Cost-benefit analysis of the monitoring measures for the malaria elimination stage in Fujian, China

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Research

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Abstract

**Background** Malaria is an insect-borne infectious disease that spreads through bites from infected *Anopheles* mosquitoes. The disease seriously endangers human health and economic development. Against the background of eliminating malaria in Fujian Province, in order to understand the cost and benefit of malaria monitoring measures, the health economics of the monitoring measures should be examined.

**Methods** The malaria epidemic data during the malaria elimination stage (2005–2019) in Fujian Province were collected and sorted. The basic economic data were obtained from the Fujian Statistical Yearbook. A cost-benefit analysis was conducted for this study, based on the fundamental theories in health economics. Moreover, the Cost (C) of monitoring measure during the malaria elimination stage was calculated, and the Benefit of malaria elimination stage (B) was analyzed.

**Results** The total cost of monitoring measures in the malaria elimination stage was about 607,878,783.36 yuan (USD $87,534,544.80). The proportions of the costs were as follows: case detection and treatment was 66.62%, health education was 13.31%, epidemic monitoring was 10.05%, supervision and assessment was 5.15%, and training and meeting was 4.87%. The total benefit of the malaria elimination stage was about 116,123,417,911.81 yuan (USD$ 16,721,772,179.30), the economic benefit was 22.61%, and the social benefit was 77.39%. The cost-benefit analysis of the malaria elimination stage showed that the NB of monitoring measures was about 115,515,539,128.45 yuan (USD$ 16,634,237,634.50) and the BCR was 191.03. The monitoring cost for residents was 1.08 yuan (USD$ 0.16) per capita, and the benefit for residents was 206.12 yuan (USD$ 29.68) per capita.

**Conclusion** In the past 15 years, malaria control work has achieved excellent economic and social benefits in Fujian, China. The work should continue in strengthening the monitoring and control of imported malaria cases, increasing health education in high-risk locations (such as those frequented by entry-exit personnel), and enhancing residents’ awareness about prevention and personal protection. The work should continue to be consolidated for the elimination of malaria. The framework and results of this study conform to the principles of health economics and have a certain reference value for current malaria monitoring practices.

Background

Malaria is an insect-borne infectious disease caused by the *Plasmodium* parasite, which spreads to people during bites from *Anopheles* mosquitoes or blood transfusions from an infected person. It is a complex disease that can spread rapidly and exhibit acute onset, which are factors that can easily cause local outbreaks and epidemics and seriously endanger human life, health, and social and economic development. In 2018, about 228 million malaria cases occurred worldwide, with about 405,000 deaths. The WHO African region accounted for 93%, followed by Southeast Asia and the eastern Mediterranean region. The global results of malaria elimination efforts are expanding, with 27 countries reporting fewer
than 100 local cases and a growing number of countries reporting zero local cases, which indicates that malaria elimination is finally within reach(1, 2). Global malaria burden is reducing with effective control interventions, and surveillance is vital to maintain progress(3). Since the implementation of the China Action Plan for the Elimination of Malaria (2010–2020), remarkable achievements have been made in malaria elimination, with more than 95% of counties (cities, districts) in China reporting incidences below 1 in 10,000(4). Fujian Province has not reported any local cases since 2005, and they have since advanced to the malaria elimination stage(5). However, imported malaria cases are often reported due to frequent commercial exchanges in the coastal areas of the province, resulting in the high mobility of personnel(6). Therefore, it was necessary to conduct a health economic evaluation of the surveillance measures of Fujian Province’s malaria elimination phase. We calculated costs based on health economics analysis theory and the current status of malaria elimination in Fujian Province. We used the content of the malaria surveillance measures as the main body and determined the economic analysis framework based on the survey data, literature, and expert consultations (7–9). This approach allowed us to understand the current input and output characteristics of malaria surveillance in Fujian Province and analyze the benefits of surveillance measures in the malaria elimination stage. Our study provides a reference for further malaria elimination work and also provides a scientific basis for more rational formulations of malaria surveillance programs in Fujian Province.

