Scaling up deworming programs: implementation science approaches to guide the transition from school-based to community-wide mass drug administration for soil-transmitted helminths

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Abstract

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Soil-transmitted helminths (STH) are a group of intestinal parasites that affect 1.5 billion people globally. Pre-school and school-age children are at most-risk of various nutritional, cognitive and physical morbidities associated with chronic or high intensity STH infections. Global guidelines recommend controlling STH-associated morbidity amongst pre-school age and school age children via school-based mass drug administration (MDA) programs. However, recent clinical trial evidence suggests that an expanded community-wide MDA strategy may lead to more substantial reductions in

intensity and prevalence than school-based MDA, while mathematical models suggest that community-wide MDA may achieve STH interruption transmission, thus reducing the risk of community reinfection. The primary objective of this research is to utilize implementation science research approaches to guide the potential policy transition from school-based to community-wide MDA for STH.

We conducted a series of primary analyses using data from the DeWorm3 Project, a hybrid Type I cluster randomized trial in Benin, India, and Malawi assessing the feasibility of interrupting STH transmission via community-wide MDA. We applied three rigorous analytical methods guided by DeWorm3 implementation science research activities that aim to develop a scalable and sustainable community-wide MDA delivery model.

In the first study, we utilized social network analysis (SNA) to map all stakeholders and to systematically identify the most influential stakeholders within school-based and community-wide MDA networks. We also sought to define how network dynamics may impact implementation and scale-up across these delivery platforms. Analyses of stakeholder maps revealed an expansive network of hundreds of stakeholders in both delivery platforms, a majority of which held a positive attitude towards community-wide MDA. We found that stakeholders who were primarily responsible for program delivery exerted a high degree of influence on intervention scale-up (i.e., implementation at-scale), while stakeholders who were in charge of policymaking & program leadership often controlled resource flow. Across networks for both community and school MDA programs, we observed a high number of connections; however, these connections were not concentrated on one single stakeholder, as indicated by low network centralization scores was shared equally across stakeholders. Additionally, low network density scores suggested these networks had poor overall connectedness across administrative levels. Understanding these network dynamics provides important decision-making evidence critical for launching and scaling MDA programs, such as identifying program champions to support policy change and drive MDA uptake, as well as securing sufficient program resources for optimized MDA scale-up, and mitigating implementation bottlenecks to drive effective intervention delivery.

In our second study, we applied coincidence analysis (CNA), a novel cross-case analytical method, to identify any necessary and/or sufficient combinations of intervention delivery activities related to drug supply chain, implementer training, community sensitization, intervention duration, and implementation context that resulted in high coverage of community-wide MDA. Using pooled implementation data from three sites and across six intervention rounds, we found that efficient duration of MDA delivery (within 10 days) uniquely emerged as a fundamental component for achieving high MDA coverage when combined with other influential activities, including a conducive implementation context, early drug arrival before planned MDA onset, or a flexible community sensitization strategy. No individual activity proved sufficient by itself for producing high MDA coverage. Findings from this analysis demonstrate how effective MDA delivery can be achieved with flexible implementation strategies that incorporate various combinations of influential intervention components.

Our third study employed Mokken scaling, a nonparametric item response theory (IRT) method to assess the measurement properties of the *Structural Readiness for Scale-up Survey*, an instrument aimed to assess health system readiness to transition from school-based to community-wide MDA delivery. The 36-item instrument included five hypothesized domains of readiness – change commitment (n=8 items), change efficacy (n=13 items), capacity (n=5 items), organizational structure (n= 6 items), and flexibility (n=4 items) – as identified in several organizational readiness and change management theories. Findings from our Mokken analysis revealed the final survey structure including eight items within two unidimensional subscales – change efficacy (n=5 items) and organizational structure (n=3 items). Our findings providing a potential starting point for assessing health system readiness to scale-up mass deworming programs. We discuss the challenges of using organizationally-oriented tools to measuring readiness within complex, multi-organizational health systems in low-and middle-income (LMIC) countries and conclude that additional qualitative validation is necessary to further refine the survey items and develop applicable readiness instruments for use in LMIC settings.

This dissertation contributes to the growing global health implementation science literature by evaluating key factors influencing successful delivery and scale-up of community-based programs such as MDA, including strong stakeholder networks, valid pre-implementation readiness assessments, and implementation plans that are context-specific. Study findings provide useful insights for policy makers and implementers in STH-endemic countries aiming to interrupt STH transmission and reduce infection burden by transitioning from school-based to community-wide MDA.

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DEDICATION

For my parents & ancestors

Also, for every Black girl pursuing higher education – we got this!

CHAPTER 1. INTRODUCTION

Approximately 1.5 billion people globally are infected with soil-transmitted helminths (STH), a group of intestinal parasites prevalent in various low-and middle-income (LMIC) countries with poor sanitation and hygiene infrastructure (1,2). Pre-school and school-age children are at especially high-risk of experiencing adverse nutritional and cognitive outcomes associated with chronic or severe STH infections (1–3). Thus, in STH-endemic areas, global guidelines recommend periodic, large-scale distribution of anthelmintics i.e., mass drug administration (MDA) to all at-risk children (3,4).

