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From Control to Elimination: Integrated Impact of Malaria Interventions in the Yunnan Province of China from 1983 to 2013

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Abstract

Background: Malaria remains a significant public health problem in the border areas of Yunnan Province, China. Yunnan faces an increasing risk of imported malaria cases from its border countries of Myanmar, Laos and Vietnam. Imported malaria has slowed efforts to eliminate malaria in the province. The aim of this study is to understand the past and present malaria situation in Yunnan Province and to identify the challenges involved in controlling the disease.

Methods: A retrospective study was conducted of the past 30 years of surveillance data from relevant sources on malaria in Yunnan. Researchers collected data on malaria cases from 1983 to 2013 from the China Information System for Disease Control and Prevention, as well as from case investigation reports.

Results: From 1983 to 2013, a total of 375,602 malaria cases were reported in Yunnan Province; 739 of these resulted in death. Of the total number of malaria cases, 72.71% were infected with *Plasmodium vivax*, 21.17% with *P. falciparum*, 0.02% with *P. malariae*, 1.43% with mixed infection cases, and 4.67% of untyped cases. Of the total number of reported cases, 207,956 were reported from the border 25 counties, comprising 55.4% of the total malaria cases and 44.6% (167,646) were reported from the inland counties (the other 104 counties) of the province. The malaria Prevalence rates (MPRs) decreased from 64.8 per 100,000 in 1983 to 0.9 per 100,000 in 2013, which is equal to a 98.6% reduction in the malaria burden. Among the border 25 counties, the malaria prevalence rates decreased from 179.8 per 100,000 in 1983 to 4.5 per 100,000 in 2013, which equates to a reduction of the malaria burden by 97.5%. The malaria prevalence rates in the inland counties decreased from 45.4 per 100,000 in 1983 to 0.3 per 100,000 in 2013, which equates to a reduction of the malaria burden by 99.3%. In 1983, malaria was prevalent in the northwest of Yunnan, Yuanjiang-Honghe River Valley and border areas; but it remained prevalent in the western and southern border areas of Yunnan in 2013. The population at high risk of contracting malaria is the young male farmers and migrant workers in summer and fall. An analysis of the integrated interventions showed that interventions have been effective in preventing and controlling malaria.

Conclusion: From 1983 to 2013, malaria control has been effective in Yunnan Province. Malaria has almost been eliminated in the inland areas. Future control interventions should focus on the border areas.

Keywords: Malaria; Epidemiological characteristics; Prevalence; Control and elimination; Yunnan; China

Background

Malaria, a widespread mosquito-borne disease transmitted by the bites of Anopheles mosquitoes, continues to be a major public health problem world-wide, affecting more than 100 endemic countries and resulting in almost one million deaths annually. The main endemic areas are Sub-Saharan Africa, South America, the Pacific Islands and Southeast Asian countries [1-3].

Yunnan Province, located in the southern part of China, at 97°31′-106°12′E, 21°8′-29°15′N, has a total area of 394,000 km^2. There are 16 prefectures with 129 counties. The province is bordered by the Guizhou Province and the Guangxi Zhuang Autonomous Region in the east, the Tibet Autonomous Region in the northwest, and the Qinghai-Tibet Plateau in the southwest. It also borders three countries: Myanmar in the west, and Laos and Vietnam in the south. The border between Yunnan and its neighboring countries is 4,060 km long. The Yunnan province has special geographical and climate conditions beneficial to a scope propagation of anopheles mosquitoes. In the last 30 years, Yunnan has been the most endemic area of malaria. It remains one of China's most difficult areas for the prevention and control of malaria [4-9].

Malaria cases infected with the strains *Plasmodium vivax*, *P. falciparum*, *P. malariae* and *P. ovale* have been reported in the past, meaning that malaria has remained a major public health problem in Yunnan province. However, the most prevalent species are *P. vivax* and *P. falciparum*. The malaria prevalence rate in Yunnan province dropped from 2493.8 per 100,000 in 1953 to 64.84 per 100,000 in 1983. Until 2005, the malaria prevalence rate was 29.7 per 100,000, with 15,072 confirmed and 26,084 suspected malaria cases and 37 reported deaths. And the number of malaria confirmed cases in Yunnan accounted for 15,072 of the 42,319 total cases in whole China [10]. In 2010, the Ministry of Health launched 'The malaria elimination program of China (2010-2020)' [11] and Yunnan initiated their own malaria elimination project. In recent years, the malaria prevalence rate has continued to decline, but the number of malaria cases in the Yunnan province has been and continues to be ranked in the top position in China [12-15]. Yunnan remains the main focus of China's malaria elimination program.

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This retrospective study of surveillance data and relevant reference materials on malaria in Yunnan was conducted to understand the past and present malaria situation and to identify the challenges involved in malaria control and elimination.

Methods

Research design

A retrospective study was conducted to describe the trends of malaria prevalence in Yunnan in the last 30 years (1983-2013).

