Identifying opportunities to optimize mass drug administration for soil-transmitted helminths: a visualization and descriptive analysis using in-depth process mapping

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Abstract

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Control of soil-transmitted helminths (STH) requires mass drug administration (MDA) with deworming medications to children and other high-risk groups. Recent evidence suggests that it may be possible to interrupt transmission of STH by deworming individuals of all ages via community-wide MDA. However, the impact of school-based and community-wide MDA programs is predicated upon achieving high treatment coverage. In this study, we used process mapping, an operational research methodology, to describe the activities required for effective implementation of school-based and community-wide MDA with high coverage in 18 heterogenous areas and over three years in Benin, India and Malawi. We found that implementation of community-wide MDA requires more distinct activities than school-based MDA. Community-wide MDA activities were also adapted more often, likely because new "start-up" activities were required as compared to standard of care implementation that had already been adapted over time. Many activities across MDA platforms were not implemented according to their planned timelines, but these deviations were often purposeful to improve implementation efficiency or effectiveness. Visualized process maps were created by stakeholders in each geographic area, providing a shared vision of the implementation process. Process maps can be used to optimize MDA for high coverage by identifying potential bottlenecks and unnecessary activities, and for tracking adaptations over time. Process mapping could be deployed to support a transition from a strategy of school-based STH control to community-wide transmission interruption, and potentially for integration with other community-based programs.

Background

Worldwide, over 1.5 billion people are infected with soil transmitted helminths (STH),[1,2] a group of intestinal parasites which include *Ascaris lumbricoides, Ancylostoma duodenale, Necator americanus* and *Trichuris trichiura*. These infections cause up to 2 million disability adjusted life years annually,[3] and moderate to heavy intensity infections have been associated with malnutrition, intestinal complications, anemia, poor growth, preterm birth, and cognitive impairment.[4,5] The WHO recommends that endemic countries control STH with mass drug administration (MDA)[2,6] of anthelmintic drugs (albendazole or mebendazole), targeting at least 75% coverage of highest risk populations[7]. These populations include pre- and school-aged children and women of reproductive age, and MDA is commonly implemented through school-based delivery platforms. These campaigns are some of the largest primary healthcare initiatives in the world,[8] and coverage is the primary performance indicator through which MDA programs are monitored. Broadly, MDA consists of identifying the number of people who are at risk for infection, procuring and transporting deworming drugs to the local level, and administering drugs to people in their homes or through the school system. Though the number of children treated worldwide has increased from about 30 to 90 million in the past decade,[8] many STH programs fail to achieve 75% coverage,[9,10] which attenuates the potential impact of MDA programs. Research indicates that common barriers to achieving high coverage MDA in schools or communities includes a lack of adequate community sensitization about the campaign and the safety of deworming drugs, inadequate human resources to deliver drugs, limited training of drug distributors, and a lack of coordination between national or regional program managers with local communities. This suggests that multiple infrastructural and contextual factors affecting *how* MDA is implemented impact coverage and compliance rates. [11–14]

Recent evidence suggests that increasing coverage and broadening treatment eligibility to all age groups through delivery of community-wide MDA (cMDA) may interrupt STH transmission in targeted geographic areas.[15–17] Transitioning to a policy of STH transmission interruption will require new approaches to MDA and high coverage will be fundamental for achieving elimination. Process mapping (PM) provides an opportunity to identify activities necessary for delivery of cMDA with high coverage, which can inform microplanning of transmission interruption programs delivered at scale. PM is a systems science tool by which implementers inventory the activities or steps necessary for successful implementation and map the flow, or process, of these steps.[18,19] PM has been used extensively in healthcare institutions throughout the world to study the flow of patients through inpatient care[20–23] and in quality improvement efforts for outpatient visits and procedures[24,25]. PM can help create shared understanding of workflows and responsibilities, identify potential gaps in care, pinpoint bottlenecks and accelerators in implementation plans, and assist with adaptation of implementation guidance to local context.[18,26] PM of MDA across settings can provide evidence about the influence of context on implementation over time.

We analyzed PM data from the DeWorm3 project, a cluster randomized trial in Benin, India, and Malawi testing the feasibility of interrupting STH transmission via twice annual cMDA. The purpose of this analysis is to describe the implementation pathways that select clusters in the DeWorm3 Project followed to implement school-based MDA and cMDA, and to analyze their differences and similarities over time. Findings from this multi-country analysis may inform future creation of a tool to guide context-adapted implementation of cMDA for STH.

