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The Impact on Absence from School of Rapid Diagnostic Testing and Treatment for Malaria by Teachers

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Abstract. Malaria is the principal preventable reason a child misses school in sub-Saharan Africa and the leading cause of death in school-aged children. We describe a model for teachers to use rapid diagnostic testing (RDT) for malaria and treatment with Artemisinin-based combination therapy (ACT) to enhance education by reducing school absence due to malaria. Conduct: A 2-year pilot program in 4 primary schools in rural Uganda. Year 1, Pre-intervention baseline evaluation (malaria knowledge; school practices when pupils become sick; monitoring of days absent as a surrogate for morbidity and teachers trained to administer RDT/ACT as the Year 2 intervention. Findings: Teachers identified malaria as a barrier to education, contributed to logistic design, participated willingly, collected accurate data, and readily implemented/sustained RDT/ACT program. Pre-intervention: 953/1764 pupils were sent home due to presumed infectious illness; mean duration of absence was 6.5 days (SD: 3.17). With school-based teacher-administered RDT/ACT 1066/1774 pupils were identified as sick, 765/1066 (67.5%) tested RDT positive for malaria and received ACT; their duration of absence fell to 0.6 days (SD: 0.64) ($p<0.001$) and overall absenteeism to 2.5 (SD: 3.35). The RDT/ACT program significantly reduced days of education lost due to malaria and empowered teachers; this model is applicable to schools globally.

Keywords: Absenteeism; Community-based education; Health promoting schools; Malaria.

Introduction

Malaria is the principal reason why a child will be absent from school where the disease is endemic and the main reason a school-aged child will die in sub-Saharan Africa. The burden of malaria and negative impact on education is greatest amongst children in low resource settings and rural areas (Brooker, et al., 2000; Jukes, et al., 2008; Kimbi, et al., 2005). The duration of malaria-related absence from school, frequency of absence due to repeated infection, compromise to learning due to residual malaise after sub-optimal treatment or when permanent neurological complications occur with falciparum malaria all negatively impact children's education (Kihara, et al., 2006; Kimbi, et al., 2005; Snow, et al., 2003). To minimize the adverse effects (morbidity) of malaria the WHO advocates early, accurate diagnosis of infection and prompt, effective treatment within 24 hours of the onset of illness (WHO, 2014).

Schools promoting health using the WHO Health Promoting School (HPS) model provide opportunities within the formal curriculum to improve 'knowledge' and conduct a range of activities to educate pupils about 'healthy practices' (Macnab, et al., 2013; St Leger, et al., 2009; WHO, 1997). But, while many schools in Africa do this in the context of malaria (Macnab, et al.; 2014), the impact of such programs is limited because it is difficult to make a diagnosis of malaria as symptoms are not specific, and diagnostic blood tests are often not readily available. In addition, a lack of knowledge about appropriate treatment and limited access to care in the community commonly contribute to malaria morbidity (Kallander, et al., 2004). Hence, simple, accurate and inexpensive diagnostic tools and wider availability of effective therapy are recognized as urgently needed to reduce the impact of this disease on children (Mutabingwa, 2005).

The combined use of Rapid Diagnostic Test (RDT) kits to diagnose malaria with administration of Artemisinin-based combination therapy (ACT) in those testing positive meets this need. RDT/ACT use has improved the accuracy of diagnosis and efficacy of treatment for malaria, but deployment of RDT and ACT has been slow, especially in low resource settings. This is because the social engagement necessary to spread the knowledge that this approach is effective and make it accessible to rural populations has been missing (Mutabingwa, 2005).

Our hypothesis was that if school-based rapid diagnostic testing for malaria by teachers was made available, all sick children usually sent home with a presumed infectious illness would be screened using RDT, and be given ACT when they tested positive. Educational benefit would accrue from a significant reduction in days absent from school; less absence being a surrogate measure for reduced morbidity from malaria. Also, in addition to improving school attendance, better health outcomes should translate into an enhanced ability to learn and better educational attainment in the long-term. An improvement in children's knowledge and community practices related to malaria would be a secondary outcome.

Importantly, RDT kits are now available in Uganda and the feasibility of using them has been demonstrated in rural clinics (Guthmann, J, et al., 2002; Kilian, et al., 1999), and most recently in shops selling medicines (Mbonye, et al., 2010). However, training low cadre health care workers, including school nurses, to use these simple kits has not been done. Artemisinin-based combination therapy has

been adopted as a first line treatment for malaria, but while village health workers have been taught home-based management of fever and ACT administration, school nurses have not been trained comparably (President's Malaria Initiative, 2005).