**Methods**

**Sources of data**

We collected malaria epidemic data during the malaria elimination stage in Fujian Province from 2005 to 2019. The annual malaria report is based on reports of surveillance work and epidemic investigations in various cities of Fujian Province. Malaria case investigation data were from direct reports from the China Disease Prevention and Control Information System network. Cases were counted according to the time of onset, and duplicate cases were excluded. Demographic and economic data were obtained from the Fujian Statistical Yearbook.

**Cost Definition and Measuring Method**

Costs were expressed in currency units (yuan, RMB). The basic economic data was obtained from the Fujian Statistical Yearbook. The labor cost of personnel was calculated by 50 yuan per person. Based on the domestic and international malaria-related economics literature(5-9), discussions in the research team, consultations with malaria control experts, the Operation Manual of the Malaria Surveillance Program in Fujian Province, and general characteristics of malaria surveillance work, we divided surveillance measures in the malaria elimination phase into five categories: 1) case detection and treatment; 2) epidemic surveillance; 3) health education; 4) training meetings; and 5) supervision and assessment.

1. **Case detection and treatment**
The cost of a blood test includes the cost of blood collection, film preparation, evaluation, and so on. It is estimated that a single blood smear slide is about 10 yuan.

The accompanying rate of case treatment was set at 1, and direct medical costs included the cost of drug treatment (staffed by a person) such as with primawaline and clowax and the cost of hospitalization/observation stay (drugs, nursing care, laboratory costs, etc.). These were approximately 300 yuan per case. Direct non-medical costs, including transportation, communication, and catering expenses, were calculated according to consumption levels in Fujian Province in the same period. The cost of hospitalization-related labor loss for patients and their family members was a missed work fee converted into a monetary amount by the per capita national income method: Cost of missed work = days off work × (annual per capita net income/306) × 2.84. Each patient missed about eight days of work.

2. Epidemic surveillance

The wages of the two professionals were measured according to wage levels in institutions in Fujian Province during the same period. Material, transportation, and labor costs for media control and surveillance were measured and calculated in units of surveillance sites. The cost of disinfection drugs to treat locations of epidemics was calculated according to the actual amount used and the market price at that time. Material costs were for case verification and investigation, and labor costs were for the two professionals.

3. Health education

The Centers for Disease Control and Prevention conducts “National Malaria Day” health education activities on April 26 each year to measure the costs of health education activities and materials, staff salaries, and labor.

4. Training meetings

Because the workload in the malaria elimination phase is less than that for other infectious diseases, conference fees were converted to 5% of the training course cost. The cost of the training (for materials, sites, lectures, accommodation, transportation, etc.) was calculated by applying the comprehensive quota standard (130 yuan per day from 2005 to 2014; and 400 yuan per day from 2014 to 2019).

5. Supervision and assessment

These were the mid-year supervision and end-of-year assessment costs for materials, staff wages, and labor as well as for transportation and accommodation.

Determining Benefit Indicators

We reviewed the domestic and international literature on the economic evaluation of malaria(9, 11, 12), had discussions with the research team, consulted experts, and then determined the economic and social
benefit indicators. Economic benefits included the direct treatment benefits from avoiding illness-related hospitalization, the indirect non-medical benefits from avoiding illness-related hospitalization, and the benefits of avoiding illness-related work absence. Social benefits included the malaria staff benefits from improvement in surveillance capacity, the benefits from residents’ improved health levels, and the benefits from residents’ improved awareness of malaria protection.

Cost-benefit analysis method

Based on fundamental theories in health economics, we used a cost-benefit analysis method for the study. We calculated the annual average cost (C) of surveillance measures in Fujian Province’s malaria elimination phase to analyze the corresponding annual average reduction in incidence and created benefits (B).

