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Utility of rapid diagnostic tests and microscopy to detect malaria in health facilities across the Solomon Islands

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Abstract

Background Accurate and efficient malaria diagnosis is critical for effective malaria control and elimination. Rapid diagnostic tests (RDTs) have been deployed over the last decade, particularly in rural and low-and-middle-income countries, as an alternative to microscopy-based diagnosis.

Methods This study analysed retrospective health data from the Solomon Islands District Health Information System (DHIS2) for 2017–2019, focusing on factors affecting diagnostic test selection and positivity rates for microscopy versus RDTs.

Results The national Annual Parasite Incidence (API) of malaria declined over the 3 years, with localised increases in specific health zones. The choice of malaria diagnostic test was associated with administrative division, patient age, health facility type and year. Overall, RDTs had higher malaria positivity rates than microscopy for both *Plasmodium falciparum* (microscopy, 6%; RDT, 11%) and *Plasmodium vivax* (microscopy, 10%; RDT, 14%).

Conclusions RDTs were more widely used than microscopy in health facilities and had higher test positivity rates. This study highlights the factors influencing diagnostic test selection and underscores the importance of considering detection limits and potential overdiagnosis when interpreting positivity rates from different diagnostic methods.

Keywords Malaria, Diagnosis, Rapid diagnostic test, DHIS2

Background

Over the past two decades, substantial progress has been made in reducing the global incidence of human malaria [1]. While several nations have committed to malaria elimination by 2030, global progress has recently reached a plateau [2, 3]. In regions approaching malaria elimination, the disease becomes increasingly spatially heterogeneous [4]. Hence, national malaria elimination programmes are urged to utilize local evidence, facilitated by a robust surveillance system to enhance the understanding of national malaria risks and accurately target interventions [5–7].

Accurate diagnostics are essential for effective malaria surveillance and control. The World Health Organization (WHO) recommends parasitological tests to confirm suspected malaria cases [2]. The traditional gold standard for malaria diagnosis has been microscopy. However, the accuracy of this method depends on the skill of the microscopist and the quality of equipment, causing variable interpretations, particularly in rural regions where deployment is difficult [8, 9]. Therefore, RDTs

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are increasingly favoured in rural and low-and-middle-income countries for their simplicity, minimal infrastructure requirements, and rapid results [9–11].

The Solomon Islands has made substantial progress in malaria control, through increased vector control, improved diagnostics, and therapeutic drugs [12]. The Solomon Islands Malaria Strategic Plan 2021–2025 aims "to achieve and maintain quality-assured testing of 100% of suspected malaria cases". The plan prioritizes the availability of malaria RDTs in every health facility, with microscopy limited to a subset of larger facilities. Historically, there was an extensive network of microscopy points maintained throughout the country, including community-based microscopists, but this network has been gradually dismantled, and the number of functional microscopy points has decreased. As malaria control and elimination programmes transition away from microscopy to RDTs [13], there is a need to understand the acceptability and utility of these diagnostic tools under programmatic settings [14].

This paper explores the use and performance of malaria diagnostics across different health facilities, examining diagnostic choices (microscopy vs. RDTs) and test positivity rates across various regions and times. The findings of this analysis can support informed actions to ensure that effective use of malaria diagnostics is promoted across health facilities with varying capacities.

Methods

Study setting

Solomon Islands is a Pacific island nation lying between 5° and 12° south of the equator, with an estimated population of 708,482 in 2021 [15]. Malaria is endemic to all provinces excepting Rennell and Bellona Province. The healthcare infrastructure encompasses 45 health zones housing 393 facilities, categorized into hospitals, Area Health Centres (AHCs), Rural Health Clinics (RHCs), and Nurse Aid Posts (NAPs). All facilities aim to have RDTs available and the brands distributed over the study period in the Solomon Islands were First Response® Malaria Ag (pLDH/HRP2) Combo Card Test (advertised limit of detection (LOD): 200 parasites/μL) [16] and One Step test for Malaria Pf/Pv Ag MERISCREEN Malaria Pf/Pv Ag (advertised LOD: 50 parasites/μL for *P. falciparum*; 200 parasites/μL for *P. vivax*) [17] which are both WHO pre-qualified, as well as and iCare Malaria P.f/P.v (JAL Medical; advertised LOD: 200 parasites/μL) [18].

Data sources

Data on the use of malaria diagnostics (microscopy and RDTs) was obtained from the District Health Information System (DHIS2) for the years 2017–2019. The data included information on administrative division hierarchy (Province > Health Zone > Health Facility), test type, test result and patient age and gender. For microscopy, positive malaria cases were identified to species, and for RDTs cases were identified as *Plasmodium falciparum* or non-*P. falciparum*. For both tools mixed infections were recorded. Two final datasets were used in the analysis: 1. Patient level data, and 2. Health facility level data.

The patient level data was the most granular, and the health facility level data was an aggregation captured from the clinic weekly summary registers. Both datasets included the parameters: test type, test result, health facility, health zone and province. Patient level data also included patient age and patient gender. Incomplete data encoding and typos were major factors that distorted the number of entries in the two datasets. To clean the health facility data, entries from health facilities for particular time intervals were excluded if more positive test results were reported than the total number of tests conducted.