Malaria RDT kits provide a diagnosis in minutes by detecting the presence of malaria parasites in human blood. RDT kits vary, but the principles of how they work are similar (WHO, 2015; Wongsrichanalai, et al., 2007). Most are packaged for individual use and include a lancet to obtain blood from a finger-prick. A drop of blood from a potentially infected individual is put onto a strip of nitro-cellulose housed in a plastic cassette to test for the presence of specific proteins (antigens) produced by malaria parasites. If malaria antigens are present, they bind to the dye-labeled antibody in the kit, forming a visible complex in the results window. A control line confirms the integrity of the antibody-dye conjugate. The sensitivity and specificity of RDTs are such that they can replace conventional testing for malaria (Abba, et al., 2011; Murray, et al., 2008).

ACTs are the best anti-malarial drugs available nowadays, and the first-line therapy for P. falciparum malaria recommended by WHO for use worldwide since 2001 (International Artemisinin Study Group, 2004; Malaria Consortium, 2016; WHO, 2016). Natural Artemisinin is sourced from Artemesia annua; the herb, native to China, has a long-standing reputation for efficacy in treating fevers; Artemisinin is now also made synthetically. ACTs combine Artemisinin, which kills the majority of parasites within a few hours at the start of treatment, with a partner drug of a different class with a longer half-life, which eliminates the remaining parasites (Benjamin, J, et al., 2012). Several preparations combining these two components in a single fixed-dose tablet are now available. Benefits of ACTs include high efficiency, fast action, few adverse effects and the potential to lower the rate at which resistance emerges and spreads; to make best use of ACT issues related to access, delivery and cost have to be addressed (Malaria Consortium, 2016).

Since 2006 we have used the WHO Health Promoting School (HPS) model to engage communities in rural Uganda and deliver low cost health education in schools (Kizito, et al., 2014; Macnab & Kasangaki, 2012; Macnab, et al., 2014). From dialogue with teachers in these communities we learned that absence from school due to malaria is high and most children sent home due to febrile illness do not subsequently access clinics where RDT/ACT are used, due to factors including distance, cost, and lack of awareness of the importance of treatment. Hence the logic of our initiative to offer school communities teacher training and support to enable school-based RDT and ACT to be provided. The incentive for teachers was the potential to improve the education of their pupils by reducing the length of time they are absent from school due to malaria, and decrease the negative impact that sub-optimal management of this disease is known to have on children's ability to learn.

This intervention was designed as a logical and medically expedient response to the concern voiced by teachers in Uganda. However, the same barriers to childhood education exist worldwide where malaria is endemic, hence the broad relevance of the health promotion model we describe, particularly for schools serving children in rural resource-poor settings.

Methodology/Approach

This initiative was delivered as a community outreach project conducted in 4 newly established health promoting schools by the Health and Development Agency (HEADA) Uganda. HEADA is a non-governmental agency funded by the Hillman Medical Education Fund to implement comprehensive health education, treatment, and support programs in Western Uganda. The project employed the principles of participatory action research and followed recommended steps for achieving participation and trust in communities engaged in health promotion. Action research is problem-centered, community-based and action-oriented. It is an interactive process that co-develops programs with the people who use them and balances collaborative problem-solving action(s) with data collection and validation of efficacy (Baum, et al., 2006). Community trust comes via conscientious dialogue, synergistic engagement, joint decision-making, and feedback that shares what does and does not work (Laverack & Mohammadi, 2011; Macnab, et al., 2014b). Figure 1 summarizes the steps taken to implement this project.

In the school communities dialogue established how absence from school due to malaria has a negative impact on the education of a large number of pupils. The teachers described that their current practice was to send children home who were sick or had fever; they assume many have malaria but it is left to the parents to decide whether action to diagnose or treat their child occurs. Many children are absent for more than a week, and often those returning clearly remain unwell and unable to participate fully in class for several days, or even weeks.