Data collection

Data from the China Information System for Disease Control and Prevention and case investigation reports were employed in a retrospective analysis of data on malaria cases and interventions. Based on malaria diagnostic criteria, malaria cases included microscope and/or rapid diagnostic test cases, typical clinic cases and suspected cases [16]. National censuses and Yunnan yearbooks supplied population data. Annual malaria prevalence rate was calculated for both the border and inland counties. Analyses of the characteristics and changes in malaria prevalence were conducted from three perspectives: seasonal, geographical, and demographic. In order to correlate the data from the three perspectives, the researchers used ArcGIS10.1 software to generate a map of malaria prevalence rate and a chart of the average monthly Prevalence rate (AMPR) for the years 1983-1992, 1993-2002 and 2003-2013 and the average monthly Prevalence rate for 1983, 1993, 2003 and 2013 respectively. The sex, age and occupations were compiled for patients who had malaria in1993 and 2013.

Researchers correlated interventions and Prevalence rates (PRs) with the aid of the SPSS 21.0 statistics. To analyze the interventions between 1993, 2003 and 2009, respectively, malaria prevalence rates were compared of the counties taking interventions and not taking interventions counties for the years 1992 and 1993, 2002 and 2003, 2008 and 2009. the following data were collected: the comparative malaria prevalence rate of the counties of taking interventions and contrast counties, together with data on 4 main kinds of malaria interventions: (1) Organizational interventions: malaria microscopy examination stations, training, supervision and technical guidance; (2) Surveillance interventions: blood smear examination of febrile patients, blood smear examination of local residents, blood testing of temporary local population, blood testing of local population returning from overseas, and blood testing of input personnel; (3) Treatment interventions: treated for anti-relapse in spring, Mass administration medicine, prophylaxis during transmission season and radical treatment of malaria patients; (4) Anti-mosquito interventions: insecticide spraying indoor/outdoor, ITNs/LLINs: using insecticide-treated mosquito nets/long-lasting insecticide-treated nets. Control malaria interventions were used as the independent variables and malaria prevalence rates as the dependent variables in the logistic regression analysis.

Statistical analysis

A descriptive analysis of the three-dimensional (seasonal, geographical and demographic) distribution was generated from data entered in Microsoft Excel 2007 spreadsheets to calculate the malaria prevalence rates. An electronic map was drawn using ArcGIS 10.1 software. The SPSS 21.0 software was used to correlate interventions with malaria prevalence rates. The associations between proportions were tested using the chi-square test and 95% confidence intervals. Spearman's correlation analysis and multivariate stepwise linear regression analysis were used to explore the relationship between vector densities and interventions. All reported p-values are two sided: differences were considered statistically significant if $p<0.05$ in two-tailed tests.

Ethical considerations

The Ethics Committee of the Yunnan Institute of Parasitic Diseases approved this study. All data used were approved and documented by the China Information System for Disease Control and Prevention, Government of China.

Results

Overall prevalence of malaria

A total of 375,602 malaria cases were reported in Yunnan Province from 1983 to 2013. The average annual malaria prevalence rate was 32.8 per 100,000 for the entire time period. The Figure 1A shows that malaria prevalence has been decreasing continuously, the highest prevalence was recorded as 64.8/100,000 in 1983 and the lowest was recorded as 0.9/100,000 in 2013. This time period the malaria cases increased from 1986 to 1989, 1996 to 1999 and 2000 to 2003 respectively. Especially, the malaria prevalence rate for the border counties has not been stable. Out of the total number of malaria cases reported, 55.4% were in the border 25 counties and 44.6% were in inland counties. The average annual prevalence rate for province decreased 98.6% from 1983 to 2013(from 64.8 per 100,000 in 1983 to 0.9 per 100,000 in 2013). The average annual malaria prevalence rate for the border counties decreased 97.5% from 1983 to 2013 (from 179.8 per 100,000 in 1983 to 4.5 per 100,000 in 2013). The average annual malaria prevalence rate for the inland counties decreased 99.4% from 1983 to 2013(from 45.4 per 100,000 in 1983 to 0.3 per 100,000 in 2013).

Of all the malaria cases, 273,103 (72.71%) were infected with *P. vivax* mosquitoes, 79,501 (21.17%) cases with *P. falciparum*, 63 (0.02%) cases with *P. malariae*, 5,367 (1.43%) with mixed infection cases and 17,568 (4.67%) with untyped cases. 739 (0.2%) cases died. The *P. vivax* prevalence decreased by 98.3% from 44.4 per 100,000 in 1983 to 0.8 per 100, 000 in 2013. *P. falciparum* prevalence decreased by 99.0% from 16.2 per 100,000 in 1983 to 0.2 per 100, 000 in 2013. Figure 1B showed that infection with the *P. vivax* strain had two peaks: in 1992 (35.4 per 100,000) and 2003 (25.8 per 100,000) although it sharply decreased from 2007 to 2013.

Effect of seasonality on malaria prevalence

Obvious seasonal characteristics were observed in malaria prevalence rates during the study period (Figure 2). The average monthly prevalence rate increased in March 1983-1992, 1993-2002 and 2003-2013. Malaria prevalence was highest between May and September in 1983-1992, 1993-2002 and 2003-2013. From 1983 to 1992, the highest rate of average monthly prevalence was recorded in June (7.0 per 100,000), and the lowest was recorded in February (1.0 per 100,000), with the average monthly prevalence rate decreasing continuously from October. Malaria prevalence was highest between May and July, from 1993 and 2002, with the average monthly prevalence rate decreasing in August and increasing (2.0 per 100,000) in October. The highest recorded rate was in June, and the lowest was in February. Malaria prevalence was highest between April and June, from 2003 to 2013. The highest average monthly prevalence rate was recorded in May and the lowest from November to December.