Cost-benefit analysis of malaria surveillance per capita

The cost of malaria surveillance per capita of residents = average annual surveillance cost / number threatened by malaria infection; the benefit of malaria surveillance per capita of residents = average annual benefit / number threatened by malaria infection.

\[
\text{Benefit-Cost Ratio (BCR)} = \frac{B}{C} = \frac{\text{Average Annual Benefit}}{\text{Average Annual surveillance Cost}}
\]

\[
\text{Net Benefit (NB)} = B-C = \text{Average Annual Benefit} - \text{Average Annual surveillance Cost}
\]

When the BCR is higher than one, and the NB is positive, it is economically advantageous to implement the measure. When the BCR is less than one and the NB is negative, the cost of the measure is higher than its efficiency. In other words, the implementation of this measure is economically burdensome, and the strategy should be adjusted (12, 13).

Assumptions of cost-benefit accounting

Surveillance is less intensive but more targeted in a malaria elimination phase. Thus, we could assume that without the surveillance work, large fixed assets would need to be depreciated and could be excluded from costing. Statutory working hours of relevant staff can be fully utilized with effective surveillance measures. However, without them, all identified cases will require hospitalization and the assistance of a caregiver (with a rate of 1), and neither patients nor caregivers can work during hospitalization. We decided it would be practical to calculate the cost of training and health education activities according to the project, and the estimation method did not significantly interfere with the social benefits in the cost-benefit analysis model. Regarding the cost-benefit analysis framework for the surveillance measures, the expert we consulted believed that the indicators that did not meet the inclusion criteria had no significant impact on the overall analysis model.

Results
Costs of malaria surveillance

Costs of case detection and treatment: According to the number of personnel required by the surveillance program (8), there were 2,210 professionals in 105 townships from 2005 to 2015, 170 professionals in 85 counties from 2010 to 2015, and 85 professionals in 85 counties from 2016 to 2019. According to wages in institutions during the same period, the average annual total staff wage from 2005 to 2019 was about 31,823,563.67 yuan. The annual blood test rate required by the surveillance program from 2005 to 2009 was not less than 2% in Nanping and Sanming, not less than 5/1,000 in southern Fujian, and not less than 1/1,000 in other cities(8). From 2010 to 2019, if the annual blood test rate was not less than 5/10,000, the annual number of blood tests was 110,178, and the annual cost of blood tests for febrile patients was about 2,203,560.00 yuan. A total of 1,191 cases of malaria were reported from 2005 to 2019. The cost of antimalarial drugs, examination fees, and nursing fees per capita was 319.35 yuan, and the annual average cost of direct treatment was about 38,002.65 yuan. According to the average annual consumption level in Fujian Province in the same period, the estimated cost of transportation, accommodation, and other expenses was about 218.94 yuan, while the annual average direct non-medical costs was about 52,107.72 yuan. In the same period, the net income per capita in urban and rural areas of Fujian Province was about 19 million yuan per year, and the estimated cost of missed work was 1,407.05 yuan per person, so the average annual cost of missed work was about 334,877.90 yuan.

Cost of epidemic surveillance: According to the requirements of the surveillance program, each surveillance site was equipped with 2 professionals, and there were 5 surveillance sites for floating population gathering places. From 2005 to 2015, there were 15 counties in the southern Fujian area and 22 counties in the northwestern Fujian area. A survey of residual Anopheles anthropophagus distribution was carried out in Nanping and Sanming from 2016 to 2019, with 20 sites monitored in two counties each year and 7 sites monitored in one county each year in the remaining cities. There were 74 staff members during the period 2005–2015 and 64 professionals from 2016 to 2019. According to the salary of public institutions in the same period, the average annual total staff salary was about 3,970,643.60 yuan. The surveillance site carried out media density surveillance 6 times per year, with a cost totaling about 1000 yuan for 2 professionals and 2 nights each time. Thus, the cost of media density surveillance in the whole province is about 214,000.00 yuan. For the treatment of pesticide retention spraying and mosquito control in epidemic sites, we calculated the annual average cost of extermination drugs based on actual dosages and market prices at the time to be about 51,333.33 yuan. The cases were investigated and verified by two professionals. Labor service and transportation subsidies were about 90 yuan per person, and the annual average was about 21,420.00 yuan.