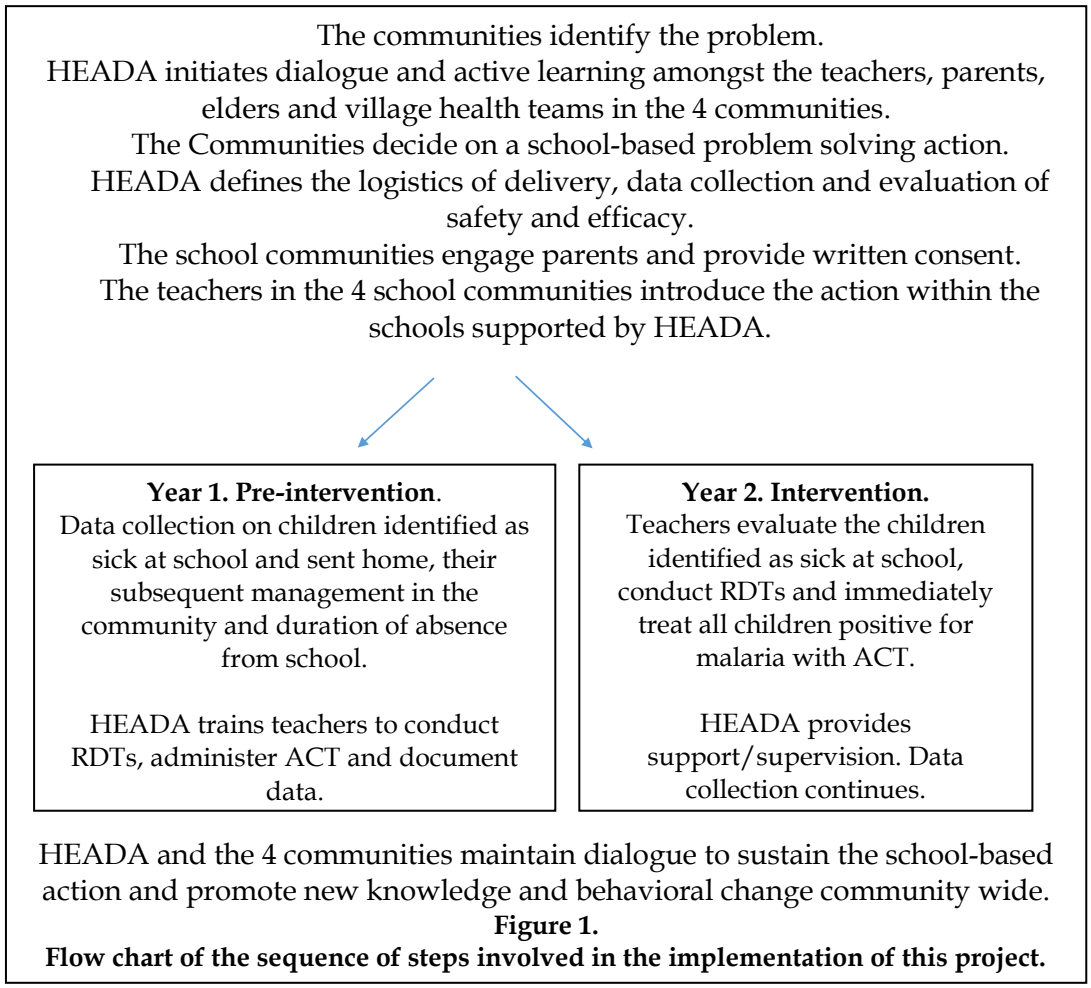

Figure 1.
Flow chart of the sequence of steps involved in the implementation of this project.

Public forums were initiated by HEADA to generate dialogue and active learning about malaria causation, diagnosis, and treatment amongst the teachers, parents, elders and village health team members. These took the form of presentations with question and answer sessions that summarized current knowledge about the benefits of interventions available elsewhere in Uganda and the practicalities of delivering them, particularly the use of RDT kits for prompt, accurate diagnosis in government clinics and the importance of early treatment with ACT.

The communities decided that they wanted a school-based program; problem-solving discussions were used to explore the options available and potential hurdles the schools would face. These included if teachers would want to invest the time to take the training required and to run a school-based program, and be prepared to conduct testing involving collection of a blood sample by finger prick. HEADA then defined the logistics of a teacher delivered RDT and ACT program and a data collection strategy to evaluate safety and efficacy. The teachers engaged parents in community-wide sessions to invite participation, allow dialogue with HEADA regarding the process and pros and cons of involvement, and obtain consent (Okello, et al, 2013).

Ethical considerations were addressed as follows: It was explained to parents that in Year 1 data on absenteeism would continue to be recorded as usual by the school for evaluation purposes, and in Year 2 those children who became sick with fever or had signs suggestive of an infectious illness would be assessed by a trained teacher, the use of RDT /ACT considered, and additional data collected. Each school signed an agreement to follow the co-developed action protocol. The school obtained consent from parents for all pupils participating; no parents wanted their child excluded; separate informed consent was obtained from parents prior to follow up visits conducted by HEADA in the community. Each child identified as sick and needing assessment at school was required to give verbal assent for conduct of an RDT, and treatment with ACT if the RDT was positive. Pictographic information sheets on how the RDT is conducted were used to aid education of parents and children in this context. A young investigator was included in our team to facilitate the comprehension and engagement of pupils.

The teachers in the 4 school communities introduced the action protocol into the school's routine supported by HEADA staff who visited the schools weekly to assist and respond to queries, and where necessary make adjustments to accommodate community-driven needs.

