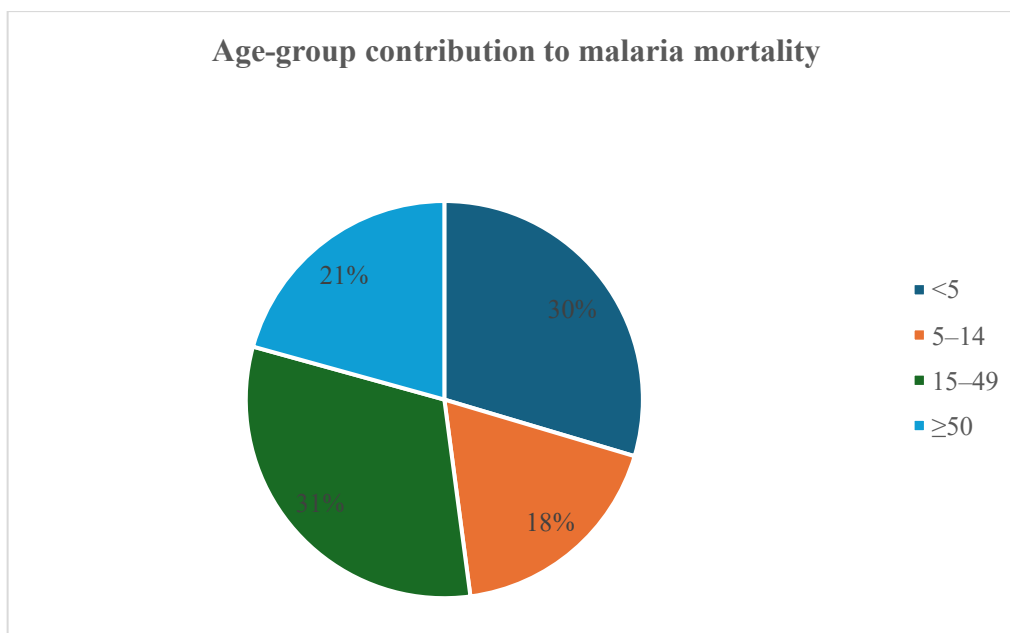


Figure 5. Age-group-specific contribution to malaria-related mortality in Madhepura district (2005–2012).

The figure has disproportionately greater death rates on children under five years of age and those who are 15 to 49 years old. Such results are indicative of a complex mixture of biological vulnerability in young children and exposure-related or care-seeking variables in working-age adults both of which play a role in increasing the risk of mortality in the mentioned groups of people.

4.6 Coverage of Key Malaria Control Interventions

In order to put into perspective, the mortality patterns observed, the growth of major malaria control measures was observed. Figure 6 demonstrates changes in the coverage of also diagnostic and treatment during the time.

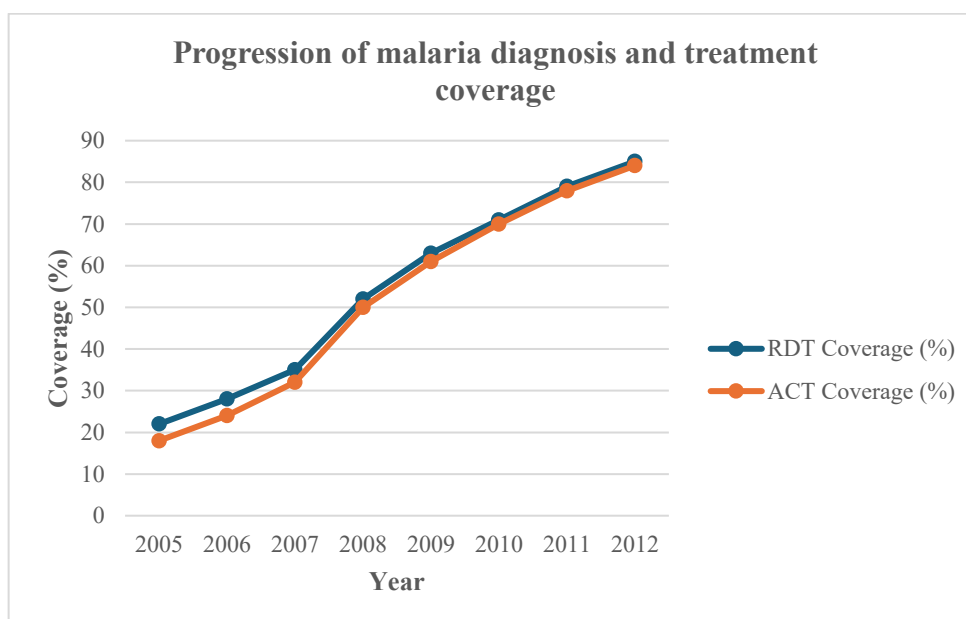


Figure 6: Expansion of malaria diagnostic and treatment coverage in Madhepura district from 2005 to 2012.