Methods

Study sites

In Benin, the DeWorm3 project takes place in the Commune of Comè and includes the town of Comè (population 30,000) and peri-urban surrounding area. In India, the DeWorm3 site is in Thimiri and the Jawadu Hills of Tamil Nadu state, and is primarily rural. In Malawi, the study site is in Mangochi District on the south side of Lake Malawi, and is also primarily rural. Each DeWorm3 site includes at least 80,000 individuals and each cluster includes approximately 3,000 people. The DeWorm3 study design is described in detail elsewhere.[27]

Cluster sampling

In-depth PM was conducted in six clusters in each site: four clusters implementing cMDA and two clusters implementing standard-of-care school-based delivery (SBD) of deworming drugs. Clusters were selected using a stratified, randomized process to total four intervention and two control clusters at each site. Because clusters that have successfully implemented MDA with high coverage in the past may be more likely to successfully implement MDA in DeWorm3, selection was also stratified by historical coverage for recent MDA campaigns to ensure that half of the selected clusters were in areas with previous high coverage (over 80%) and half in areas with previous low coverage (below 60%). To determine historical coverage, clusters were associated with most congruent geographic unit for recent MDA campaigns: school-based MDA for STH in India, lymphatic filariasis MDA coverage data in Benin, and trachoma MDA coverage data in Malawi. High and low coverage clusters were then numbered and selected randomly to identify the participating clusters.

Data collection

Prior to the first round of cMDA in the trial, DeWorm3 staff, Ministry of Health and/or Education and partner organization staff familiar with MDA planning and implementation participated in PM workshops at the cluster level (N=18 workshops). Each workshop followed a standardized guide to identify all activities (e.g. training of nurse supervisors) considered necessary for delivering MDA with high coverage in the given setting (e.g. gold standard implementation). Each activity was then categorized into one of seven pre-determined categories: drug supply chain, community sensitization, training, planning, drug delivery, monitoring and evaluation, or other. For each activity, workshop participants identified the ideal goal and timeline for completion of the activity. For example, for an activity such as ‘contact village leaders to notify them of the upcoming MDA campaign’, the teams might select a target of 100% of village leaders notified and a target timeline of one month prior to commencing MDA. Participants also developed a visual map to diagram the flow of activities and cascading relationships between activities. PM workshops used a participatory, nominal group technique to reach consensus and produce a shared vision of implementation activities.

Baseline process maps (pre-MDA) were updated once annually for three years. During MDA in years 1, 2 and 3, observed progress towards activity goals and timelines were tracked in real time for all activities. After MDA, each cluster updated their process maps to report upon observed progress for all previously identified activities, including reporting any deviations from implementation plans. These updates also recorded reasons for any deviations (such as delays due to dependencies across activities, deviations to improve efficiency, or community influences such as religious holidays or weather events). In addition, new activities could be added during annual PM update or activities no longer implemented could be removed from the maps. Each activity was also categorized into one of five mutually exclusive timing categories according to the activity's ideal timeline: up to 2 months before MDA, 2 months to 2 weeks before MDA, 2 weeks before to the start of MDA, during MDA, or after MDA.

Data analysis

The characteristics of baseline process maps were compared across sites, delivery method (SBD or cMDA), historical coverage level and timing category. The range and average number of activities per cluster and by activity category were calculated. Additionally, the number and proportion of adaptations and deviations to implementation were calculated over time. An adaptation reflects each time that an activity was added or removed from the implementation plan. For example, start-up activities no longer required after the first round of MDA, and that are thereafter removed from the implementation plan, would be considered adaptations. The percent growth in number of activities needed to implement MDA was calculated over time.

In order to assess fidelity to implementation plans, the total number of deviations were calculated for each annual update. Deviations were defined as changes in implementation from planned goals or timelines. For example, activities that occurred later than planned would be considered a deviation. Likewise, activities that took place ahead of schedule were also considered a deviation. Thus, deviations are not necessarily negative reflections of implementation but rather reflect planned and unplanned changes to implementation. The reason for a deviation was noted, and open text responses about why deviations occurred were categorized into one or more of eight deviation options, including: purposeful changes to increase efficiency, purposeful changes to increase effectiveness, competing priorities or dependency delays, community influences, resource constraints, Ministry of Health decisions, COVID-19 related changes, or another reason. For instance, if an activity was delayed because a national program decided upon MDA dates later than normal, the reason was attributed to Ministry of Health decisions. The proportion of activities that deviated from activity-specific goals and timelines were reported separately for each PM update.

Process maps were digitized using the DiagrammeR package in R. Digitizations depict all activities mapped at a cluster-level, including those that were added or removed over the course of the trial. These maps visualize how implementation processes change over time, allowing for comparison between clusters and countries. Digitized process maps depict the flow of activities required to implement MDA, including any dependencies in the cascade of activities. These dependencies can generate potential inefficiencies or bottlenecks in implementation. Digitized maps can also help implementers identify opportunities for coordination between sectors and implementation actors, and viable adaptations to optimize delivery.

Ethical approval

The DeWorm3 study was reviewed and approved by the Institut de Recherche Clinique au Bénin (IRCB) through the National Ethics Committee for Health Research (002-2017/CNERS-MS) from the Ministry of Health in Benin, The London School of Hygiene and Tropical Medicine (12013), The College of Medicine Research Ethics Committee (P.04/17/2161) in Malawi, and the Institutional Review Board at Christian Medical College, Vellore (10392). The DeWorm3 Project was also approved by The Human Subjects Division at the University of Washington (STUDY00000180). Consent was not required to participate in PM workshops.