Cost of training meetings: The training course lasted about 3 days each time. There were 3,121 professionals (clinicians, prevention and treatment personnel, and inspectors) who participated in the training from 2005 to 2013 and 15,421 professionals from 2014 to 2019. The average annual cost of training was about 1,314,826.00 yuan. The conference cost was calculated as 5% of the training cost, with an average annual cost of about 65,741.30 yuan.
Cost of health education: Every April 26, the “National Malaria Day” propaganda and education activities were held in the province, for which the average annual cost of health education activities was calculated to be around 20,000 yuan. Publicity and education activities were carried out 86 times in 85 counties and in 9 cities in the province and their districts, with 94 professionals participating. The average annual salary of public institution professionals was about 571,000 yuan, with a total salary and subsidy of about 5,895,074.53 yuan.

Costs of supervision and assessment: During 2005–2019, 36 professionals from higher units went to lower units for supervision and assessment a total of 188 times, and their annual average salary and total labor costs were about 2,075,614.40 yuan. The material cost was estimated to be about 40 yuan each time, with an annual average material cost of about 7,520 yuan. The cost of transportation and accommodation was estimated to be about 200 yuan per capita according to the consumption expenditure in the same period, with an annual average of about 75,200.00 yuan.

Table 1 shows that the annual average cost of surveillance measures in the malaria elimination phase from 2005 to 2019 was about 481,635.10 yuan. In terms of the cost component ratio of each surveillance project (Figure 1), the cost of case detection and treatment (34,452,111.94 yuan) accounted for the highest at 71.53%, followed by the cost of health education (5,915,074.53 yuan), which accounted for 12.28%. The cost of epidemic surveillance (4,257,396.93 yuan) accounted for 8.84%, the cost of training meetings (1,380,567.30 yuan) accounted for 2.87%, and the cost of supervision and assessment (2,158,334.40 yuan) accounted for 4.48%.

Economic and Social Benefits of Malaria Surveillance

The average annual resident population of Fujian Province from 2005 to 2019 was 37.56 million. We used the incidence rate of 1,972 (238.25/10,000) as the study control and calculated that 894,867 cases were avoided due to malaria surveillance(8). The actual number of reported cases was 1,191 (about 119 cases per year); thus, from 2005 to 2019, the annual average number of cases actually avoided was 894,748 cases.

We assumed that without effective malaria surveillance, all cases would have been hospitalized for antimalarial treatment. The direct treatment cost of each case was 319.35 yuan, and the annual average benefit of avoiding hospitalization was about 285.74 million yuan. The direct non-medical cost of each case was 218.94 yuan with an accompanying rate of 1, so the annual average direct non-medical benefits avoided was about 391.79 million yuan. The indirect cost of each case was 1,407.05 yuan with an accompanying rate of 1, so the benefit of avoiding hospitalization-related work absence was about 2.52 billion yuan, as shown in Table 2.

We used the number of professionals trained in Fujian Province from 2005 to 2019 multiplied by the per capita training benefit to calculate the benefit of improving professionals’ surveillance ability. The estimated per capita training benefit was about 250 yuan. The total number of professionals trained from 2005 to 2019 was 18,542, and the average annual benefit of improving their surveillance ability was
about 309,033.33 yuan. Combining the level of per capita health care expenditure and the results of a resident survey in Fujian Province during 2005–2019, it was estimated that residents would be willing to pay about 300 yuan to avoid the health loss caused by malaria. According to the actual number of cases avoided in this stage, we estimated that the average annual benefit of improving residents’ health level was about 268 million yuan. We supposed that through different forms of health education and propaganda, the residents acquired enough knowledge about malaria protection to avoid malaria infection and suppress malaria incidence, and the per capita social benefit was estimated at 100 yuan. Then, the average annual benefit of the residents’ awareness of malaria protection was about 3.756 billion yuan. As shown in Table 2, the total economic benefit was about 3.195 billion yuan, accounting for 44.26% of the total benefit. The social benefit was about 4.025 billion yuan, accounting for 55.74% (notably more than 50%).