The patient-level and health facility-level data were used to examine diagnostic choices (microscopy vs. RDT), test positivity rates, and how demographic and geographic factors influenced test use over time. The health facility level dataset was used to calculate two ratio-based parameters, the positivity rate and the annual parasite incidence (API), as follows:

i) The positivity rate, being the proportion of positive tests, was calculated by dividing the number of positive tests (microscopy or RDT) by total tests completed for each test type.
ii) The API per 1,000 population was calculated by dividing the number of positive tests (all test types)

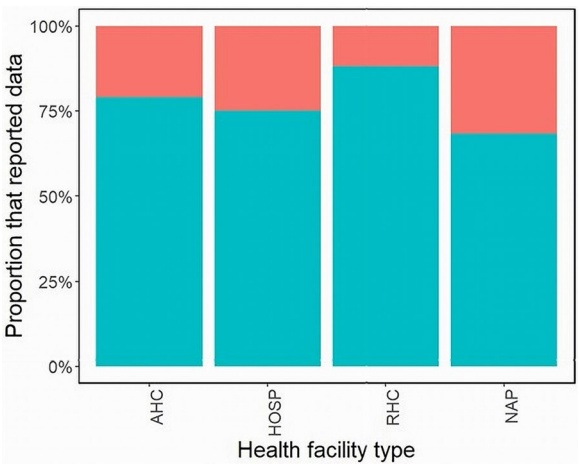

Fig. 1 Relative comparison of the percentage of health facilities in the Solomon Islands that reported (blue) or failed to report (red) data by facility type averaged across 2017–2019

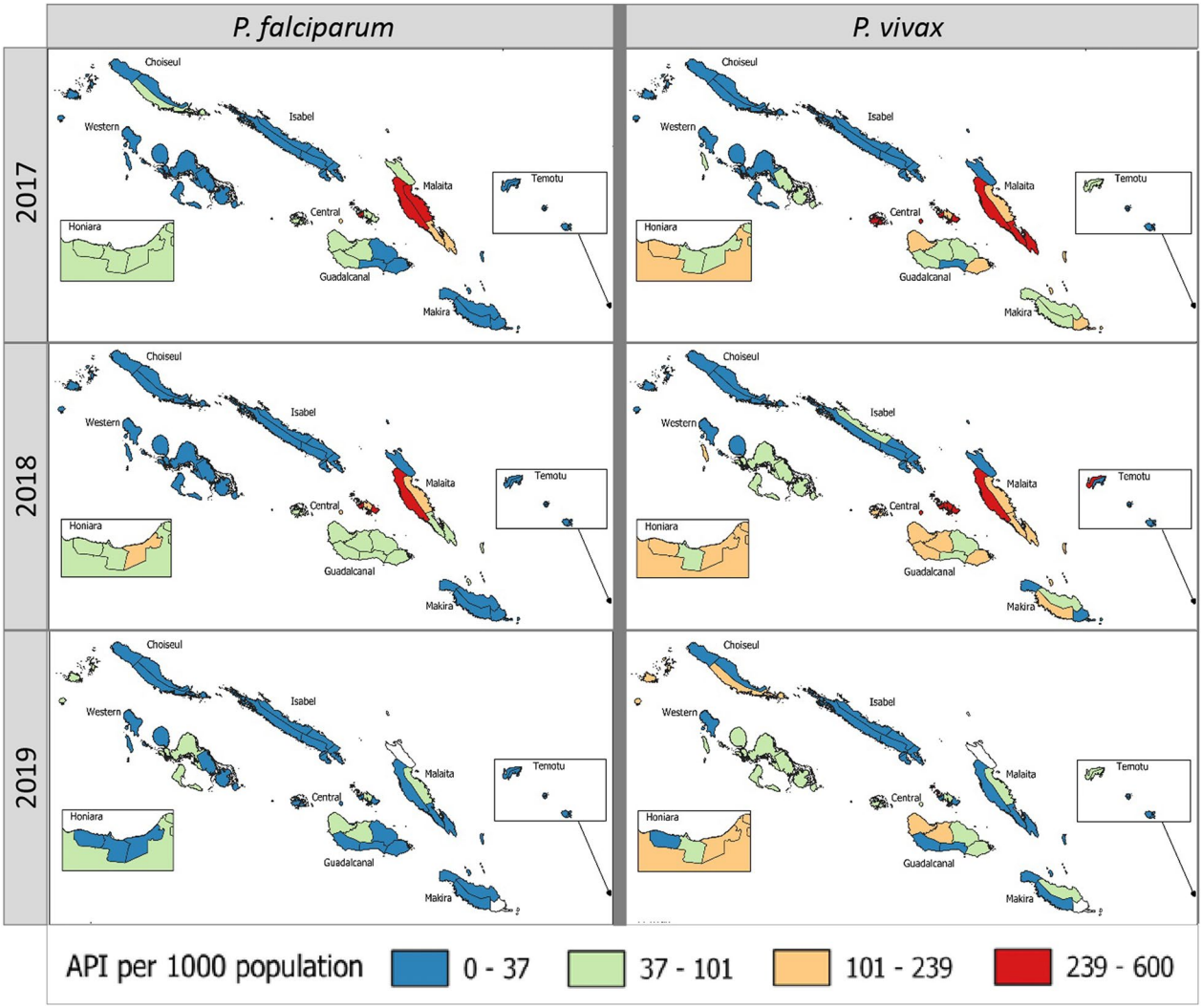

Fig. 2 The annual parasite incidence (API) of *P. vivax* and *P. falciparum* malaria species in health zones across the Solomon Islands from 2017 to 2019

by the population of people residing in the designated area (Province or health zone). Population data was sourced from the 2009 census data and was projected for each year using a growth rate of 0.009% [12].