Results

This study analyzed data from MDA delivery in 18 geographic areas across three countries, and over three years of implementation. PM data indicate that there is a high degree of variability in implementation processes across countries and across clusters implementing cMDA and SBD and little variation between areas with historically high and low treatment coverage. An active adaptation period occurred between baseline planning and the year 1 update, though adaptations persisted at lower levels throughout the study period. While deviations from plans were common, many deviations represented changes in the timing of activities and many deviations were purposeful to increase the efficiency or effectiveness of implementation.

Implementation plans

Eighteen clusters conducted PM workshops in April and May of 2018 to describe plans for implementing SBD or cMDA (Table 1). These plans indicate that clusters in India identified a larger number of activities needed to achieve high coverage (average of 72), as compared with Benin (average of 28) and Malawi (average of 31). A larger proportion (39%) of activities in India were planning activities, as compared to the other two sites (9% in Benin, 20% in Malawi). Across all sites, clusters implementing cMDA had a larger number of planned activities (average of 48) than clusters implementing SBD (average of 34). The distribution of activities across implementation categories was similar between cMDA and SBD, however cMDA included a larger relative proportion of community sensitization activities (average of 19%) than SBD (average of 12%). At a country level, similar trends between SBD and cMDA are observed (Appendix 1). Differences in the number and distribution of activities by activity category across historically high and low coverage areas were negligible.

Table 1: Characteristics of MDA implementation plans prior to the first round of MDA

	Total activities	Proportion of activities, by category (%)

	Average	Number (range)	Planning	Drug supply chain	Training	Community sensitization	Drug delivery	M&E	Other
Country									
Benin	27.5	165 (19 – 32)	9.1%	23.0%	20.0%	20.0%	21.2%	4.2%	2.4%
India	72.0	432 (49 – 91)	39.4%	26.6%	6.9%	15.3%	10.2%	1.4%	0.2%
Malawi	30.5	183 (27 – 36)	20.2%	18.0%	8.2%	19.7%	14.2%	19.1%	0.5%
Intervention[1]									
SBD	34.3	206 (19– 53)	31.6%	23.3%	9.2%	11.7%	15.0%	8.7%	0.5%
cMDA	47.8	574 (27 – 91)	27.4%	24.0%	10.2%	19.3%	12.9%	5.2%	0.9%
Historical coverage									
Low coverage	43.0	387 (26 – 82)	25.1%	27.1%	11.9%	17.1%	12.9%	5.7%	0.3%
High coverage	43.7	393 (19 – 91)	32.1%	20.4%	7.9%	17.8%	14.0%	6.7%	1.3%
Activity timing									
Up to 2 months before MDA	4.4	79 (1 – 20)	36.7%	41.8%	7.6%	13.9%	0.0%	0.0%	0.0%
2 months – 2 weeks before MDA	16.2	292 (2 – 48)	43.8%	22.6%	12.3%	19.2%	1.4%	0.0%	0.7%
2 weeks – beginning of MDA	11.1	199 (2 – 35)	21.1%	29.1%	15.6%	32.2%	2.0%	0.0%	0.0%
During MDA	6.1	109 (2 – 12)	10.1%	4.6%	0.0%	3.7%	71.6%	7.3%	2.8%
After MDA	4.7	85 (2 – 12)	1.2%	28.2%	0.0%	0.0%	22.4%	47.1%	1.2%

[1] SBD includes data from 6 clusters and cMDA includes data from 12 clusters

Activities were clustered in time, according to the type of activity (e.g. planning, drug supply chain). Most activities that took place pre-MDA fell into the activity categories of planning, drug supply chain and community sensitization. Community sensitization activities mostly took place within the two months leading up to MDA, while planning and drug supply chain activities took place even earlier. During MDA, drug delivery activities were most common. After MDA, drug supply chain and monitoring and evaluation activities predominated. This analysis reiterates that drug supply chain activities occur throughout the pre and post-MDA periods, reflecting the importance of ordering, acquiring and transporting drugs before MDA, and collecting and storing drugs after MDA has finished.

Adaptations to plans

Adaptations are defined as activities that are removed or added over the course of three years of implementation. The majority of adaptations were reported during the year 1 PM update, where progress was reviewed. In Benin, the maps generally expanded as more activities were added than were removed. In India and Malawi, more activities were removed than added from the plans made at baseline. An average of five adaptations to cMDA were made at each update, while an average of three adaptations to SBD were made per update. Adaptations continued to be made over three years of implementation, across activity categories. While adaptations at year 1 were largely focused on refinement of processes, adaptations made in years 2 and 3 include further refinement along with responses to contextual factors, such as extreme weather events and the COVID-19 pandemic.