Cost-benefit analysis of malaria surveillance

The average annual cost of malaria surveillance measures in Fujian Province during 2005–2019 was about 481.635 million yuan, and the total annual benefit obtained was about 722 billion yuan. Thus, the per capita cost of malaria surveillance for residents was 1.28 yuan, and the per capita benefit of malaria surveillance for residents was 192.23 yuan. This shows that the investment per capita cost of malaria surveillance measures in Fujian Province was lower than the per capita benefit that was obtained. Hence, the effect of the malaria surveillance work was very beneficial.

By subtracting the annual average cost from the annual average total benefit, we calculated that the annual average net benefit resulting from malaria surveillance was 7.172 billion yuan. We calculated an annual average benefit-cost ratio of 149.91:1, which indicates that every input of 1 yuan for malaria surveillance could produce social benefits of 149.91 yuan.

Discussion

Cost-benefit analysis is one of the most important tools in health economics research, and it can be used to effectively evaluate the impacts of health and epidemic prevention efforts (14). This study identified characteristics of malaria elimination efforts in Fujian Province and comprehensively analyzed inputs and outputs. The results of the analysis can help managers and decision-makers reduce the costs and improve the benefits of their programs.

Literature has shown that implementing more effective malaria surveillance and control methods can result in greater economic benefits(15-21). Presently, malaria management in Fujian Province is incorporated into overall public health efforts. The surveillance and management of imported malaria cases has been strengthened; the knowledge and skills of clinicians, prevention and control personnel, and inspectors have been increased. Health education and promotion activities have been carried out through multiple channels, and the achievements at the malaria elimination phase have been consolidated. In all, enormous economic and social benefits have been achieved.
The study estimated the cost inputs based on the surveillance measures, though some influencing factors could not be taken into account. We assume there was no significant interference. At present, Fujian Province is at the stage of malaria elimination, and malaria-related efforts are gradually being reduced. If we had used traditional cost accounting, the accuracy of the results may have been adversely affected. Therefore, in our framework, we determined the cost structure according to the item classifications in the malaria surveillance measures. This approach was intended to more accurately reflect the direct cost inputs of the surveillance measures, similar to the accounting methods in other relevant studies (7, 14).

The results showed that the annual average cost of surveillance measures during the malaria elimination phase from 2005 to 2019 was about 48.1635 million yuan. Although the cost of surveillance measures was large, it was still within a reasonable range for infectious disease control and prevention. The cost of case detection and treatment accounted for 71.53% (34.4521 million yuan/year) of the total cost, health education accounted for 12.28%, epidemic surveillance accounted for 8.84%, supervision and assessment accounted for 4.48%, and training meetings accounted for 2.87%. The proportion of cost for case detection and treatment was the highest. The population is generally susceptible to malaria. At present, the majority of imported malaria cases in Fujian Province are falciparum malaria cases. The vector density of the Anopheles sinensis mosquitoes is very low, it is generally believed that the risk of re-transmission of falciparum malaria is very low in Fujian Province. Therefore, the current focus of Fujian Province's elimination phase is discovering and treating the sources of infection and reducing the mortality. This focus on infectious sources is quite different from that in parts of Africa that are still in the epidemic stage. Malaria-endemic areas in Africa mainly concentrate on epidemic surveillance, which emphasizes blocking infectious sources, controlling transmission routes, and protecting susceptible populations (19, 22, 23). In the malaria elimination phase, on the other hand, staff should adopt more targeted surveillance measures, focusing on the screening and detection of imported infectious sources. Staff should also consider forming a special malaria working group to carry out surveillance measures to reduce the proportions of wages and investments in the total surveillance costs and scientific accounting. In malaria surveillance in Fujian, the focus of training should be shifted to continuously improving the surveillance capacity of clinical medical staff. In addition, cost investments in health education should be increased, specifically in the area of health education in malaria prevention for personnel traveling to high-prevalence areas. This would improve residents' knowledge level of malaria prevention and enhance their personal protection awareness.