Statistical analysis

Statistical analyses were conducted to explore trends in diagnostic test usage, test positivity rates, and the influence of demographic and geographic factors on diagnostic choices over time using the R package (v4.0.0) [19] and were visualised using gglpot (*package* ggplot2 in R). Maps were constructed using QGIS3. Note that for the RDT results, all "Non *P. falciparum*" results were assumed to be *Plasmodium vivax*, which was justified by the extremely low rates of *Plasmodium ovale* and *Plasmodium malariae* [20]. In the current dataset, microscopy detected only 39 positive *P. malariae* cases over

Table 1 Multi-model inference (MMI) comparing the influence of administrative division hierarchy on the use of microscopy compared to RDTs for malaria diagnosis in the Solomon Islands for 2017 to 2019

	df[a]	AIC	ΔAIC[b]	*w*AIC
Base	1	141233.3	30973.4	0
Province	11	135453.8	25193.9	0
Health zone	44	129812.9	19553.0	0
Health facility	331	110259.9	0.0	1

[a] *df*, degrees of freedom

[b] ΔAIC, change in AIC from lowest AIC

the 3 years and these were excluded from analysis. The reporting rate of health facilities was analysed using an ANOVA (*package* car).

Patient level dataset

The choice of test type was determined by limiting the dataset to the positive test results, as the negative test results were not associated with the type of test used in the patient level dataset. The influence of demographic, spatial and temporal explanatory variables on the choice of diagnostic test (microscopy versus RDT) at each administrative division was analysed using a series of generalized linear models (GLM; *package* lme4) that compared test used as a binary factor.

First, the influence of location on test choice was assessed using the overall administrative division hierarchy with quantitative step-forward multi-model inference (MMI) selection procedures. Model selection was based on ranking the value of the Akaike's Information Criterion (AIC). The hierarchical nature of the administrative divisions meant that these factors were highly correlated and could not be fitted simultaneously in a single model. Thus, the influence of location was analysed separately at four administrative divisions: national, province, health zone and health facility. Although health facility had the greatest influence on test choice of all administrative divisions (see results), programmatic decisions are made at different administrative divisions, and thus it was relevant to include models run at all administrative divisions. The explanatory factors included in the series of models were administrative division (excepting for national model), health facility type, gender, year and age. Models were fitted to examine the influence of these explanatory factors on test choice using the overall dataset for all positive *Plasmodium* spp. results.

Health facility level dataset

The health facility level dataset was analysed to examine the influence of spatial and temporal explanatory variables on the positivity rate of malaria diagnostics (microscopy vs RDT). Noting that for this dataset, the negative test results were recorded by test type. The series of models constructed were GLMs (*package* lme4) that compared positivity rate as a binary factor. Following the same structure as above, initially the influence of the administrative division hierarchy on the positivity rate was assessed using quantitative step-forward MMI selection procedures. Sequentially, the explanatory factors that influenced the positivity rate were analysed separately at three administrative divisions: national, province and health zone for each *Plasmodium* species. The explanatory factors included in the series of models were geography (excepting for the national model), test type, year and API.

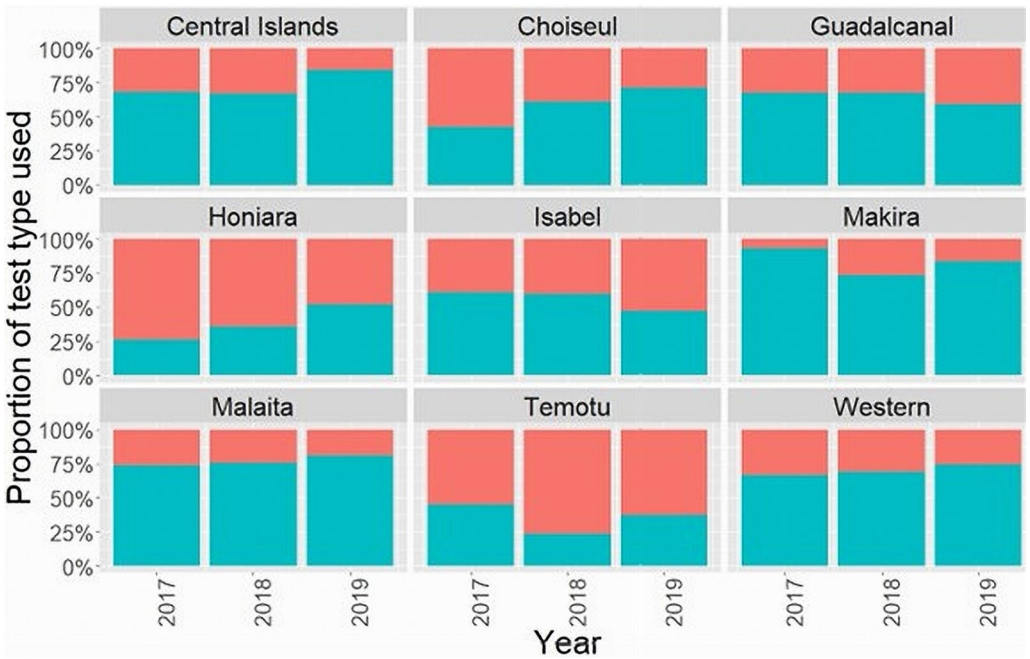

Fig. 3 The proportional use of RDT (blue) and microscopy (red) for malaria diagnosis in the Solomon Islands by province from 2017 to 2019