In Year 1 the protocol involved data collection related to sick pupils sent home and subsequently absent. School absence for reasons other than presumed infectious illness was excluded; e.g. injury, bad behavior, caring for a sick sibling, domestic work or failure to pay school fees. HEADA trained the teachers to conduct RDT and administer ACT in one-day interactive workshops supervised by a physician and run by trained laboratory staff (2) and nurses (2). These health and education professionals trained one teacher as the primary evaluator and one as back up for each school. After a knowledge pre-test, instruction included: evaluation of a child for symptoms suggesting an infectious illness (headache, malaise, nausea/vomiting, fatigue/somnolence, aches and pains +/- fever); theory and practice related to the conduct of RDT and use of ACT; record

keeping; needle safety and waste disposal techniques; and post exposure prophylaxis standard operating procedures and access to anti-retroviral therapy in case of accidental needle pricks. Practical competency was evaluated and a post-test administered. A refresher course was given in Year 2.

The RDT kits used were: Malaria Ag pan/Pf Malaria test kits 'Malarascan' (Zephyr Biomedical Systems) which targets HRP2 and Pan Aldolase of Plasmodium falciparum and other less common Plasmodium species (P. vivax, and P. ovale); sensitivity (96.3%) and specificity (98%) are high.

In Year 2 the protocol added screening with RDT for malaria and treatment of those testing positive with ACT by the trained teachers. A single dose ACT preparation was used rather than the conventional 3-day 12 hourly regimen to ensure a full course of treatment was completed; this was to avoid the potential for partial treatment bias if any of the five additional doses that would have had to be given at home were missed. The ACT chosen was Arco (Artemisinin-Napthoquine) (Midas Care Uganda, Ltd). The drug was given with milk or juice to aid tolerance and taken under teacher supervision. Children were observed for at least 1 hour for side effects; the protocol called for another dose to be given if vomiting occurred.

Throughout the 2-year intervention HEADA and representatives from the 4 communities maintained dialogue to sustain the program and promote new knowledge about malaria and encourage behavioral change community wide. In the schools, this involved the core approaches of the WHO HPS model (Macnab, 2013): classroom education to increase knowledge and school-based activities to develop practices and behaviors that benefited the children in the context of malaria. Assessment of children's knowledge preceded these activities and post-intervention assessment followed for comparison. In the community HEADA provided feedback via workshops on the conduct and efficacy of the school-based intervention.

Results

Four primary schools were engaged in geographically separate low resource rural settings in south-western Uganda; Bwizibwera Town School, Rutooma Modern, Kaguhanzya Primary and Ruhunga Primary. Ninety kilometers separated the 4 schools; a motorcycle and fuel costs were included in the budget; HEADA staff travelled more than 20,000 km in the course of coordinating the project. Total pupil enrollment was 1764 in Year 1 and 1774 in Year 2 across classes primary 1 – 7.

Community-based dialogue (May – September 2013) led to the collaborative decision to introduce school-based teacher-administered RDT and ACT. Quotes from Head Teachers include 1) "This is exactly what we need, testing and treating malaria at school. We are ready to collaborate". 2) "Our children suffer from fever and malaria, but we send them home where they are given local herbs and paracetamol. Malaria affects children's brains and ability to learn; it is a great opportunity for us to be trained to prevent this from continuing to happen". 3) "Our teachers are enthusiastic about being involved in testing and treating children after they have undergone training. Our School Board Chairman has endorsed the idea. We are grateful for this initiative".

Baseline assessment, logistic planning, teacher training and inquiry of how sick children sent home were managed by parents took place in Year 1 (September 2013 - August 2014), and RDT/ACT intervention with ongoing evaluation followed in Year 2 (September 2014 - August 2015). This allowed a 2-year evaluation where pre and post intervention data were collected over comparable 3 term periods during 2 consecutive school years, recognizing the seasonal nature of malaria.

Children's knowledge and awareness about malaria causation, transmission, prevention, diagnosis and management were assessed in classroom sessions. Pre-intervention, less than 20% of children knew mosquitos transmitted the disease, the relevance of bed nets as a preventive measure, how diagnosis is made and the importance of prompt and effective treatment. By Year 2 essentially 100% of children had a comprehensive grasp of these facts, knew the symptoms and signs of probable infection and how to access appropriate diagnosis and treatment.