Our analysis of the monthly prevalence rates in 1983, 1993, 2003 and 2013 showed that malaria was the most prevalent between June

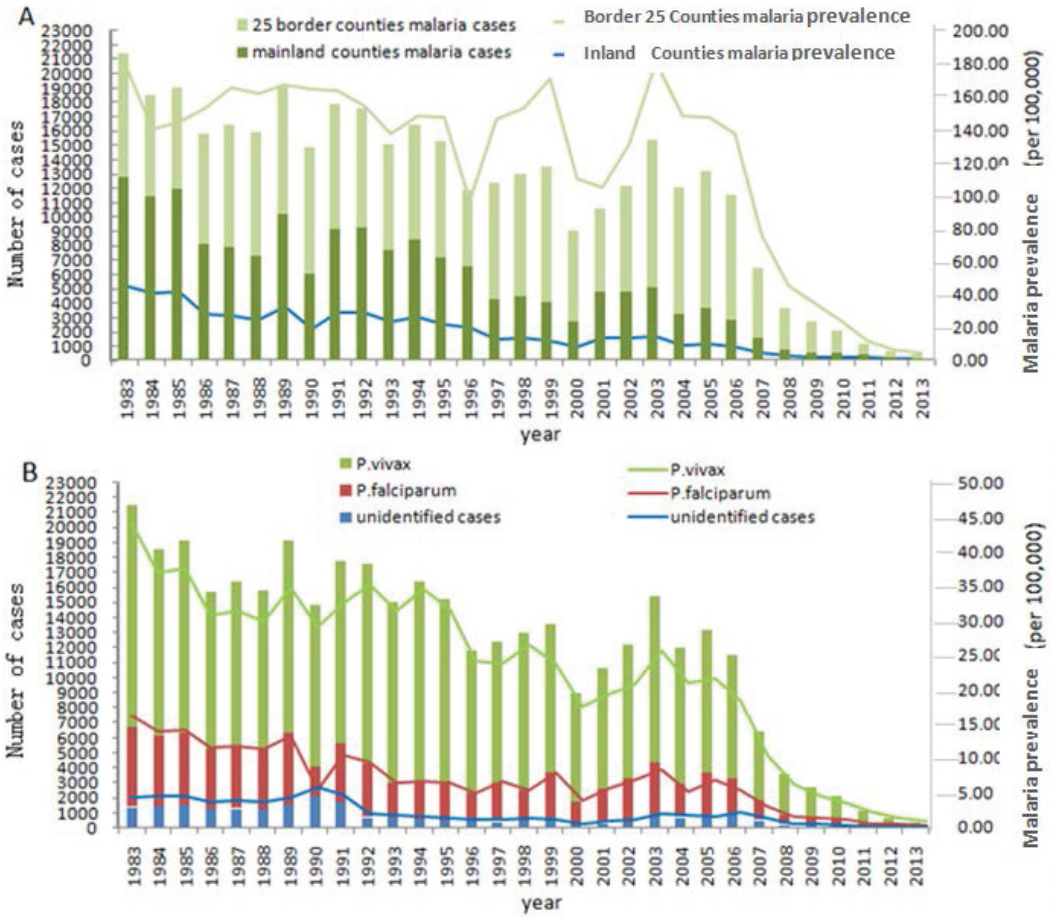
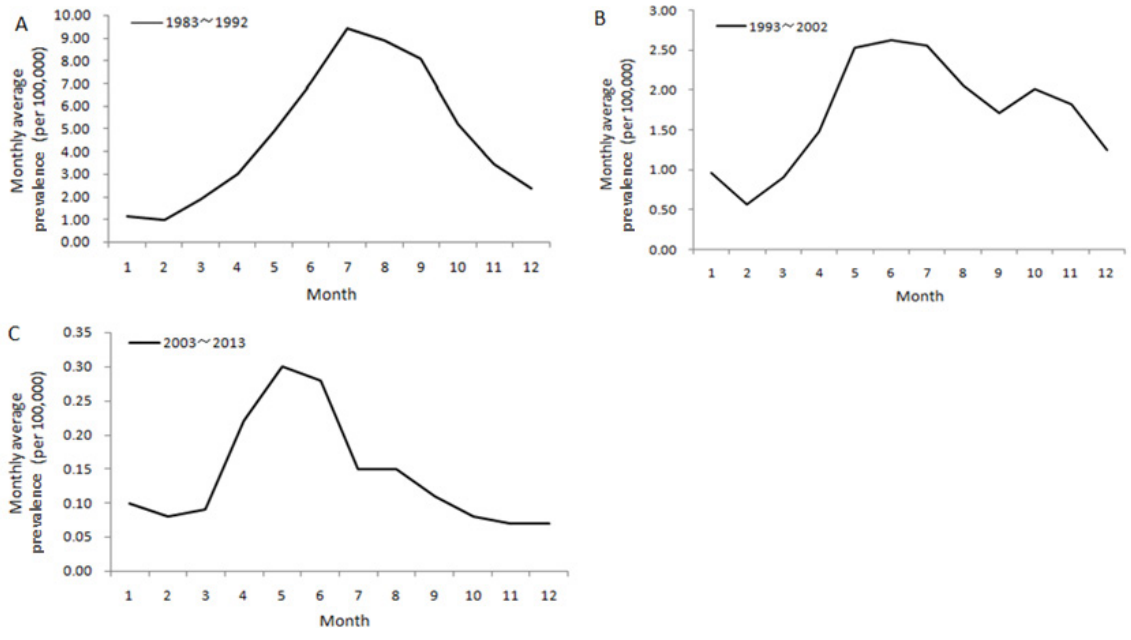


Figure 1: The annual prevalence of malaria and reported malaria cases in Yunnan from 1983 to 2013.
A: Border counties and prevalence inland counties malaria prevalence rates and cases; B: *P. vivax, P. falciparum* and untyped malaria prevalence rates and cases.