A cost-benefit analysis of Fujian Province's malaria elimination phase showed that the annual average total benefit value of malaria surveillance from 2005 to 2019 was about 7.22 billion yuan. The net social benefit of malaria surveillance was about 717,200 yuan, with an average annual BCR of 149.91:1. This indicates that the surveillance measures in the elimination stage are economically favorable and that the incidence of imported case reports will tend to increase with lower-cost investment. Further, the surveillance measures in the elimination stage appear to have good prevention and control effects, and high sensitivity is maintained in case surveillance.
The study results show that health education investment only accounted for 12.28% of the total cost, while the benefit from improving residents’ awareness of malaria prevention accounted for 52.02% of the total benefit, indicating that the cost-output ratio for health education was relatively high. Therefore, in Fujian Province's malaria surveillance efforts and particularly during the health education activities on National Malaria Promotion Day, we should focus on increasing residents’ knowledge about malaria prevention and personal protection to improve the cost-effectiveness ratio of malaria surveillance. We should do this especially in gathering places for entry-exit personnel. Meanwhile, the cost and benefit of malaria surveillance per capita are 1.07 yuan and 192.23 yuan, respectively. This indicates that the cost per capita of malaria surveillance was relatively small, while the effect of malaria surveillance was positive.

In sum, Fujian Province can effectively control and manage malaria cases based on various risk levels, with a particular focus on the surveillance and management of imported cases. The surveillance measures being implemented in the elimination stage of malaria are feasible and effective, and strong economic and social benefits have been achieved. These findings are in line with the global malaria strategy put forth at the World Health Assembly in 2015 and are also similar to many studies (16, 20, 24).

To date, very few health economics evaluations have been conducted in the context of malaria surveillance. The framework and results of this study conform to the principles of health economics, and they have a certain reference value for current malaria surveillance practices. Given time and research capacity constraints, some potentially influential factors (such as the policy environment) were not considered at this stage. Some data were estimated based only on the actual situation and interview results, which may have interfered with the accuracy of the analysis model. It is hoped that in the future, modifications to this approach will allow for more precise results, which will serve as an even more comprehensive reference for the real work of malaria surveillance.

**Conclusion**

A cost-benefit analysis approach allowed us to understand the current input and output characteristics of malaria surveillance in Fujian Province and analyze the benefits of surveillance measures in the malaria elimination stage. The framework and results of this study conform to the principles of health economics, and they have a certain reference value for current malaria surveillance practices. Our study provides a reference for further malaria elimination work and also provides a scientific basis for more rational formulations of malaria surveillance programs in Fujian Province.

**Declarations**

**Ethics approval and consent to participate**

This study belongs to the study of health economics and does not involve ethical requirements.

**Consent for publication**
Not applicable

**Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors’ Contributions**

SZ and CH conceived of and designed the study; ZC, HX, and RO contributed to data collection; CH drafted the manuscript; and SZ and ZC revised the manuscript. All authors read and approved the final manuscript.

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**Declarations**

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Authors’ Contributions
SZ and CH conceived of and designed the study; ZC, HX, and RO contributed to data collection; CH drafted the manuscript; and SZ and ZC revised the manuscript. All authors read and approved the final manuscript.

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List Of Abbreviations

BCR: benefit-cost ratio

NB: net benefit

References

1. Global Malaria Programme. World Malaria Report 2019. Geneva: WHO; 2019. Available from: https://www.who.int/publications-detail/world-malaria-report-2019.

2. Howes R, Battle K, Mendis K, Smith D, Cibulskis R, Baird J, et al. Global Epidemiology of Plasmodium vivax. Am J Trop Med Hyg. 2016;95:15-34.

3. Kigozi S, Giorgi E, Mpimbaza A, Kigozi R, Bousema T, Arinaitwe E, et al. Practical Implications of a Relationship between Health Management Information System and Community Cohort-Based Malaria Incidence Rates. Am J Trop Med Hyg. 2020.

4. Tang L, Gao Q. Proposal of China's Action Plan to Eliminate Malaria. Shanghai: Shanghai Science and Technology Publishers; 2013.

5. Tang L. Diagnosis, treatment and management of imported malaria. Shanghai: Shanghai Science and Technology Publishing House; 2010.