Inquiry by anonymous questionnaire established that all teachers except one wanted to be trained to do RDT for malaria, and all would administer ACT and agree to take on the responsibility and additional work of evaluating sick children as per the action protocol. The schools calculated that each needed 2 trained staff to conduct the duties required; one as the primary evaluator and one to be available as back up throughout the intervention. A total of 11 teachers were trained in interactive workshops over 2 years; performance at school and refresher course evaluation confirmed all had good knowledge retention and practical competency. Safe waste disposal was ensured by use of sharps boxes for used blood lancets and biohazard bags. No adverse events requiring anti-retroviral treatment occurred; every 50th positive RDT was checked by a laboratory and all proved accurate.

Figure 2.
Management by parents of a subset of 104 febrile children with symptoms compatible with malaria after they had been sent home from school.

In Year 1 the management of 104 febrile, sick children was evaluated once they were sent home from school. All had symptoms compatible with malaria, however, parental management of the majority was not in keeping with WHO

recommendations (prompt assessment, accurate diagnosis and comprehensive treatment within 24 hours of the onset of illness) (WHO, 2014). Only 1 out of every 4 (26%) was taken for any form of conventional diagnostic measure or clinic-based anti-malarial treatment; 42% were only given an anti-pyretic (e.g. paracetamol); 19% received a local traditional herbal remedy; 8% were taken to church; and 5% were cared for by a traditional healer. Figure 2 summarizes these data.

Table 1 shows the demographic and study data from Year 1 (pre-intervention) and Year 2 (intervention). The number of children identified by their classroom teachers as being sick with a potential infection and needing to be sent home using the school's regular criteria in the pre-intervention year was 953. In the intervention year this number was 1066. These 1066 were evaluated by a trained teacher, the presence of symptoms compatible with infection confirmed, and RDTs done. The RDT was positive in 715 of the sick children (67.5%), and all received immediate treatment with the single dose ACT preparation (Artemisinin-Napthoquine).

The mean duration of absence from school in children sent home with a presumed infectious illness pre-intervention was 6.5 days from onset of illness to return to class. During intervention mean duration of absence was 2.5 days overall ($p < 0.001$), 0.6 days in the 715 children RDT positive for malaria treated immediately with ACT ($p < 0.001$) and 4.6 days in those RDT negative. Many treated children felt well enough to ask to return to class of their own volition within a few hours of receiving ACT, and hence had no days of absence from school. Some very small variations in absenteeism rates were evident over the 2 years between schools, across classes (grades) and from term to term (season). Overall, absence from school was reduced by 60.8% during intervention with RDT/ACT.

Also, with 67.5% of sick children RDT positive in Year 2, if the same percentage of children sent home in Year 1 also had malaria, this equates to 1358 cases in 1775 children over 2 years; or a malaria incidence rate of 79% across the 4 schools. No adverse events occurred in the context of RDT screening and no adverse reactions resulted from administration of the single dose ACT preparation which was well tolerated. No children died from malaria during the intervention year.

Post-intervention dialogue identified a consensus amongst teachers that participating children had derived significant health and educational benefit from provision of school-based RDT/ACT. In addition to missing less school due to absence, those treated for malaria were reported to appear fully engaged and able to benefit from being back in class. HEADA staff identified that in the broader community new knowledge was affecting behavioral change over how suspected malaria was managed. It was agreed that the 4 schools would continue to offer RDT/ACT, but via a modified intervention where RDT positive children would now be given a conventional 3 day ACT regimen (Artesunate-Amodiaquine) in the interest of cost. Knowledge transfer was also extended beyond the community, with research reporting, publication and dialogue to engage the Health Ministry.

Table 1. Demographics and Study data: Year 1 Pre-intervention and Year 2 Intervention with school-based RDT/ACT administration by teachers.

Pre-intervention		**Year 1**			
Children (total)	1764				
Age range / years	5-13				
Gender M/F %	49/51				
Schools		Bwizibwera	Rutooma	Ruhunga	Kaguhanzya
Children by school. Year at start/at end		412/424	451/451	189/185	712/715
Sick/sent home Total	953				
Sick/per school		221	200	218	314
Sick/per term					
Tested RDT	n/a				
Positive RDT MALARIA	n/a				
Positive vs Negative RDT	n/a				
Treated ACT	n/a				
Absence (Days) Sick sent home TOTAL	6.5 (3.17)	6.2	6.5	6.7	6.6
Absence (Days) Sick sent home RDT = MALARIA	n/a				
Absence (Days) Sick sent home RDT = NEGATIVE	n/a				
Intervention		**Year 2**			
Children (total)	1774				
Age range / years	5-13				
Gender M/F %	49/51				
Schools		Bwizibwera	Rutooma	Ruhunga	Kaguhanzya
Children by school. Year at start/at end		422/422	451/451	189/188	712/712
Sick/sent home Total	1066				
Sick/per school		263	201	300	302
Sick/per term		56/127/80	27/97/77	55/135/110	70/133/99
Tested RDT	1066				
Positive RDT MALARIA	715	27/92/49	20/74/57	28/68/106	35/98/62
Positive vs Negative RDT		168/263	151/201	202/300	195/302
Treated ACT	715	27/92/49	20/74/57	28/68/106	70/133/99
Absence (Days) Sick sent home TOTAL	2.55 (3.35) $p< 0.001$	2.4	2.8	3.0	2.5
Absence (Days) Sick sent home RDT = MALARIA	0.59 (0.64) $p< 0.001$	0.49	0.66	0.72	0.48
Absence (Days) Sick sent home RDT = NEGATIVE	4.62 (3.54)	4.1	6.1	4.5	3.8