Table 2 The influence of geography, age, gender and health facility type on the choice of microscopy or RDT for malaria diagnosis in the Solomon Islands during the years 2017–2019 for all *Plasmodium* species, determined through generalized linear models (GLMs)

Explanatory factors	All *Plasmodium* spp. infections		
	$\chi^{2(a)}$	*df*[b]	*P* value[c]
National level model			
Age	863.7	95	< 2e-16*
Gender	2.5	2	0.2876
HF type	14534.2	4	< 2e-16*
Year	789.7	1	< 2e-16*
Provincial level model			
Province	11847.4	8	< 2e-16*
Age	461.7	96	< 2e-16*
Gender	0.5	20	0.8854
HF type	13912.5	4	< 2e-16*
Year	934.0	1	< 2e-16*
Health zone level model			
Health zone	30812.2	43	< 2e-16*
Age	341.6	96	< 2e-16*
Gender	5.9	2	0.0527
HF type	15030.6	4	< 2e-16*
Year	1342.0	1	< 2e-16*
Health facility level model			
Health facility	84959	330	< 2e-16*
Age	263	96	< 2e-16*
Gender	26	2	1.907e-06*
Year	1878	1	< 2e-16*

[a] χ^2, Chi-square values that measure the difference between observed and expected value

[b] *df*, degrees of freedom

[c] *P < 0.05, indicates significant influence on the choice of diagnostic test type

Results

Data coverage and reporting rate

Within the retrospective study period, there were 393 functional health facilities within the Solomon Islands including 13 hospitals, 38 AHCs, 117 RHCs and 225 NAPs. The rate of data reporting did tend to improve over the years, with the overall percentage of health facilities that did not report data or reported incomplete data being 27% in 2017, 25% in 2018 and 21% in 2019. The missing or incomplete data was excluded during the cleaning process. Variability in reporting rates by health facility type (P = 3.808e-14) was evident. NAPs had the lowest proportion of facilities that reported data across all 3 years with an average of 68% of health facilities reporting data, and RHCs had the highest reporting rate with an average of 88% reporting data (Fig. 1).

Overall malaria transmission rates

The nation-wide API in 2017 was 87 (positive tests per 1,000 population for all diagnostic test types) for *P. vivax* and 62 for *P. falciparum*; in 2018 the API was 100 for *P. vivax* and 67 for *P. falciparum*; and in 2019 the API was 53 for *P. vivax* and 15 for *P. falciparum*. The API was extremely heterogeneous by province and health zone. At the health zone level, the API ranged from 0 to 542 for *P. vivax* and up to 584 for *P. falciparum*. Across the years, there was some variability as to which health zones had the highest malaria rates, although generally the highest rates of malaria were concentrated in Guadalcanal, Central and Malaita Provinces (Fig. 2).

Despite the overall nation-wide reduction in API across the 3 years, there were some health zones (total = 44) where the API increased. For *P. vivax*, the API increased by > 25% in ten health zones and increased by > 50% in seven health zones. For *P. falciparum*, the API increased by > 25% in 15 health zones and increased by > 50% in ten health zones (Fig. S1 – S2).

Choice of malaria diagnostic

Analysis of test choice by administration divisions

All administrative divisions (Province > Health Zone > Health Facility) significantly influenced test choice, with health facilities explaining the greatest amount of variability in the data set, meaning that test choice was most strongly influenced at the level of the individual health facility (Table 1). At the provincial level, only Temotu relied predominately on microscopy for malaria diagnostics across all 3 years. All other provinces had a greater proportion of RDT than microscopy use in at least one of the years and 39/44 health zones had a higher proportion of RDT test usage averaged over the 3 years. The provinces where RDT usage increased by > 25% compared with microscopy across 2017 to 2019 were Honiara and Choiseul (Fig. 3, Figure S3).

Health zone data identified 12 health zones where microscopy was preferred over RDTs (> 50%) for malaria diagnosis in one or more years (Fig. S4). At a health facility level, there was substantial variability, with some relying entirely on microscopy or RDTs and others not at all (Figs S5-S13).

Influence of explanatory factors on test choice

The explanatory factors that influenced test choice at all administrative divisions were the administrative division, patient age, health facility type and year (Table 2). For patient age, there was a tendency to use microscopy more frequently for testing older patients (Fig. 4A). For the type of health facility, microscopy was more commonly used in hospitals, while RDTs were more frequently used