Table 2: Adaptations to MDA implementation processes over time

	Total adaptations		Percent change in number of activities from previous year		
	Average per round	Total over three years (range)	Year 1	Year 2	Year 3
Country					
Benin	4.3	77 (3 – 18)	22.4%	5.4%	4.2%
India	4.2	75 (5 – 22)	-9.0%	-3.1%	0.0%
Malawi	4.6	83 (10 – 18)	-17.5%	12.6%	-1.2%
Intervention[1]					
SBD	2.6	47 (3 – 14)	-3.4%	-2.5%	-1.6%
cMDA	5.3	190 (7 – 22)	-4.7%	4.2%	1.8%
Historical coverage					
Low	4.3	115 (6 – 18)	-1.8%	1.6%	1.0%
High	4.5	122 (3 – 22)	-6.9%	3.3%	0.8%
Activity timing					
Up to 2 months before MDA	0.4	23 (0 – 10)	-21.5%	0.0%	0.0%
2 months – 2 weeks before MDA	1.1	61 (0 – 8)	-7.5%	-1.5%	2.6%
2 weeks – beginning of MDA	1.1	62 (0 – 9)	3.0%	4.4%	1.4%
During MDA	0.7	40 (0 – 8)	10.9%	13.9%	0.7%
After MDA	0.8	42 (0 – 7)	-15.7%	-1.4%	-5.8%
Activity categories					
Planning	0.9	47 (0 – 10)	-7.2%	-9.2%	0.0%
Drug supply chain	0.8	44 (0 – 8)	-10.3%	9.7%	0.6%
Training	0.3	15 (0 – 9)	9.1%	0.0%	-2.4%
Community sensitization	0.9	48 (0 – 8)	-0.7%	8.1%	0.0%
Drug delivery	0.9	51 (0 – 12)	16.3%	8.3%	7.6%
M&E	0.5	28 (0 – 6)	-41.7%	3.6%	-10.3%
Other	0.1	4 (0 – 2)	-33.3%	-25.0%	33.3%

[1] SBD includes data from 6 clusters and cMDA includes data from 12 clusters

During the year 1 PM update, most adaptations involved stopping several activities that took place more than 2 months before MDA and several post-MDA activities. Many of these activities were one time, start-up activities, such as performing a census, or changes to the drug supply chain or reporting requirements. Conversely, the number of activities performed in the two weeks leading up to MDA and during MDA increased during the first process mapping update due largely to new additions in Benin. At baseline, Benin maps had the fewest activities on average, and thus new activities were added as implementation plans were solidified.

Fidelity to plans

We evaluated two aspects of implementation fidelity: fidelity to implementation goals and fidelity to targeted implementation timelines. In general, there was higher fidelity to activity goals than timelines in all years, when 30 – 50% of activities were not executed according to planned timelines (Table 3). Timeline fidelity was highest for activities which took place during drug delivery. Fidelity to implementation goals was generally high, but reduced in year 3 due to the COVID-19 pandemic for SBD (33% of activities had deviations) and planning (21%), training (20%) and community sensitization (18%) activities for both delivery methods.