Discussion

This study shows that the education of children in rural Uganda can be advanced by training teachers to screen children for malaria using RDT and provide immediate ACT treatment at school for those infected. This intervention

significantly reduced the number of days of schooling missed due to malaria, and prompt effective treatment is known to reduce long-term complications that negatively impact a child's ability to learn.

Amongst sick primary school children, who teachers would otherwise just have sent home, 67.5% tested positive for malaria and received ACT. Within hours, many of these children felt well enough to rejoin their class rather than go home, presumably due to the promptness of treatment relative to their symptoms beginning, and rapid parasite clearance rate achieved by Artemisinin (Benjamin, et al., 2012). Overall, the duration of absence from onset of malaria symptoms to return to class for the children teachers treated fell 60.8% when compared to the duration of absence in the pre-intervention cohort sent home with a presumed infectious illness.

This translates to a reduction from more than a week of absence to less than 1 day of education lost in children diagnosed and treated with our school-based intervention. With prior research emphasizing that up to 50% of preventable school absenteeism is due to malaria (Brooker, et al., 2000), RDT /ACT use by trained teachers offers an effective means to combat morbidity from malaria amongst school children.

Importantly, while children diagnosed and treated in this initiative missed less school because they recovered quickly, from what teachers reported it is also probable that they recovered more completely. The observation that they interacted and behaved normally on return to class suggests that having malaria which was diagnosed and treated promptly had little or no long-term consequences on their ability to learn. Hence, although not directly measured, it is likely that school-based RDT /ACT programs can improve overall learning potential and educational outcome.

In this context it is relevant that malaria in Uganda is predominantly caused by Plasmodium falciparum ('cerebral malaria'). Such infection is often associated with loss of cognitive and fine motor function when diagnosis and treatment are delayed or absent. Educational compromise often results because the resulting loss of function may be permanent and can involve all cognitive spheres (language, attention, memory, visuospatial skills and executive functions) (Birbeck, 2010; Fernando, et al., 2003; Jukes, et al., 2008; Kihara, et al., 2006; White, et al., 2013; WHO, 2015).

The potential for school-based RDT/ACT to provide important educational benefits through the early diagnosis and effective treatment it affords is endorsed by studies in schools where children take prophylactic chloroquine to prevent malaria. In these children improved educational attainment is evident in addition to reduced absence from school, when they are compared to children given a placebo (Fernando, et al., 2010; Jukes, et al., 2006).

With any school-based intervention teacher participation and the feasibility, sustainability and validity of what is done are clearly relevant. It was the teachers in the participating schools who identified that malaria was a barrier to their pupils' education. They participated willingly in the required skills training, successfully delivered RDT and ACT at school, consistently collected the data necessary to evaluate efficacy and sustained the intervention. The broader community (parents, elders, health teams) endorsed a school-based intervention, reported seeing benefits for their children as it was implemented and felt better

educated themselves about how to manage malaria. Importantly, in addition to being feasible, our approach of making RDT and ACT use accessible to school children is valid; prior research has shown RDT/ACT can provide rapid, accurate diagnosis and efficient treatment, is simple enough to adopt outside health care facilities, and improves the health of those least able to withstand the consequences of illness (Amexo, et al., 2004; Moody, 2002; Mutabingwa, 2005).

From an educational standpoint, children's knowledge and awareness related to malaria also improved. Children now knew how malaria was caused, symptoms suggesting infection, that diagnosis and effective treatment are available and the importance of both. Parents also learned first-hand that malaria can be rapidly diagnosed and that there are benefits from early treatment with ACT. This later change is significant as the schools were all in low resource rural settings, where prior to our initiative we identified that only 1 in 4 febrile children sent home from school received management for malaria that met WHO recommendations (WHO, 2014). These findings match prior research (Uganda Bureau of Statistics, 2010); and the school-based RDT/ACT model used by our trained teachers met the WHO criteria for managing malaria with prompt, accurate diagnosis and comprehensive treatment within 24 hours of the onset of illness (WHO, 2014).