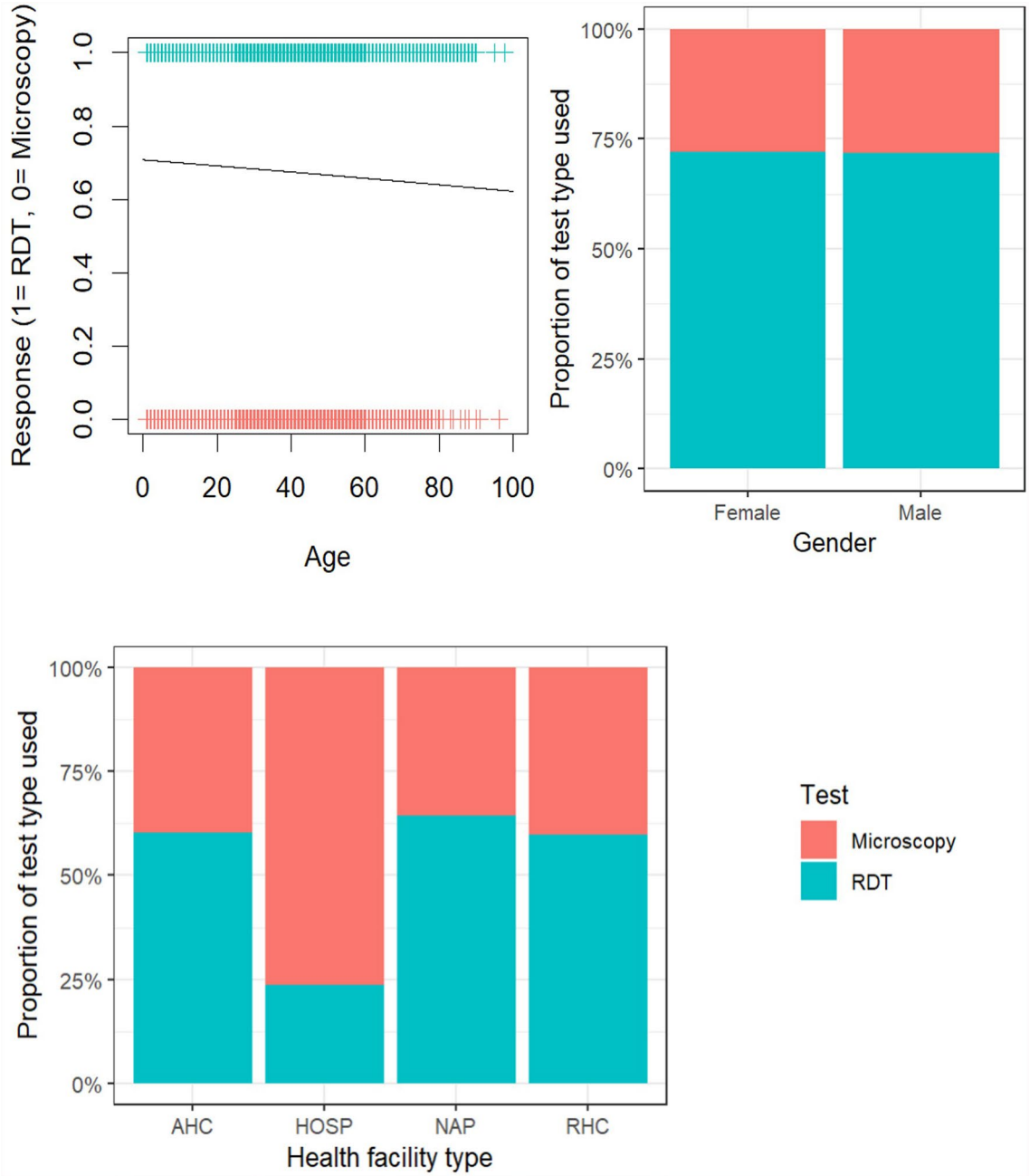

Fig. 4 Relative use of microscopy (red) compared to RDT (blue) for the explanatory factors of patient age, gender and health facility type (AHC, HOSP, NAP or RHC) in the Solomon Islands

at NAPs, RHCs and AHCs (Fig. 4C). Regarding gender, this factor influenced test choice at the health facility level (Table 2). Overall, there was a tendency towards using RDTs preferentially for females, but the pattern was not strong throughout the country and equitable usage of the tests across gender was often observed (Fig. 4B).

Influence of test type on positivity rate

Administrative division trends in positivity rate

The positivity rate of both RDTs and microscopy varied across the administrative divisions of province (Fig. 5) and health zone. The province had the most significant impact on the variability of positivity rates, indicating that the broader administrative division trends influenced the incidence of malaria recorded (Table 3). The