Table 3: Fidelity to planned activity goals and timelines

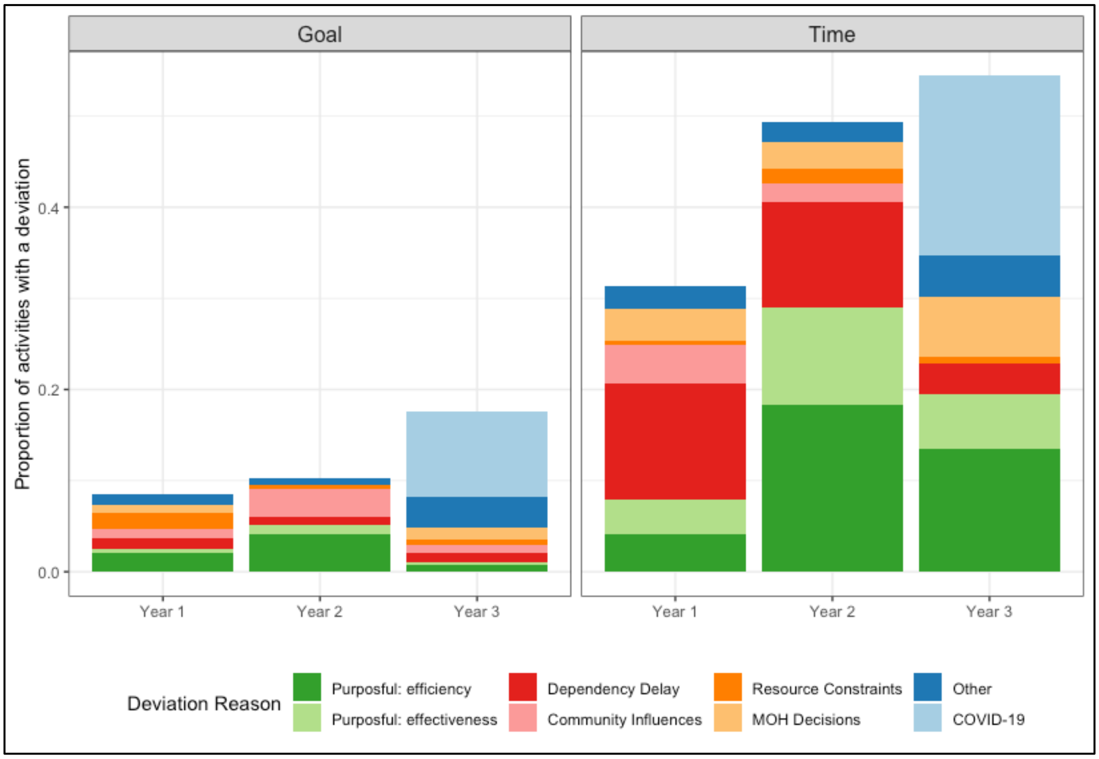
	Total deviations				Proportion of activities with deviations					
	Average per round		Total over three rounds		Year 1		Year 2		Year 3	
	Goal	Time	Goal	Time	Goal	Time	Goal	Time	Goal	Time
Country										
Benin	2.7	4.8	48	185	9.3%	32.8%	5.9%	32.7%	9.9%	31.1%
India	7.5	12.8	135	522	6.4%	30.5%	7.6%	57.7%	21.8%	49.9%
Malawi[1]	4.6	11.1	73	178	16.3%	42.4%	25.5%	53.3%	14.5%	40.4%
Intervention[2]										
SBD	6.5	11.4	103	182	10.7%	24.4%	14.9%	50.0%	32.6%	30.0%
cMDA	4.3	8.1	153	703	7.9%	34.9%	8.8%	49.4%	11.6%	46.7%
Historical coverage										
Low coverage	5.4	8.8	140	460	8.0%	35.5%	10.8%	49.9%	19.5%	42.8%
High coverage	4.5	7.1	116	425	9.0%	30.0%	9.8%	49.0%	14.2%	42.2%
Category										
Planning	1.4	5.3	75	274	6.8%	27.2%	13.2%	63.7%	20.9%	58.2%
Drug Supply Chain	0.8	4.0	44	210	10.5%	37.9%	3.6%	47.6%	13.3%	44.0%
Training	0.6	2.7	30	140	5.5%	63.0%	10.8%	57.8%	20.4%	55.4%
Community Sensitization	0.8	3.9	44	201	9.5%	41.4%	7.9%	57.4%	18.1%	63.0%
Drug delivery	0.9	0.7	48	38	7.5%	6.5%	15.7%	16.5%	18.2%	9.9%
M&E	0.2	0.4	12	21	17.6%	6.5%	15.4%	50.0%	19.2%	23.1%
Other	0.1	0.0	3	1	25.0%	0.0%	33.3%	33.3%	33.3%	0.0%
Activity timing										
8 – 2 months before MDA	0.6	1.6	29	82	6.5%	32.2%	10.1%	52.5%	32.2%	52.5%
2 months – 2 weeks before MDA	1.3	8.4	67	437	8.9%	40.3%	7.9%	65.1%	9.9%	68.6%
2 weeks – beginning of MDA	1.3	5.4	69	280	7.4%	42.3%	5.0%	55.3%	23.1%	48.2%
During MDA	0.9	0.3	47	14	7.3%	1.0%	16.5%	8.3%	16.5%	2.5%
After MDA	0.7	1.3	35	65	16.0%	26.0%	17.9%	49.3%	22.4%	28.4

[1] Two SBD clusters in Malawi did not submit data for Year 1

[2] SBD includes data from 6 clusters and cMDA includes data from 12 clusters

Implementation fidelity varied across the three study sites, highlighting the importance of implementation context. Though cMDA was only recently introduced and underwent much adaptation, fidelity to implementation goals and timelines was similar between cMDA and SBD. Clusters with historically high and low coverage also exhibited similar implementation fidelity. As previously noted, low fidelity is not inherently negative. In fact, many observed deviations were intentional to increase implementation efficiency or effectiveness (Figure 1).

Figure 1: Proportion of activities with deviations due to common reasons[1]