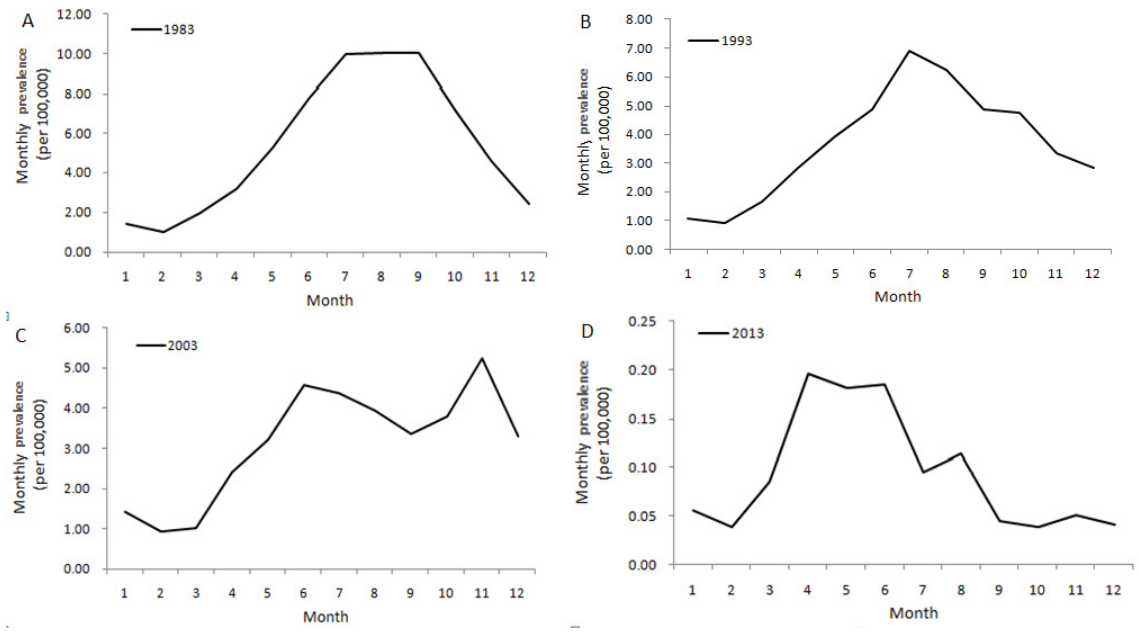
The epidemic curve shows infection with *P. vivax*, *P. falciparum* and *P. malariae,* mixed infection cases and untyped cases

Figure 2: Average monthly prevalence rate of malaria in Yunnan from 1983 to 2013.

and September in 1983. The highest monthly prevalence rate was observed in July, and the lowest monthly prevalence rate was observed in February with the monthly prevalence rate decreasing continuously from October. In 1993, June to September was the most prevalent season for malaria; the highest monthly prevalence rate was observed in July, with the monthly prevalence rate decreasing continuously from October. There were two high prevalence rates in 2003: in June (4.6 per 100,000) and November (5.3 per 100,000). In 2013, the highest monthly prevalence rate was observed in April. The monthly prevalence rate began decreasing in June and then increased in August (Figure 3).