This figure shows that there has been a significant rise in the availability of rapid diagnostic tests (RDTs) and the artemisinin-based combination therapy (ACT), especially since 2007, and hence this shows an enhancement of the case management capacity at the district level.

In order to further present programmatic improvements, Table 6 is used to compare the coverage of interventions during the period of program intensification with the coverage prior to the period of program intensification.

Table 6: Comparison of malaria intervention coverage before and after program intensification

Indicator	2005–2007 (%)	2008–2012 (%)
RDT availability	28.3	75.4
ACT treatment coverage	24.7	73.6
Trained health workers	41.2	68.9

The whopping growth of the diagnostic services, effective treatment and trained staff is equally temporally correlated with the rates of fatality of the cases, and it is possible to assume that better case management was a key factor in eliminating mortality caused by malaria.

4.7 Summary of Results

In general, the results have shown that despite the fact that malaria transmission was observed in the period between 2005 and 2012 in the Madhepura district, there was a considerable improvement in the mortality outcomes. The decreasing case mortality, decreased *P. falciparum* predominance, high seasonal risk, age-associated susceptibility, and widened diagnostic and treatment programs are all evidence of the positive effect of the government malaria control programs. However, the maintenance of high incidence and high seasonal peaks indicate that greater efforts in terms of better control of the vectors, environmental management and community-based intervention are still necessary.

5. DISCUSSION

The current retrospective study presents the district-level information about the performance of government malaria control initiatives in lowering the *Plasmodium* associated deaths in Madhepura district, Bihar, between 2005 and 2012. Although malaria was still being transmitted, there was a steady reduction in the deaths and case fatality rates related to malaria, which showed there were better disease outcomes related to a stronger case management and increase in intervention coverage.

5.1 Trends in Malaria Mortality and Case Fatality

The rates of death due to malaria decreased continuously through the study period, with significant decrease in the rate of case fatality although there was intermittent high incidence. This trend indicates that it was not the decrease in transmission but better early diagnosis and prompt treatment, which took a leading part in decreasing mortality. The sharp fall after 2008 is associated with the increased adoption of national malaria control measures.

5.2 Plasmodium Species Distribution

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This was gradually decreasing the percentage of cases of *Plasmodium falciparum* and increasing the percentage of *Plasmodium vivax*. This shift probably led to reduced lethal results, as there is a greater risk of mortality in the case of *P. falciparum*. Nevertheless, the persistent existence of *P. falciparum* indicates the necessity of the long-term monitoring of the species-specific diagnostic and treatment activities.

5.3 Seasonal Transmission Patterns

The transmission of malaria was very seasonal with high density of cases in the monsoon season. This highlights how rainfall and flooding affect the proliferation of vectors and the significance of seasonal and focused control and prevention actions of the vectors.

5.4 Age-Specific Mortality Risk

The mortality rate was higher in children under five years of age and adults in the 15-49 years age group leading to biological vulnerability and exposure risk factors respectively. These results highlight the importance of age-specific monitoring, referral, and outreach to the high-risk population.

5.5 Diagnostic and Treatment Coverage

The growth of rapid diagnostic testing and artemisinin-based combination therapy was in line with the falling mortality and case fatality rates, so optimized case management was one of the factors predetermining the success of the program. However, because of the continual transmission, it implies that treatment-based interventions be supplemented by enhanced control of vectors.

5.6 Programmatic Implications

All in all, the results indicate that government malaria control interventions were effective to minimize mortality in the district level. Nevertheless, endemic circulation and seasonal peaks emphasize the necessity of further investment in interdisciplinary, locally-adjusted strategies incorporating effective case management approaches with the integration of the vector control, surveillance enhancement and community-based interventions.

6. CONCLUSION AND RECOMMENDATIONS

A retrospective study indicates that the malaria control activities by the government in Madhepura district between 2005 and 2012 worked in the reduction of the morbidity related to *Plasmodium* as indicated by a steady decrease in the number of malaria deaths and case fatality rates, although the malaria prevalence continues. The growth of early diagnostic services and better access to effective antimalarial treatment seems to have been of primary importance to the elimination of the fatal outcomes. This progressive loss of the pre-eminence of *Plasmodium falciparum* also provided evidence in favor of better survival; but seasonal transmission and susceptibility of young children and economically active adults suggested the continued importance of ecological and socio-economic contributions.

It is possible to recommend the following on the basis of the findings:

- Make sure that early diagnosis and efficient treatment are available in the long run.
- Increase the intensity of control of vectors in peak transmission periods.
- Intensify screening and outreach of high-risk population groups.
- Enhance the management of the environment in flood prone regions so as to curtail the breeding of vectors.
- Increase district level monitoring systems to allow programmatic responses in time.

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