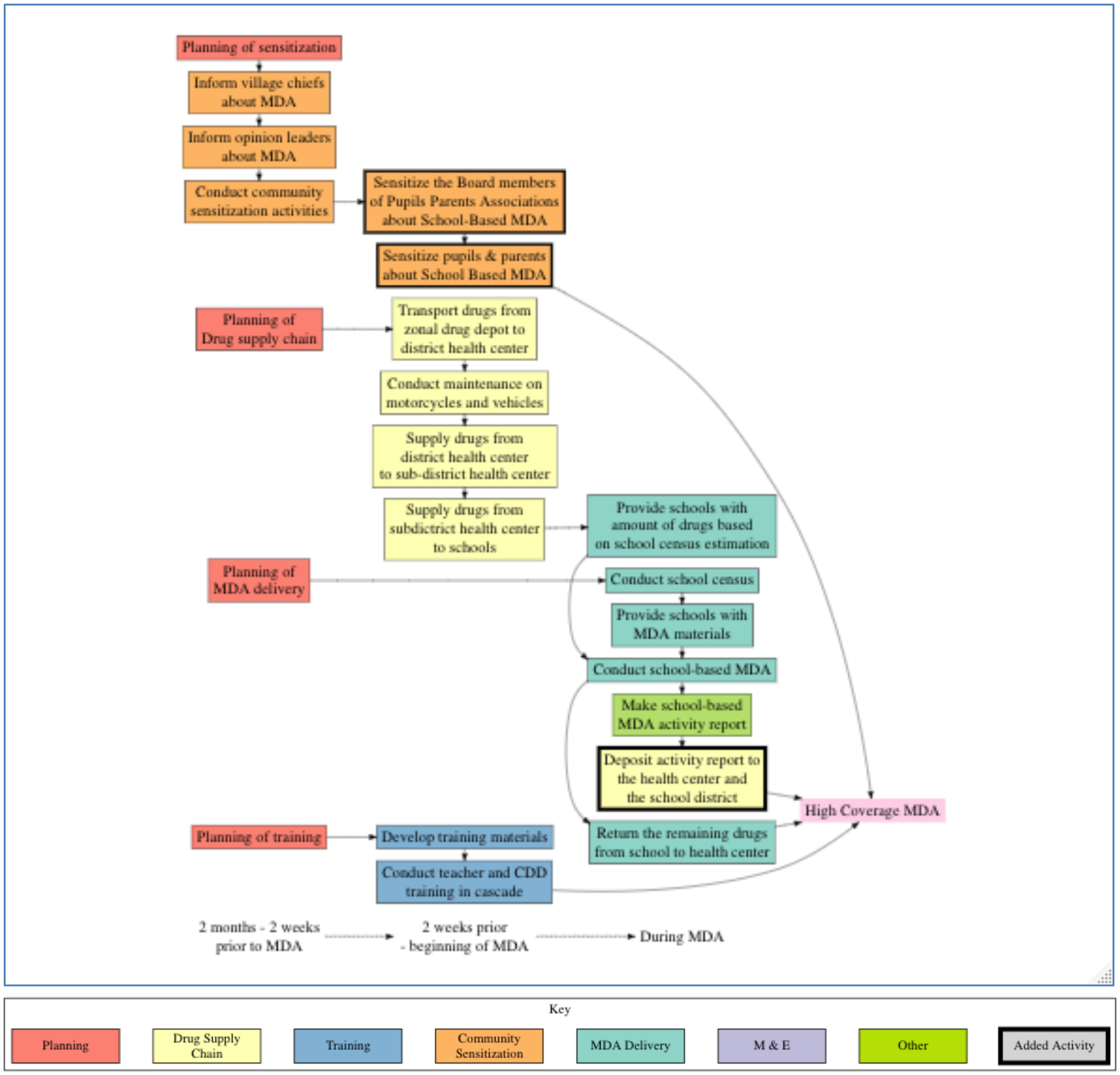
[1]: More than one reason could be selected

For example, during the year 2 PM update, 29% of activities were not executed on their planned timeline for purposeful reasons and during year 3, when MDA took place during the COVID-19 pandemic, 19% of timeline deviations were for purposeful reasons. Many training activities, for instance, happened later than planned in order to increase retention of the drug delivery workforce, and some planning and drug supply chain activities occurred earlier than planned in order to reduce workloads closer to MDA. PM can capture and track these transient changes to processes over time to determine how implementation is necessarily and unnecessarily changed over time.

Process map visualizations

Figure 1 below shows the process map for an SBD cluster in Benin, including activity types (indicated by color), time categories, and activities which were added after baseline PM workshops (indicated by bolded outlines). The map indicates that, in this cluster, planning activities occur between two months and two weeks before MDA, sensitization two months prior to MDA and most drug supply chain activities within the two weeks prior to MDA. The map also shows two specific sensitization activities which were added after baseline. These adaptations specify specific audiences for community sensitization activities.

Figure 1: Digitized process map for cluster 6, Benin



Discussion

This study utilized PM to provide detailed, activity-based descriptions of the implementation process used in MDA for STH across 18 heterogenous locations. Baseline maps indicate that clusters implementing cMDA planned for a larger number of implementation activities, as compared to clusters implementing SBD. Most notably, cMDA required more community sensitization activities. Compared to clusters implementing SBD, clusters implementing cMDA were also more likely to adapt their implementation plans, meaning they added and removed more activities from their maps at each annual update. Across all clusters, fidelity was consistently higher to activity goals than activity timelines; this was often attributed to dependency delays or purposeful changes to increase efficiency and effectiveness of campaigns. Visualization of the maps highlights opportunities to identify potential bottlenecks (e,g, weak points) in the implementation process and track adaptations over time.