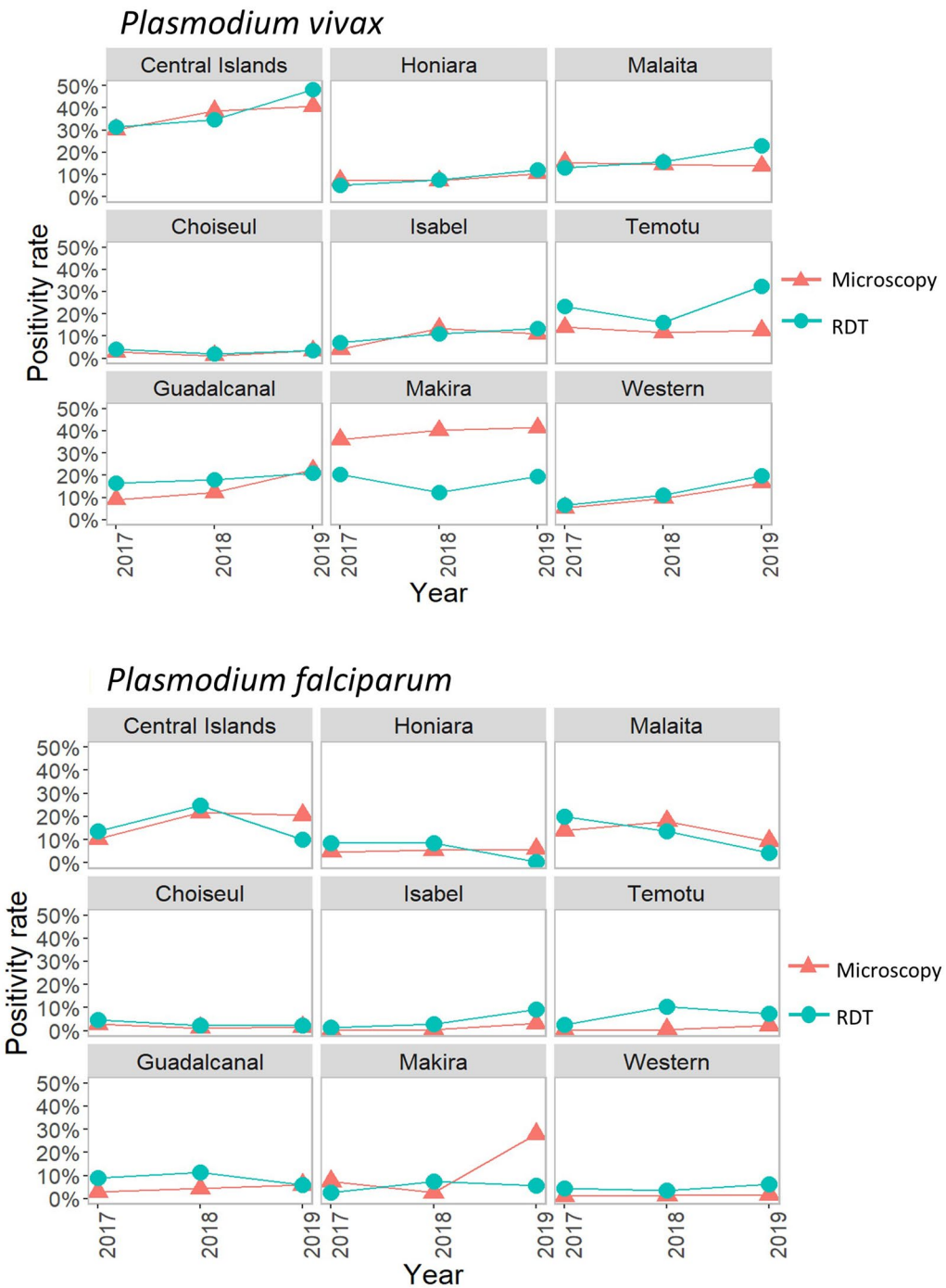

Fig. 5 The positivity rate for microscopy and RDT for *P. vivax* (top) and *P. falciparum* (bottom) in different Provinces of Solomon Islands over the years 2017–2019

positivity rates for each *Plasmodium* spp. also varied across provinces and health zones, ranging from 0 to 63% for *P. vivax* and up to 42% for *P. falciparum* (Table S1).

Influence of explanatory factors on positivity rate

There was variability in the positivity rates of both the RDTs and microscopy across different APIs (Fig. 6). The explanatory variables associated with the positivity rate of malaria diagnostics for both *Plasmodium* species

Table 3 Multi-model inference (MMI) comparing the influence of administrative division hierarchy on positivity rate derived from microscopy and RDT test results in the Solomon Islands across 2017 to 2019

	df[a]	AIC	ΔAIC[b]	*w*AIC
base	1	74270	56318	0
Health Zone	40	21254	3302	0
Province	9	17952	0	1

[a] *df*, degrees of freedom

[b] ΔAIC, change in AIC from lowest AIC

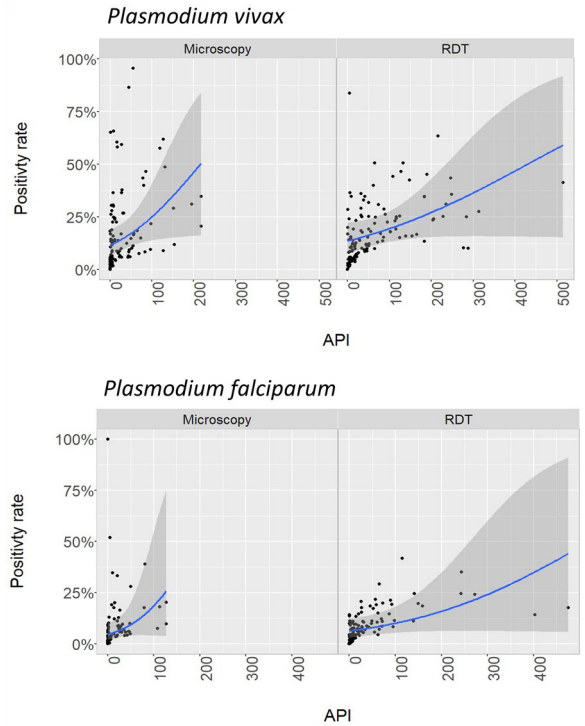

Fig. 6 Relationship between positivity rate and API for detecting *P. vivax* and *P. falciparum* with microscopy or RDTs in the Solomon Islands using cumulative data

were the administrative division, year and API (Table 4). These parameters are intuitively linked with the positivity of malaria diagnostics, via their influence on malaria incidence, as outline above (Fig. 2). For test type (RDT versus microscopy), this influenced the positivity rate for *P. falciparum* at all administrative divisions, and for *P. vivax* at the national and provincial level and was almost significant at the health zone level (Table 4). However, overall, the positivity rate of RDTs was higher, than that of microscopy to detect both *P. falciparum* and *P. vivax* infections (Fig. 7).