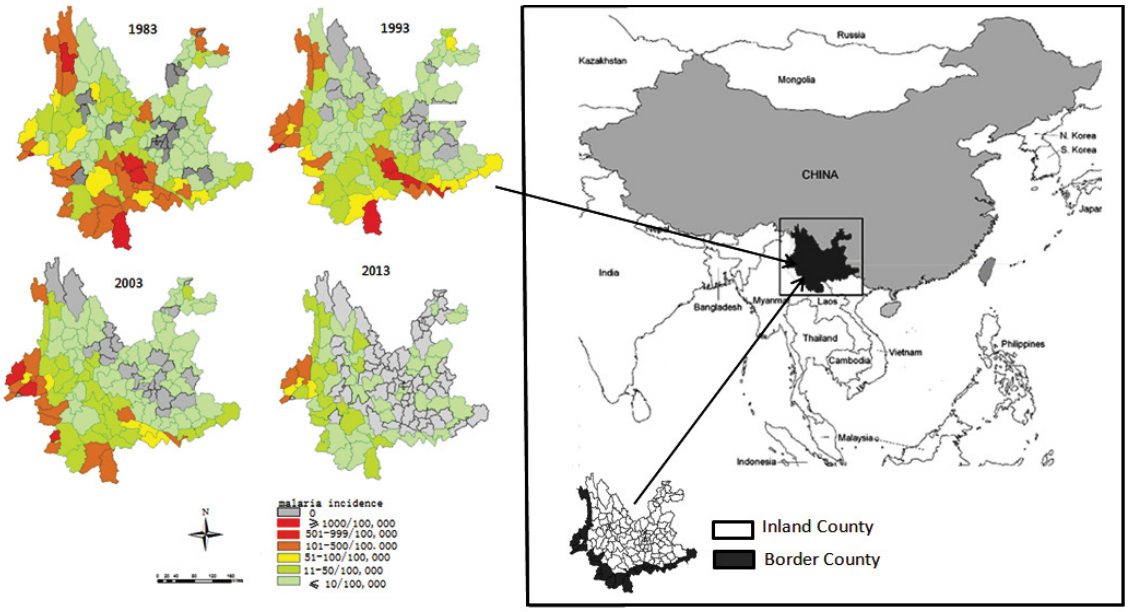
Geographical distribution

Figure 4 shows the geographical distribution of malaria in Yunnan. The malaria-endemic areas were in the northwest part of



The epidemic curve shows infection with *P. vivax*, *P. falciparum* and *P. malariae,* mixed infection cases and untyped cases

Figure 3: Effect of seasonality on malaria prevalence in Yunnan, by month.



Note: In 1983, Weixi County, Fugong County, Gongshan County and Tengchong County in the northwest, in Suijiang County, Yanjin County and Shuifu County in the northeast, in the main counties of the Yuanjiang-Honghe River Valley and border areas of Xin Ping County, Yuanjiang County, Honghe County and Yuanyang County, as well as Myanmar to the west of Yunnan and Laos and Vietnam in the south

Figure 4: Geographical distribution of malaria in Yunnan, in 1983, 1993, 2003 and 2003.

Yunnan Province, in the Yuanjiang-Honghe River Valley and border areas in 1983, 1993 and 2003. However, the most malaria-prevalent region was in border areas of Yunnan in 2013.The prevalence rate of malaria changed markedly in the Yunnan Province from 1983 to 2013. The average annual malaria prevalence rate of Mengla and Weixi counties was more than 1,000 per 100,000 in 1983 and for Mengla County in 1993; Yuanjiang and Xinping counties in 1983, Hekou, Honghe, Yuanyang Counties in 1993, Rui Li City in 1993, Ximeng and Ying Jiang Counties and Mang City in 2003 had malaria prevalence rates between 501 and 1,000 per 100,000; border 25 counties had the average annual malaria prevalence rate of 51-500 per 100,000 in 1983. The same number as the average annual malaria prevalence rate also be seen in 11 counties in 1993, 13 counties in 2003, and three counties in 2013. The number of the average annual malaria prevalence rate of more than 50 per 100,000 has continually decreased from 1983 to 2013. However, the number of counties which the average annual malaria prevalence rate is less than 50 per 100,000 has not changed markedly, and the number of counties which are not reporting malaria cases has increased each year.

Demographic features

Figure 5A shows that Males were more likely to have malaria, with the proportions of male-to-female ratios of 66.1% to 33.9% in 1993 and 85.5% to 14.5% in 2013, respectively. The proportion of male malaria patients in 2013 is risen than in 1993. Figure 5B shows that the proportion of malaria cases among the 0-15 age group decreased during the study period. Malaria cases were mainly predominant among young and middle-aged people in 1993 and 2013; the proportion of malaria cases among the 30-59 age group increased from 36.6% in 1993 to 53.6% in 2013, while the malaria prevalence rates in the other age groups decreased.

Figure 5C shows that malaria mainly affected farmers and farmer workers, with the proportion of malaria cases occurring among farmers increasing from 63.7% in 1993 to 68.9% in 2013 and among farmer workers from 9.2% in 1993 to 18.1% in 2013. The rate of malaria steadily decreased among other occupational groups from 1993 to 2013.

Analysis of the correlation between malaria interventions and prevalence rates

Statistics and analysis of malaria interventions in 1993, 2003 and 2009, the correlation between malaria interventions and prevalence rates was analyzed for this year, malaria prevalence rates were compared for the counties taking interventions and those that took no interventions for the years 1992 and 1993, 2002 and 2003, 2008 and 2009. Table 1 shows that statistically significant differences were also observed between organizational, surveillance, treatment and anti-mosquito interventions taken in 2009, with malaria prevalence rates in the counties taking interventions and contrasted with those not taking interventions from 2008 to 2009. However, the interventions taken in 1993 did not markedly affect the malaria prevalence rate between 1992 and 1993.

The researchers conducted logistic regression analyses of data pertaining to treatment and anti-mosquito interventions in 2003 and organizational, surveillance, treatment, and anti-mosquito interventions in 2009. The Wald chi-square test showed that the difference was statistically significant ($p<0.05$). The above are mainly interventions of how malaria