Baseline plans for MDA were highly context specific. On average, India identified over twice as many activities needed to achieve high coverage MDA as the other two countries. A much higher proportion of these activities were planning activities in India (39%) , as compared to Benin (9%) and Malawi (20%). Within countries, there was considerable heterogeneity in the distribution of activities across the seven activity type,s suggesting that there are many viable pathways for implementing MDA and implementation plans must be tailored to local context. On average across countries, cMDA cluster maps included more activities (48) than those implementing SBD (34). This suggest that cMDA may be a more complicated process than SBD, requiring more steps and potentially more time to implement. Compared to SBD, a higher proportion of cMDA activities were community sensitization activities. This may be because deworming days take place during the school-day and thus less mobilization is needed to ensure high student participation in campaign delivery. Previous research suggests that low community awareness of upcoming MDA campaigns and lack of investment in community sensitization can result in low treatment coverage.[12,13,28,29] Because PM is a participatory tool used to map the entirety of the implementation process, including at the local level, it may help to support detailed planning for the larger amount of community sensitization activities necessary for achieving high coverage of cMDA.

In this study, clusters implementing cMDA adapted their implementation plans more often than clusters implementing SBD. This may be driven by the fact that cMDA for STH was newly launched in these areas, while SBD had already been implemented for a number of years. Therefore, an active adaptation period was not necessary for SBD. Persistence of adaptations over time demonstrates that MDA implementation is inherently dynamic. More resources may be required during the “start-up” phase of a new program, until implementation plans have stabilized in a given context. In fact, evidence from preventative programs indicates that adaptations should be expected to occur and tracked to further improve the fit of implementation processes in a given context.[30,31] PM offers one viable way to collect information about adaptations over time and visualize how processes have changed. This is relevant both for introduction of cMDA campaigns but also other proposed programmatic shifts for STH control programs.

On average, there were 3.7 times as many deviations from planned activity timelines as compared to planned activity goals. One exception to this pattern was activities that were included in the activity category of “drug delivery”. This indicates that, once begun, drug delivery may require a time-sensitive series of events over a short period of time (1 – 5 days), and thus closer attention to timeline fidelity is required, as compared to activities implemented pre- and post-drug delivery. Timeline deviations were often due to purposeful reasons (7 – 29% at each round) and rarely due to unforeseen community influences (less than 4% of activities at each round) or resource constraints (less than 2%). Evidence suggests that low fidelity to implementation plans leads to reductions in intervention effectiveness, highlighting the importance of monitoring implementation fidelity over time.[32–34] However, there is a dearth of information regarding how implementation fidelity affects implementation outcomes, such as MDA treatment coverage. Detailed information on implementation fidelity, such as that produced through PM, can identify core components of an intervention to which high fidelity is needed to achieve desired outcomes.[37,38] Because evidence from this study indicates that many deviations are purposeful to improve efficiency and effectiveness, it may be necessary to measure fidelity to core activities while allowing—or perhaps encouraging—variation in the implementation of "peripheral" activities. Future DeWorm3 research will help determine the linkage between fidelity and cluster-level coverage, including potential "core" indicators.

The PM workshops included a consensus-building visualization activity to create a shared plan of the implementation process amongst stakeholders. Visualizations may also help identify inefficiencies in implementation, and opportunities to optimize delivery. For example, in one cluster (Figure 2), all supply chain activities were intended to take place in the two weeks leading up to MDA. Because these activities cascade from one another, a delay in one activity has major cascading effects. These dependencies could be mitigated by, for example, moving vehicle maintenance earlier in the MDA activity cascade. Finer grained time categories may further reveal potential dependency delays, such as between conducting the school census and apportioning drugs to schools based on census results, which occur in the same time category (Figure 1). Ministry of Health NTD Program Managers can also compare process map visualizations across locations with similar contexts (e.g. within the same district or country) to identify common adaptations which can be incorporated into core implementation plans. Most guidance issued by global NTD coordinating bodies is purposefully general so that it can be used to guide implementation across endemic settings,[39] however process mapping offers an opportunity to add detail and nuance to implementation plans. For instance, PM visualizations in this study expand upon the notion of "drug delivery" as a single activity by including multiple activities such as distribution of apportioned drug lots to drug distributors, completing coverage reporting activities, and counseling refusals. Thus, baseline PM can form the foundation of iterative microplanning and realistic budgeting efforts at local levels. After baseline process maps are created, they can be used iteratively to make future microplanning efforts more efficient. The visual representation of implementation can be easily communicated, so as to efficiently orient planning teams or new organizational members to tailored implementation processes.

As national NTD programs seek to reduce campaign costs and improve efficiency, there is increasing momentum to integrate implementation activities across NTD progams.[40] PM could help identify areas where integration between NTDs or other programs can be most beneficial – for example between STH cMDA and other community-based campaigns such as bed net distribution or immunizations. Implementers can use PM at multiple levels, such as national or local levels, to identify common activities and synergies in timing and responsibilities, such as congruencies in national supply chain activities, training activities, or community-level outreach activities.