6. Ou Yang R, Chen Y, Xie H, Lin Y, Xiao L, Zhang S. Prevalent trend and control strategy of imported malaria in Fujian Province, China, 2011-2017. C J Zoonosis. 2019;35(4):359-62.

7. Fang H. The current situation of malaria surveillance ability and its cost-effectiveness analysis in grass-root areas of China. Wuhan: Huazhong University of Science and Technology; 2016.

8. Huang C. Effect and health economics evaluation of surveillance measures at malaria elimination stage in Fujian Province. Fuzhou: Fujian Medical University; 2017.

9. Huang C, Yang F, Ou Yang R, Chen Z, Zhang S. Cost-effectiveness analysis of surveillance measures at different stages of malaria elimination in Fujian Province. Chinese Journal of Zoonosis. 2017;33(10):933-7.

10. Liu X, Chen Y. Socioeconomic Research on Malaria Control. Haikou: Nan Hai Publishing Co.; 1997.

11. Akhavan D, Musgrove P, Abrantes A, d'A Gusmão R. Cost-effective malaria control in Brazil. Cost-effectiveness of a Malaria Control Program in the Amazon Basin of Brazil, 1988-1996. Soc Sci Med. 1999;49(10):1385-99.

12. Zhuang R, Wang S. How to evaluate the economic burden of disease? Chin J Prev Med. 2001;2(4):245-7.

13. Sudathip P, Kongkasuriyachai D, Stelmach R, Bisanzio D, Sine J, Sawang S, et al. The Investment Case for Malaria Elimination in Thailand: A Cost-Benefit Analysis. Am J Trop Med Hyg. 2019;100(6):1445-53.
14. Chang AY, Horton S, Jamison DT. Benefit-Cost Analysis in Disease Control Priorities, Third Edition. Washington (DC): The International Bank for Reconstruction and Development /The World Bank; 2017 2017-11-27.

15. Ezennia I, Nduka S, Ekwunife O. Cost benefit analysis of malaria rapid diagnostic test: the perspective of Nigerian community pharmacists. Malar J. 2017;16(1):7.

16. Kim H, Kang G, Lee S, Yoon C, Kim M. Cost-Benefit Analysis of Malaria Chemoprophylaxis and Early Diagnosis for Korean Soldiers in Malaria Risk Regions. J Korean Med Sci. 2018;33(10):e59.

17. Devine A, Parmiter M, Chu C, Bancone G, Nosten F, Price R, et al. Using G6PD tests to enable the safe treatment of Plasmodium vivax infections with primaquine on the Thailand-Myanmar border: A cost-effectiveness analysis. PLoS Negl Trop Dis. 2017;11(5):e0005602.

18. Chaccour C, Alonso S, Zulliger R, Wagman J, Saifodine A, Candrinho B, et al. Combination of indoor residual spraying with long-lasting insecticide-treated nets for malaria control in Zambezia, Mozambique: a cluster randomised trial and cost-effectiveness study protocol. BMJ Glob Health. 2018;3(1):e000610.

19. Hailu A, Lindtjørn B, Deressa W, Gari T, Loha E, Robberstad B. Cost-effectiveness of a combined intervention of long lasting insecticidal nets and indoor residual spraying compared with each intervention alone for malaria prevention in Ethiopia. Cost Eff Resour Alloc. 2018;16:61.

20. Sauboin C, Van Bellinghen L, Van De Velde N, Van Vlaenderen I. Economic Impact of Introducing the RTS,S Malaria Vaccine: Cost-Effectiveness and Budget Impact Analysis in 41 Countries. MDM Policy Pract. 2019;4(2):2381468319873324.

21. Assebe L, Kwete X, Wang D, Liu L, Norheim O, Jbaily A, et al. Health gains and financial risk protection afforded by public financing of selected malaria interventions in Ethiopia: an extended cost-effectiveness analysis. Malar J. 2020;19(1):41.