Although use of RDT kits and ACT treatment is endorsed at government level, their use in a school-based program by appropriately trained teachers is novel as far as we are aware. Importantly, our experiences are broadly in agreement with previous studies on a), the logistics of RDT/ACT use that indicate that RDT kits can be stocked and used appropriately outside formal health facilities (Mbonye, et al., 2015), and b), that training comparable to our instruction of teachers enables diagnostic kits to be used reliably (Mbonye, et al., 2010). Our diagnostic rate for malaria of 67.5% in children with presumed infectious illness is directly comparable to the 72.9% of patients with fever who tested positive in a recent trial where RDT was introduced into registered drug shops (Kyaabayinze, et al., 2010). The authors of this trial (designed and implemented by the Ugandan Ministry of Health) stated their results demonstrated that 'when introduced as part of a comprehensive intervention, RDTs can serve to guide better diagnosis of malaria", and, that there is "evidence to support scale up of RDT and ACTs" (Mbonye, et al 2010); this indirectly endorses our school-based approach.

Importantly, we believe our results and the benefits we describe can be generalized to schools in most areas of Uganda with a similar endemic setting, as our intervention took place in 4 geographically separate rural schools and all children identified as sick due to a presumed infectious illness were included. Also there is the potential for our school-based model for diagnosis and treatment to be explored in other regions in Africa and elsewhere, as malaria is the most prevalent parasitic disease that affects human beings worldwide. It is endemic in 108 countries, estimates indicate that >3 billion people are at risk, >85% of cases and 90% of deaths occur in sub-Saharan Africa, and that the burden of disease is highest amongst children in rural and low resource communities (White, et al., 2013).

The cost and cost-benefit of RDT/ACT are relevant. The cost of ACTs especially has been identified as a potential barrier to scale up of initiatives that use them (Mbonye, et al., 2015; Mutabingwa, 2005). Our cost for RDT was about

US$ 0.50 per kit. But how easy it is to perform the diagnostic test and train personnel to use a given RDT kit are additional considerations (Moody, 2002). We chose to use a relatively expensive (US$ 2.2) single dose ACT formulation to eliminate any partial treatment bias during our evaluation phase. Now a conventional 3-day, 6 dose ACT preparation is being used which is considerably cheaper (US$ 1.0).

Other school-based health promotion programs involving teachers have already proved valuable and cost-effective, including nationwide anti-helminth treatment in Uganda (Brooker, et al., 2008b), provision of intermittent anti-malarial therapy in Kenya (Okello, et al 2012; Temperley, et al., 2008) and prophylactic chloroquine in Sri Lanka (Fernando, et al., 2006). Teachers have also administered various diagnostic and treatment protocols successfully in Tanzanian schools (Magnussen, et al., 2001). Analysis also shows that health program delivery costs can be reduced by having teachers implement them (Drake, et al., 2011).

The WHO health promoting school model engages each school in the context of the local community (Lasker & Weiss, 2003; Zakus & Lysack, 1998) with recognition of the central role of teachers (St Leger, et al., 2009; Tang, et al., 2009). This ensures that day-to-day realities and local imperatives are reflected in the design and conduct of programs developed to address any health problem (Laverack & Mohammadi, 2011; Macnab, et al., 2014b). In our four project schools teachers' input was central to the development of a realistic school-based strategy for RDT/ACT, and ongoing active participation by the staff was integral to the success of the intervention. Interestingly, two funding submissions were unsuccessful as reviewers stated that teachers would not be prepared to conduct RDT, not be willing to invest the additional time required to evaluate the children, and be unable to sustain the intervention over time. Inquiry in Year 1 found the first 2 assumptions incorrect and 3 years later all 4 school communities continue to provide RDT/ACT, and teachers, pupils and parents all report benefits to learning in parallel with better health in participating children.

No complications were reported from teachers performing RDTs or giving ACT. We did follow recommendations to deploy RDT expertise by conducting our teacher training using good visual aids and ample opportunities to practice practical skills (Murray, et al., 2008). Neither the refresher training provided midway through the project nor the confirmatory checks by a laboratory on every 50th positive RDT sample identified any concerns; both were considered important for quality assurance.