There are a number of limitations to this study. First, there may be variations in how PM workshop participants perceived the scope of a single activity. For example, some clusters identified an activity such as “planning of training”, while others split this into three smaller tasks, identifying a separate activity for each. To address this, extensive quality checks were conducted for each cluster and activities were standardized using the same naming conventions after baseline maps were created, yet comparison of the number of activities across countries may still be limited. In addition, we collected only two characteristics of implementation fidelity for each activity (fidelity to goals and to timelines). Future work is needed to develop tools to measure other aspects of implementation fidelity.[34] Finally, in this study PM was supported by a research team which provided additional support (training, data quality checks, and analysis) for PM. While we believe PM may be an efficient way to plan and monitor MDA, there is currently no guidance for how to deploy PM during routine MOH-run MDA programs.

Conclusion

Delivery of MDA with high coverage requires coordination of many actors and an appropriate sequencing of activities. We used PM to establish consensus about activity cascades needed to implement school-based and community-wide MDA. We found that implementation varies at a local level, and these variations in implementation are rarely reported or evaluated. Because MDA is repeated at least annually and is time and resource intensive, optimizing implementation plans may result in programs that are more efficient and/or achieve higher coverage. PM is a low-technology, easy to learn tool which can be used as an entry point for microplanning efforts, a guide for process improvement over time, and to identify core components and potential areas for integration with other campaigns. While commonly used in quality improvement projects and hospital-based settings, to our knowledge this is one of the first applications of PM in community-based healthcare campaigns in resource limited settings.

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Appendices

Appendix 1: Baseline process maps for each participating cluster

Cluster characteristics				Proportion of activities, by category (%)						
Cluster Name	Delivery method	Historical coverage	Total #	Planning	Drug supply chain	Training	Comm. Sens.	Drug delivery	M&E	Other
Benin										
Cluster 1	cMDA	Low	32	6.3%	37.5%	25.0%	25.0%	6.3%	0.0%	0.0%
Cluster 2	cMDA	High	31	12.9%	19.4%	12.9%	19.4%	16.1%	6.5%	12.9%
Cluster 3	cMDA	High	30	3.3%	23.3%	23.3%	23.3%	23.3%	3.3%	0.0%
Cluster 4	SBD	Low	26	15.4%	15.4%	23.1%	15.4%	23.1%	7.7%	0.0%
Cluster 5	cMDA	Low	27	3.7%	18.5%	18.5%	18.5%	37.0%	3.7%	0.0%
Cluster 6	SBD	High	19	21.1%	21.1%	10.5%	15.8%	26.3%	5.3%	0.0%
India										
Cluster 7	SBD	High	49	46.9%	12.2%	8.2%	12.2%	10.2%	8.2%	2.0%
Cluster 8	cMDA	Low	75	26.7%	25.3%	10.7%	24.0%	10.7%	2.7%	0.0%
Cluster 9	cMDA	High	82	39.0%	26.8%	4.9%	19.5%	9.8%	0.0%	0.0%
Cluster 10	cMDA	High	91	46.2%	23.1%	5.5%	13.2%	12.1%	0.0%	0.0%
Cluster 11	cMDA	Low	82	42.7%	26.8%	4.9%	15.9%	9.8%	0.0%	0.0%
Cluster 12	SBD	Low	53	34.0%	47.2%	9.4%	1.9%	7.5%	0.0%	0.0%
Malawi										
Cluster 13	cMDA	Low	27	7.4%	14.8%	14.8%	25.9%	14.8%	18.5%	3.7%
Cluster 14	cMDA	High	36	19.4%	5.6%	5.6%	25.0%	13.9%	16.7%	0.0%
Cluster 15	cMDA	High	27	18.5%	7.4%	7.4%	22.2%	11.1%	22.2%	0.0%
Cluster 16	SBD	High	28	28.6%	7.1%	3.6%	17.9%	21.4%	21.4%	0.0%
Cluster 17	SBD	Low	31	25.8%	22.6%	3.2%	16.1%	16.1%	16.1%	0.0%
Cluster 18	cMDA	Low	34	20.6%	20.6%	14.7%	8.8%	8.8%	20.6%	0.0%

Appendix 2: Early and late time deviations

	Total deviations				Proportion of activities with deviations					
	Average per round		Total over three rounds		Year 1		Year 2		Year 3	
	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Deviation category										
Purposeful change: efficiency	1.6	3.2	85	164	2.0%	2.2%	7.5%	10.9%	2.5%	9.6%
Purposeful change: effectiveness	0.5	2.0	25	103	0.6%	3.1%	2.4%	8.2%	0.5%	3.3%
Competing priorities or	0.4	3.3	21	169	2.2%	10.7%	0.4%	11.2%	0.5%	2.8%

dependency delays										
Community influences	0.2	0.7	8	35	0.3%	3.9%	0.8%	1.3%	0.2%	0.1%
Resource constraints	0.0	0.3	1	18	0.0%	0.5%	0.1%	1.4%	0.0%	0.7%
MOH Decisions	0.2	1.1	9	55	0.0%	3.6%	1.0%	2.0%	0.4%	2.4%
COVID-19[1]	1.2	3.2	22	58	-	-	-	-	1.4%	13.4%
Other	0.2	1.0	12	50	1.7%	2.5%	1.3%	0.8%	0.4%	3.7%

[1]: Calculated for Year 3 only