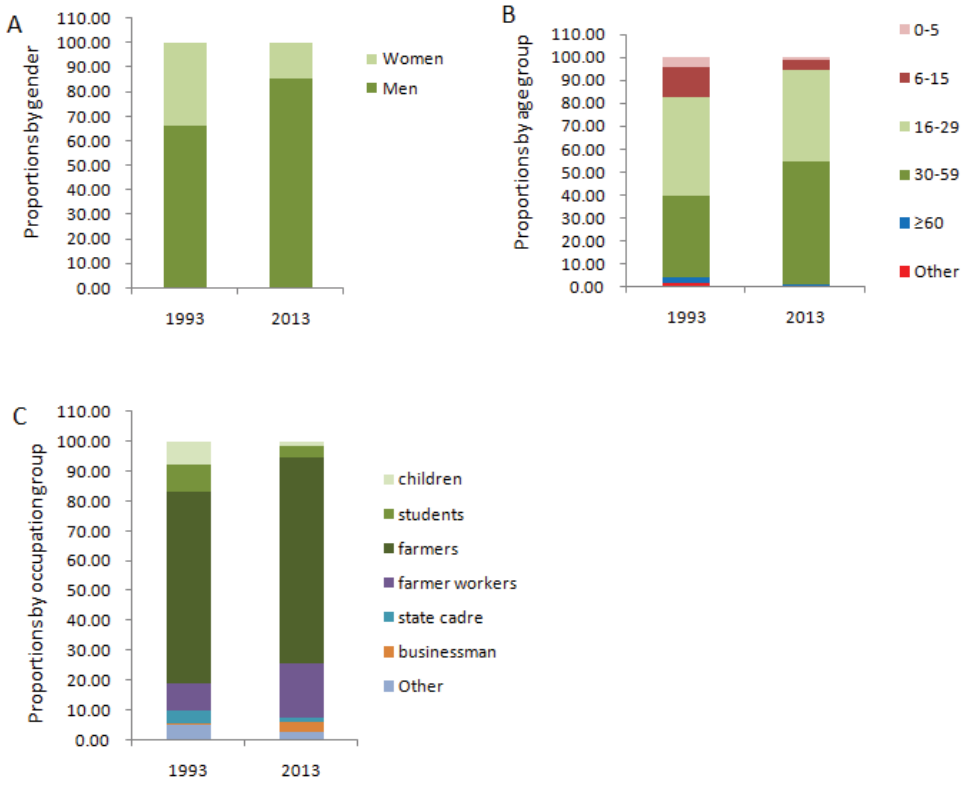


Figure 5: Gender, age and occupation of malaria cases in Yunnan, in 1993 and 2013.

Parameter	Yes/ No	Comparing malaria prevalence between 1992 and 1993				Comparing malaria prevalence between 2002 and 2003				Comparing malaria prevalence between 2008 and 2009			
		NCTI	NCC	χ2	*P*- value	NCTI	NCC	χ2	*P*- value	NCTI	NCC	χ2	*P*-value
1. Organizational measures													
MMES	Yes	*	*	*	*	42	17	3.202	0.074	66	0	-	-
	No	*	*	*	*	48	22			63	0	-	-
Training	Yes	14	45	0.890	0.170	17	42	1.000	0.317	66	0	-	-
	No	60	69			26	44			63	0	-	-
STG	Yes	*	*	*	*	18	41	0.630	0.428	37	34	16.760	0.000
	No	*	*	*	*	17	53			10	48		
2. Surveillance interventions													
BSEFP	Yes	48	11	4.640	0.031	45	14	0.200	0.658	57	14	14.55	0.00 0
	No	45	25			51	29			28	30		
BSELR	Yes	42	17	5.230	0.022	30	29	0.180	0.675	41	30	19.95	0.000
	No	36	34			33	37			11	47		
BTTLP	Yes	17	42	0.940	0.333	*	*	*	*	*	*	*	*
	No	15	55			*	*	*	*	*	*	*	*
BTLPRO	Yes	17	42	0.040	0.833	*	*	*	*	*	*	*	*
	No	19	51			*	*	*	*	*	*	*	*
BTIP	Yes	23	36	1.560	0.211	18	41	2.500	0.114	*	*	*	*
	No	20	50			13	57			*	*	*	*
3. Treatment interventions													
TRS	Yes	46	13	6.250	0.012	42	17	1.000	0.317	50	21	23.44	0.000
	No	40	30			44	26			16	42		
MAM	Yes	34	25	1.410	0.235	25	34	0.190	0.661	26	45	11.82	0.001
	No	33	37			27	43			6	52		
PTS	Yes	43	16	7.010	0.008	25	34	0.090	0.768	32	39	11.260	0.001
	No	35	33			30	40			10	48		
RTMP	Yes	46	13	2.350	0.215	44	15	0.560	0.453	39	32	17.390	0.000
	No	24	24			48	22			11	47		
4. Anti-mosquito interventions													
IS	Yes	38	21	3.860	0.050	26	33	3.260	0.071	37	34	16.760	0.000
	No	33	37			42	28			10	48		
ITNs/LLINs	Yes	35	24	2.900	0.089	24	35	0.060	0.810	42	29	21.300	0.000
	No	31	39			32	38			11	47		

Note: *: Have no data (Did not carry out this interventions); -: Missing data; Yes: Number of counties that effectively controlled malaria prevalence rate; NO: Number of counties that the prevalence rate did not change or descend; NCTI: Number of Counties Taking Interventions; NCC: Number of Contrast Counties (not taking control measures). (1) Organizational interventions: MMES: Malaria Microscopy Examination Stations, Training, STG: Supervision and Technical Guidance; (2) Surveillance Interventions: BSEFP: Blood Smear Examination of Febrile Patients, BSELR: Blood Smear Examination of Local Residents, BTTLP: Blood Testing of Temporary Local Population, BTLPRO: Blood Testing of Local Population Returning from Overseas, BTIP: Blood Testing of Input Personnel; (3) Treatment Interventions: TRS: Treated for Anti-Relapse in Spring, MAM: Mass Administration Medicine, PTS: Prophylaxis During Transmission Season, RTMP: Radical Treatment of Malaria Patients; (4) Anti-Mosquito Interventions: IS: Insecticide Spraying Indoor/Outdoor, ITNs/LLINs: Using insecticide-treated mosquito nets/long-lasting insecticide-treated nets