Discussion

This study analysed the use and positivity rates of microscopy and RDTs for the detection *P. falciparum* and *P. vivax*. While microscopy typically outperforms RDTs in detecting *Plasmodium* infections, our retrospective study revealed that, in a programmatic setting of the Solomon Islands, RDTs were the higher performer based on the overall positivity rate for both *P. falciparum* (Positivity rate: microscopy, 6%; RDT, 11%) and *P. vivax* (Positivity rate: microscopy, 10%; RDT, 14%). While this study did not directly compare the efficacy of the diagnostic tools, previous studies have demonstrated that under controlled laboratory settings, microscopy is more sensitive and specific than RDTs and even more so for detecting *P. vivax* malaria [2, 21, 22].

However, previous studies have also shown that the sensitivity and specificity of microscopy deteriorates in field settings. A recent study from Ghana, comparing results from 1,040 matched samples, found that RDTs (24.5% prevalence) outperformed microscopy (17.5% prevalence), with both tests missing over 40% of infections compared to qPCR [23]. Several malaria-endemic nations, including Kenya [24], Ethiopia [25] and Cameroon [21], have reported reduced field performance of microscopy. Also coinfections of multiple malaria species can complicate malaria diagnosis in rural field settings [26]. In contrast, the RDTs in this study, as well as in other countries such as Burkina Faso [27] and Kenya [28], consistently demonstrated comparable or higher performance in real-world settings. These findings support the increasing use of RDTs for malaria diagnosis in programmatic settings, while acknowledging that the specific RDT deployed, training, and available resources will influence performance [8, 22].

One of the key factors influencing the accuracy of microscopy in the field is the level of training and experience among staff. Inadequate training, along with the quality of microscopy equipment, reagents and supplies can lead to decreased diagnostic accuracy [29]. However, implementing and maintaining high-quality microscopy training can be challenging in low-resource settings [7]. RDTs, on the other hand, offer a simpler, less resource-intensive alternative that can be deployed across a range of health facility types, including those with fewer trained personnel or limited infrastructure.

At the facility level, the choice of diagnostic test was influenced by various factors, including the health facility type, patient age, ease of use and availability of trained staff and equipment. In centralized facilities such as hospitals, which are better equipped to support microscopy, there was a tendency to favour microscopy over RDTs. Additionally, older patients were more likely to receive microscopy as a part of their diagnostic process. This

Table 4 Results of the generalized linear models (GLMs) analysing the influence of geography, test type, year and annual parasite incidence (API) on the positivity rate of malaria diagnostics in the Solomon Islands during the years 2017–2019 for *Plasmodium falciparum* and *Plasmodium vivax*

Explanatory factors	*P. falciparum*			*P. vivax*		
	$\chi^{2(a)}$	*df*[b]	*P* value[c]	$\chi^{2(a)}$	*df*[b]	*P* value[c]
National level model						
Test	1665	1	< 2e-16*	1036.1	1	< 2e-16*
Year	621.2	1	< 2e-16*	3709.8	1	< 2e-16*
API	13184	1	< 2e-16*	12309.4	1	< 2e-16*
Province level model						
Province	15278.7	8	< 2e-16*	25686	8	< 2e-16*
Test	1534.6	1	< 2e-16*	956.5	1	< 2e-16*
Year	766.3	1	< 2e-16*	3976.1	1	< 2e-16*
API	2179.4	1	< 2e-16*	1190.1	1	< 2e-16*
Health zone level model						
Health zone	27439.7	43	< 2e-16*	44317	43	< 2e-16*
Test	211.3	1	< 2e-16*	0	1	0.4857
Year	162	1	< 2e-16*	4941	1	< 2e-16*
API	4474.9	1	< 2e-16*	2077	1	< 2e-16*

[a] χ^2, Chi-square values that measure the difference between observed and expected value

[b] *df*, degrees of freedom

[c] *P < 0.05, indicates significant influence on the choice of diagnostic test type