We recognize limitations in what we report. Principally, we recognize that the outcome measure encapsulating educational compromise and malaria morbidity that we used was absence from onset of illness to return to school. Using this measure we can only compare Year 2 data for children RDT positive for malaria with Year 1 data from the overall cohort sent home with presumed infectious illness. This is because in Year 1 it was not feasible to follow each child in the community to establish if parental care resulted in a diagnosis of malaria, and if so what treatment ensued. However, the >10 fold difference in the duration of absence between children in the intervention and pre-intervention years strongly supports benefit from the school-based RDT/ACT model that we designed and prospectively evaluated. Also, because 67.5% of sick children in Year 2 were RDT

positive and promptly treated according to WHO guidelines, this reflects a significant reduction in the burden of illness from malaria, as this was a community where the majority (74%) would not have been taken for appropriate care by their parents had they been sent home, based on the behaviors we documented prior to our intervention. In addition it is reasonable to assume that the percentage of sick children in the pre-intervention year who had malaria would have been similar to the intervention year (67.5%); in which case the malaria incidence rate across the 4 schools for the 2 years was 79%, reflecting a significant burden of disease.

Active learning by children during the intervention did increase their knowledge about malaria, as by the early months of Year 2 essentially 100% of children now knew the signs and symptoms associated with the onset of illness and were aware that malaria can be diagnosed and treated effectively, in contrast to < 20% having this knowledge at the start of Year 1. However, it is unlikely that this new knowledge resulted in any substantial bias in our results, as the process of identifying children in the classroom who were sick and needed to be sent home was the same in both years; children did not self-select themselves, and teachers had the same knowledge in Year 1 and 2 because of the community-wide dialogue and active learning that led to introduction of school-based RDT/ACT.

Our belief is that this project also benefited the broader community as evaluation indicated new knowledge was learned and practices and behaviors related to malaria began to change. Prior research has identified that improved health knowledge and altered health-related behaviors are often evident in the community as a whole where comprehensive school-based programs are delivered (Macnab, et al., 2014b; Stewart-Brown, 2006; Tang, et al., 2009). Also, as interventions such as ours improve diagnosis and treatment of a large number of individuals, malaria transmission rates within the community tend to be reduced, because each treated individual's malaria episode will be shorter, less severe, and hence less likely to result in mosquito-borne transmission to others (Malaria Consortium, 2016; Benjamin, et al., 2012); this is a secondary benefit of importance.

Malaria remains a priority area for governments, aid foundations, health care providers and educators worldwide (Brooker, et al., 2008; Mbonye, et al., 2015; WHO Regional office for Africa, 2013). While efforts to promote preventive measures rightly exist alongside those that advocate better diagnosis and treatment, it must be recognized that in addition to addressing limited supplies in low resource environments education and awareness on why and how to employ prevention are also lacking; in Uganda, < 50% of households own a mosquito net and 77% of children do not sleep under insecticide treated nets (Uganda Bureau of Statistics, 2010). Novel and effective avenues for enhancing intervention are constantly being sought, and schools are being used increasingly as platforms for delivering simple, safe and cost-effective programs that promote knowledge and healthy practices (Macnab, et al., 2014; Okello, et al., 2012). Adoption of our model by national Health Ministries is logical as the same RDT/ACT supplies provided to government clinics could be made available to schools. Similarly, this school-based program lends itself to broad adoption by NGO's and Agencies promoting effective malaria intervention, or expansion

through sponsorship of schools by philanthropic individuals or commercial partners as has happened with our program.

The low complexity, diagnostic reliability and WHO endorsement of RDT, and the efficacy and beneficial nature of ACT invite their use by appropriately trained personnel without formal medical or nursing education. But the missing link thus far has been the social engagement to educate potential users and make this approach accessible to rural populations (Mutabingwa, 2005). Now our study provides evidence that supports the feasibility of engaging teachers to deliver school-based RDT/ACT, and that the negative impact of malaria on education caused by prolonged and/or repeated absence from school can be significantly reduced by implementing this health promotion model.

Conclusions

School-based RDT/ADT provides a valid extension of proven care entities able to positively impact the high morbidity from malaria to a child population known to be at significant risk.

Providing RDT/ACT in the school setting is a logical response to the global burden of malaria on the health and educational potential of children, especially in low resource settings.

Children's ability to learn is enhanced by rapid diagnosis and prompt, effective treatment because they miss significantly less school. Communities also report their children appear healthier; probably as early intervention reduces overall morbidity in both the short and long term.

Implementing school-based RDT/ACT is feasible. Communities who recognize the relevance are readily engaged, and teachers have welcomed training and sustained program delivery.

We suggest that our health promotion model of providing RDT/ACT in the school setting is broadly applicable to other schools in sub-Saharan Africa, and in other low resource settings globally where morbidity from malaria is high.

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This paper is dedicated to the memory of Faith Gagnon who helped conceive the concept of school-based care for children with malaria at the Stellenbosch Institute for Advanced Study (STIAS) international colloquium on WHO Heath Promoting Schools in 2011, and contributed throughout her life to medical research to improve the lives of children.

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All authors have no conflict of interest to declare.

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