Table 1: Correlation of malaria interventions and prevalence rates, 1992-1993, 2002-2003 and 2008-2009.

prevalence can be controlled (Table 2). The use of malaria microscopy examination stations, training, supervision and technical guidance had lower prevalence rates of the disease than counties taking no interventions to improve the diagnosis of cases, carry out surveillance interventions, block sources of infection and reduce the chance of malaria transmission. The counties that employed control measures had a better chance than the contrast counties to reduce malaria prevalence, making the former more conducive to preventing the spread of malaria.

Discussion

This study demonstrated the great changes in epidemiological characteristics of malaria in Yunnan during a period of transition from malaria control to elimination. The prevalence rate of malaria in Yunnan Province has decreased dramatically in the last 30 years. The average annual malaria prevalence rate fell from 64.8 per 100,000 in 1983 to 0.9 per 100, 000 in 2013, a reduction of 98.6%.

Several epidemiologic stages were observed during the study period. The number of malaria cases decreased from 1983 (64.8 per 100,000) to 1986 (46.1 per 100,000), increased from 1987 (47.1 per 100,000) to 1989 (52.2 per 100,000), decreased from 1991 (47.8 per 100,000) to 2000 (21.8 per 100,000), increased from 2001 (26.0 per 100,000) to 2003 (36.0 per 100,000), and kept at a very low, stable level of less 10 per 100,000 from 2008 to 2013. The prevalence of malaria increased in 1999 and 2003 respectively, with the average annual malaria prevalence rate in border counties increasing to 171.2 per 100,000 in 1999 and 181.3 per 100,000 in 2003, demonstrating that the border area of the province is not stable. This increase can be primarily explained by the malaria outbreak in Myanmar, which also caused an epidemic in the Jinsha River Valley [17-20]. There were 118 outbreaks of malaria in the border counties of Yunnan from 1989 to 1999 [21], with the border 25 counties closest to Yunnan border accounting for more than 60% of the total cases of malaria in the whole Yunnan province and 70%

Year	Parameters	B	S.E	Sig	Risk ratio (95%CI)
2003	***Treatment interventions***				
	TRS	0.625	0.264	0.013	1.920 (1.145-3.220)
	MAM	0.904	0.314	0.004	2.469 (1.333-5.573)
	PTS	0.944	0.308	0.002	2.571 (1.407-4.698)
	RTMP	0.763	0.257	0.003	2.144 (1.297-3.545)
	Anti-mosquito interventions				
	IS	1.920	0.415	0.000	6.821 (3.026-15.371)
	ITNs/LLINs	0.962	0.328	0.003	2.616 (1.375-4.978)
2009	***Organizational interventions***				
	MMES	0.988	0.309	0.001	2.686 (1.467-4.919)
	Training	0.988	0.309	0.001	2.686 (1.467-4.920)
	STG	0.956	0.380	0.012	2.602 (1.235-5.482)
	Surveillance interventions				
	BSEFP	0.894	0.290	0.002	2.446 (1.385-4.371)
	BSELR	1.211	0.350	0.001	3.357 (1.691-6.665)
	Treatment interventions				
	TRS	1.028	0.284	0.000	2.794 (1.601-4.878)
	MAM	0.981	0.389	0.012	2.667 (1.245-5.714)
	PTS	1.028	0.346	0.003	2.794 (1.418-5.506)
	RTMP	0.998	0.319	0.002	2.712 (1.451-5.067)
	Anti-mosquito interventions				
	IS	1.046	0.373	0.005	2.845(1.369-5.914)
	ITNs/LLINs	1.014	0.345	0.003	2.755(1.403-5.415)

B: Regression Coefficient; **S.E:** Standard Error; **Sig:** *p*-value

Table 2: Logistic regression analysis of the correlation between malaria interventions and prevalence rates.

of the total cases were imported malaria from bordering counties or countries from 2001 to 2010 [22,23]. Imported *P. falciparum* malaria is increasingly seen in Yunnan.

After 2006, the rate of malaria prevalence began to drop each year. This can mainly be explained by the strengthened National Anti-Malaria Programme, involved the global fund malaria program. Thus far, the 12th five-year Malaria Control Plan has been completed. Due to the strong support for the central transfer payment project and the launching and implementation of malaria elimination projects in 2010 [11,23-26], the prevalence rate of malaria has significantly decreased in Yunnan. Several intensified anti-malaria interventions were taken as part of the programs, including organizational interventions, surveillance interventions, treatment interventions and anti-mosquito interventions. Based on our research, we recommend that these plans make full use to strengthen the prevention and control of malaria and standardize the management of malaria prevention and control work in key malaria endemic areas, in county Centers for Disease Control and Prevention, township health centers and border malaria advisory service stations. These plans or projects provided a plenty of free-of-charge Equipment and resources such as biological microscopes, Plasmodium detection reagents, and anti-malaria insecticides. Further training should be made available to personnel working in disease control institutions and grassroots malaria control. There should be active screening for malaria cases in high-risk villages, and greater access should be provided to get treatment, which can be facilitated by case tracing and recording of treatment history. Following Yunnan's example, preventive administration of anti-malarial medicines should be undertaken in high-risk populations. After Yunnan Province established three levels of malaria control, at the county, township, and village levels, malaria has been effectively controlled and the incidence rate has dropped significantly.