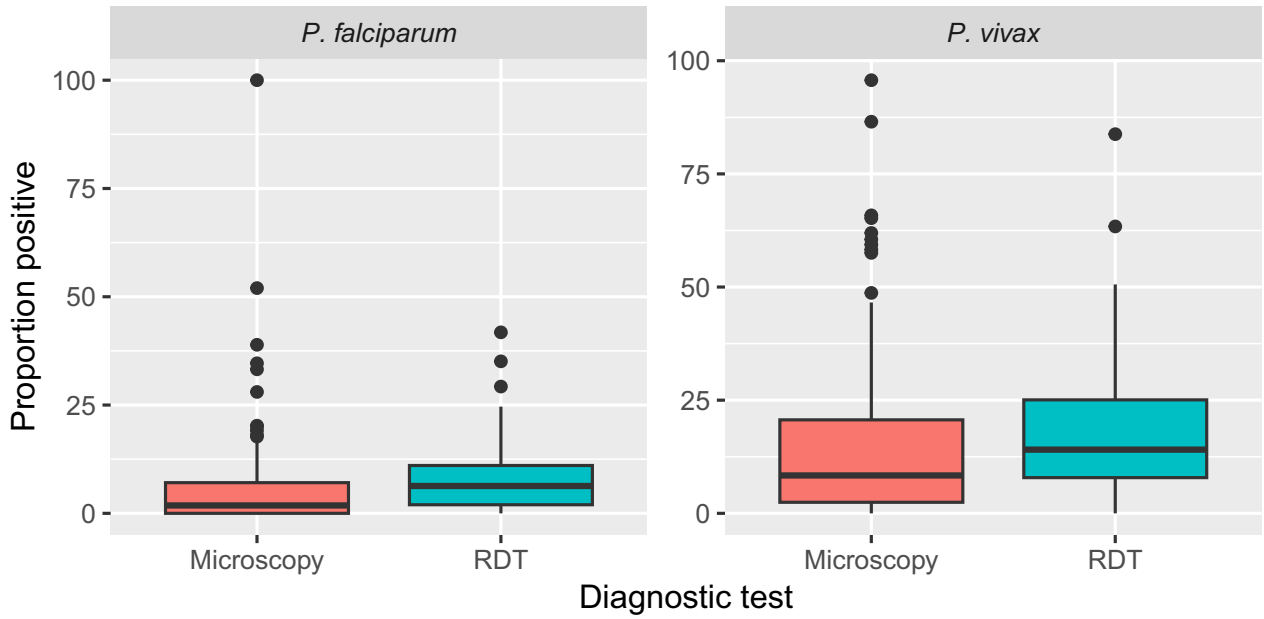

Fig. 7 National positivity rate of individual health facility positivity rates for the detection of *P. vivax* (P < 2e-16) and *P. falciparum* (P < 2e-16) with microscopy (orange) or RDTs (blue) in the Solomon Islands

trend may be due to acquired immunity to malaria, which increase with age and may decrease in parasitic load [30], influencing the choice of test.

The patient-level data analysis in this study highlighted several trends, including varying APIs, positivity rates, and test usage across regions. The results indicated that RDTs may offer a more consistent diagnostic tool across

rural settings, where access to well-equipped laboratories and expert microscopists is limited. In these settings, the higher positivity rates observed for RDTs reinforce their suitability as the primary diagnostic tool for malaria, especially for areas where *P. falciparum* and *P. vivax* are the dominant species.

Limitations

A key limitation of this study was the inconsistent data reporting which is common for most malaria endemic [2, 31]. This limitation may have led to misrepresentation of malaria diagnostic use in the dataset. To improve data quality, further support for consistent reporting across all health facilities, particularly NAPs, is needed. Additionally, the negative results were recorded using a single code for both RDTs and microscopy made it impossible to differentiate between the two test methods, resulting in the exclusion of a significant portion of the data. This study also did not directly assess the efficacy of the diagnostic tools or confirm diagnosis with qPCR, which may result in some false positive and negative cases throughout the clinical dataset. Furthermore, the potential for false negatives due to histidine-rich protein 2 (hrp2) gene gene deletions in RDTs was not addressed [32], although no reports of HRP2 gene deletions have been documented in the Solomon Islands [33]. The study also does not address the comparative cost of deploying microscopy compared to RDT testing, an aspect that warrants calculation before making decisions regarding test selection.

Conclusion

This retrospective study provides important insights into the use and positivity rates of malaria diagnostics in low-and-middle-income settings, highlighting the challenges and benefits of using microscopy and RDTs in programmatic context. Given the observed degradation in microscopy performance from laboratory to field settings, RDTs offer a more attractive option for widespread use in rural areas with limited infrastructure and expertise. The higher positivity rates of both *P. falciparum* and *P. vivax* infections detected by RDTs, particularly in remote areas, support the transition toward RDTs as the primary diagnostic tool for malaria in the Solomon Islands. IThese findings have broader implications for the global fight against malaria, particularly in areas with similar resource constraints, and can guide future efforts to improve malaria diagnostics in low-resource settings.

Abbreviations

API	Annual parasite incidence
AHC	Area health centre
DHIS2	District Health Information Systems
G6PDd	Glucose-6-phosphate-dehydrogenase deficiency
Hrp2	Histidine-rich protein 2
JCU	James Cook University
LDH	Lactate dehydrogenase
LMIC	Low-and-middle-income countries
MMI	Multi-model inference
NAP	Nurse aid post
POC	Point-of-care
RDT	Rapid diagnostic test
RHC	Rural health centre
qPCR	Quantitative Polymerase Chain Reaction
USC/UniSC	University of the Sunshine Coast
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12936-025-05468-6.

Supplementary material 1.

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Author contributions

GK: methodology, validation, formal analysis, investigation, data curation, writing—original draft, visualization. LW: conceptualization, resources, writing- review and editing. JL: conceptualization, resources, writing- review and editing. JM: Writing—review and editing. TLR: conceptualization, methodology, validation, formal analysis, investigation, writing- review and editing, supervision, project administration.

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Data availability

The data that support the findings of this study is owned by the Ministry of Health of the Solomon Islands and are not publicly available. The data was used under license for the current study. The data can be made available upon reasonable request and after receiving permission from the Ministry of Health, Solomon Islands.

Declarations

Ethics approval and consent to participate

Ethical approvals for the study were obtained from the National Health Research & Ethics Committee, Solomon Islands (HRE040/19), the James Cook University Human Research Ethics Committee, Australia (H8115) and University of the Sunshine Coast Human Research Ethics Committee (A201402). The data analyses were performed in accordance with relevant guidelines and regulations of these research boards, and as stipulated in the approvals.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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