22. Zelman B, Baral R, Zarlinha I, Coutrier F, Sanders K, Cotter C, et al. Costs and cost-effectiveness of malaria reactive case detection using loop-mediated isothermal amplification compared to microscopy in the low transmission setting of Aceh Province, Indonesia. Malar J. 2018;17(1):220.

23. Winskill P, Walker P, Griffin J, Ghani A. Modelling the cost-effectiveness of introducing the RTS,S malaria vaccine relative to scaling up other malaria interventions in sub-Saharan Africa. BMJ Glob Health. 2017;2(1):e000090.

24. Winskill P, Walker P, Cibulskis R, Ghani A. Prioritizing the scale-up of interventions for malaria control and elimination. Malar J. 2019;18(1):122.

**Tables**

**Table 1 Total cost of annual average surveillance measures for malaria elimination in Fujian Province**
| Project                          | Essential factor                          | Average annual cost (yuan) |
|---------------------------------|------------------------------------------|-----------------------------|
| Case detection and treatment    | Salaries of professionals                | 31,823,563.67               |
|                                 | Cost of febrile blood test               | 2,203,560.00                |
|                                 | Cost of antimalarial treatment           | 38,002.65                   |
|                                 | Direct non-medical costs                 | 52,107.72                   |
|                                 | Cost of missed work                      | 334,877.90                  |
|                                 | Subtotal                                 | 34,452,111.94               |
| Epidemic surveillance           | Salaries of professionals                | 3,970,643.60                |
|                                 | Cost of mosquito surveillance            | 214,000.00                  |
|                                 | Cost of mosquito control drugs           | 51,333.33                   |
|                                 | Cost of case review                      | 21,420.00                   |
|                                 | Subtotal                                 | 4,257,396.93                |
| Training meetings               | Cost of training                         | 1,314,826.00                |
|                                 | Cost of meeting                          | 65,741.30                   |
|                                 | Subtotal                                 | 1,380,567.30                |
| Health education                | Cost of organization material            | 20,000.00                   |
|                                 | Salaries and subsidies of professionals  | 5,895,074.53                |
|                                 | Subtotal                                 | 5,915,074.53                |
| Supervision and assessment      | Cost of material                         | 7,520.00                    |
|                                 | Salaries and subsidies of professionals  | 2,075,614.40                |
|                                 | Cost of accommodation                    | 75,200.00                   |
|                                 | Subtotal                                 | 2,158,334.40                |
| Total cost                      |                                          | 48,163,485.10               |

Table 2 Average Annual Benefits of Malaria Elimination Phase Surveillance in Fujian Province, 2005–2019
| Project               | Essential factor                                      | Benefit (yuan) | Constituent ratio (%) |
|-----------------------|-------------------------------------------------------|----------------|-----------------------|
| Economic benefit      | Benefit of avoiding hospitalization                   | 285,737,773.80 | 3.96                  |
|                       | Direct non-medical benefit of avoiding hospitalization| 391,792,254.24 | 5.43                  |
|                       | Benefit of avoiding hospitalization-related work      | 2,517,910,346.80 | 34.87               |
|                       | absence                                              |                |                       |
|                       | Subtotal                                              | 3,195,440,374.84 | 44.26                |
| Social benefit        | Benefit of improving surveillance ability             | 309,033.33     | 0.01                  |
|                       | Benefit of improving residents' health level          | 268,424,400.00 | 3.71                  |
|                       | Benefit of improving residents' awareness of          | 3,756,000,000.00 | 52.02             |
|                       | malaria prevention                                   |                |                       |
|                       | Subtotal                                              | 4,024,733,433.33 | 55.74                |
| Total benefit         |                                                       | 7,220,173,808.17 | 100.00               |

**Figures**

![Pie chart](chart.png)

- **Case detection and treatment**: 71.53%
- **Health Education**: 12.28%
- **Epidemic surveillance**: 8.84%
- **Supervision and assessment**: 4.48%
- **Training meetings**: 2.87%

**Figure 1**

The proportion of cost structure of annual average surveillance measures for malaria elimination in Fujian Province
Figure 2

The proportion of benefits of malaria elimination phase surveillance in Fujian Province, 2005–2019