The seasonal and geographical distribution analyses showed that malaria cases peaked between May and September from 1983 to 1992, between May and July from 1993 to 2002 and between April and June from 2003 to 2013. The highest average monthly prevalence rates were observed in July, May and June in the time periods of 1983-1992, 1993-2002 and 2003-2013. Yunnan has several climatic zones and various meteorological factors that influence the dominant vectors and result in seasonal differences in malaria prevalence. Along with rapid reductions in malaria prevalence and more sporadic cases among those who have returned from abroad, seasonal variations in cases have also changed [27,28]. The geographical distribution analysis showed that several types of malaria were prevalent in different endemic areas: northwest of Yunnan, Zhaotong City (northeast of Yunnan) and Yuan Jiang-Honghe River Valley and border areas were the endemic areas in 1983. The west and south of Yunnan and border areas were endemic areas in 2013.

The demographic characteristics of malaria cases also changed markedly during the study period, with more males and young adults (16-59 age) contracting malaria. The floating population in Yunnan Province is more complex than in other provinces, and is mainly divided into domestic personnel in tourism and business, workers from home, young migrant workers returning from foreign countries, and foreign personnel entering Yunnan for work, business or tourism, etc. [29]. The temporary local population includes businessmen, travelers, and migrant workers (including migrants from economically less developed areas to developed areas, residents of border countries visiting relatives, and those carrying out cross-border trade, logging, quarry, and plantation activities). Myanmar may have reintroduced malaria to Yunnan [30]. The main reason for this cross-border contamination is that most young migrant workers live in villages, where poor living conditions and a lack of anti-mosquito facilities are likely to increase exposure to malaria vectors.

The analysis of the correlation between malaria control measures and prevalecne rates in a random sample (1993, 2003 and 2009) showed that organization; surveillance, treatment and anti-mosquito interventions played a part in controlling malaria prevalence in 2009; the prevalence rates dropped more than twice in the counties taking interventions as compared to those not taking interventions. Yet, malaria prevalence rates were not significantly different between the counties taking interventions and not taking interventions between 1992 and 1993. Perhaps this could be explained by the fact that the prevalence of malaria in 1993 was higher than it was in 2003 and 2009 or malaria epidemic of border Countries is serious, or that only data on control interventions for a single year was studied, resulting in malaria prevalence not changing significantly between the counties taking interventions and not taking interventions in the one year (from 1992 to 1993).

Timely diagnosis and treatment of malaria are very important in order to control its spread and the strengthening of treatment of anti-relapse in spring for *P. vivax* is advantageous in order to remove the source of infection and consequently reduce the rate of transmission of *P. vivax* malaria. Anti-mosquito interventions are important too: implementing insecticide spraying and ITNs/LLINs will help to reduce the transmission of malaria vectors and curtail mosquito contact opportunities, thereby blocking malaria transmission [31].

Various malaria control strategies were undertaken in the Yunnan Province during the study period. These have included malaria cases management of mobile population, taking local neighboring interventions, classifying malaria endemic areas, highlighting the focus of malaria control and strengthening the surveillance of migrant

workers (from 1981 to 2000), including local people who move to a malaria-endemic area and local residents returning from foreign countries. After the 1990s, temporary local personnel and border areas were major problems of malaria and were the most important factors that led to the difficulty of controlling malaria [32-35]. Many ports and crossings of border areas permit frequent entry and exist, thereby increasing the number of imported cases and complicating efforts to control malaria in the border areas [20,36-38]. The focus should be on strengthening the malaria control strategy in border areas, establishing malaria protective barriers on border ports and channels and carrying out cross-border malaria control between China and Myanmar. Due to the number of malaria endemic areas in countries bordering China in 2013, Yunnan experiences a disproportionate share of imported malaria cases. It will be a great challenge to eliminate malaria in the province by 2020 [23,39].

Conclusion

The Yunnan Province's government's malaria control strategies have dramatically decreased the prevalence of malaria in the province in the past 30 years. Our research showed that the China-Myanmar border area in Yunnan was still a high-risk area of malaria transmission in 2013, resulting in more imported malaria cases in the province. Future elimination efforts should focus on the effects of cross-border activities on malaria transmission, and elimination efforts should include more intensive surveillance of temporary local personnel so that prevention and control activities can be more effective.

Authors' Contribution

Ya-ming Yang, Heng-lin Yang, and Ben-fu Li conceived the study. Ben-fu Li collected and analyzed the data, and wrote the draft. Xiao-dong Sun, Hui Liu, Xiao-tao Zhao, Chun Wei, Quan Lu and Rui Yang participated in revision of the paper and the data analysis. Hong-ning Zhou contributed to the data interpretation and coordination. Ya-ming Yang and Jian-wei Xu conceived the study and reviewed the draft paper and final paper. All authors read and approved the final manuscript.

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