School-based MDA is an efficient and cost-effective strategy for reducing STH-associated morbidity in children, reaching over 600 million children globally in 2019 (5). However, since deworming is primarily delivered at schools, this approach fails to reach adult community members who serve as infection reservoirs within communities (4,6). Recent evidence suggests that transitioning from a school-based to community-wide MDA approach that targets community members of all ages may further reduce infection prevalence and potentially interrupt STH transmission (7–9).

Scaling-up deworming efforts by transitioning from a control to elimination strategy requires considerable changes to intervention delivery infrastructure and significant increases in implementation resources (10). For example, to effectively reach all community members, an expanded MDA strategy will require strengthening drug supply chains to manage the greater quantities of required anthelmintics as well as recruiting a substantial number of community drug distributors to reach all community members. Thus, prior to scaling up pilot innovations such as community-wide MDA for STH, it is critical to assess the implementation factors that influence intervention scale-up, namely the functionality of an intervention’s delivery mechanism, the preparedness of its implementers, the availability and distribution of resources, as well as the suitability of the implementation context (12–16). Assessing these factors is essential for LMIC health systems to develop effective intervention strategies that achieve sustainable health impacts.

The overall objective of this dissertation is to generate evidence to inform the scale-up of mass deworming programs in STH-endemic countries and define key implementation dynamics relevant for the potential transition from school-based to community-wide MDA for STH. This proposed research leverages a timely opportunity, as there is growing global interest for policymakers and implementers in STH-endemic countries to align their deworming strategies towards eliminating STH by 2030 (17).

The DeWorm3 Project is a Hybrid Type I cluster randomized controlled trial in Benin, India, and Malawi assessing the feasibility of interrupting the transmission of STH using a community-wide MDA approach (18). Its hybrid design combines elements of clinical effectiveness and implementation science research. The primary objective is to evaluate the impact of bi-annual community-wide MDA versus standard-of-care school-based MDA on STH prevalence. Embedded in the clinical trial are robust implementation science research activities evaluating the implementation and sustainability of the community-wide MDA delivery model, including: stakeholder mapping to identify key stakeholders involved in the delivery of community-wide MDA; qualitative research to assess perceptions of the intervention from policymaker, implementer and recipient perspectives; readiness assessments to assess factors that drive health system motivation and capacity to deliver community-wide MDA for STH; process mapping activities to identify core and adaptable components of intervention delivery; and cost-effectiveness evaluations to compare costs and efficacy of school-based vs. community-wide MDA (19). Together, these approaches will contextualize clinical research findings, optimize intervention delivery, and identify strategies for successful intervention scale-up (19).

Using data from the stakeholder mapping, process mapping, and readiness assessments, each dissertation chapter applies a distinct methodological approach to evaluate an element guiding the transition from school-based to community-wide MDA, namely the structure of stakeholder networks engaged in MDA delivery, the effectiveness of different implementation strategies to produce high treatment coverage as well as the validity of an existing tool to assess the readiness of the implementing health system to conduct community-wide deworming.

In our first study, we employ stakeholder network analysis to identify influential intervention stakeholders and evaluate how network dynamics may guide future STH policy development. We compare and analyze the network of health system stakeholders responsible for delivering school-based and community-wide MDA for STH over the three-year duration of the DeWorm3 Project.

In our second study, we apply coincidence analysis, an innovative configurational comparative method, to identify essential components for community-wide MDA delivery and define how they come together to produce high deworming coverage. Outcomes from this analysis will inform the design of flexible, yet effective implementation strategies that can be deployed to achieve successful MDA delivery at-scale.

Our third study employs Mokken scaling, an item response theory (IRT)-based psychometric method to assess the measurement properties of a *Structural Readiness for Scale-up* instrument evaluating the motivation, technical capability, and infrastructural capacity of identified stakeholders involved in community-wide MDA delivery. We aim to develop a validated tool that can effectively define the key change management needs for health systems intending to deliver community-wide MDA for STH.

Collectively, this body of work aims to develop practical outputs for policymakers and implementers working in STH-endemic countries and provide timely evidence guiding effective implementation of community-wide MDA.

CHAPTER 2. Key influencers of mass drug administration implementation and scale-up: a network analysis of soil-transmitted helminth networks in Benin, India, and Malawi

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Abstract

***Background*:** Large community-based public health programs, like mass drug administration (MDA), require coordination across many stakeholders. We used social network analysis (SNA) to systematically identify the network of stakeholders who influence delivery of school-based and community-wide MDA for soil-transmitted helminths (STH) in Benin, India, and Malawi and determine how network dynamics may impact implementation and scale-up across these delivery platforms.

***Methods*:** This study was embedded within the DeWorm3 Project, a hybrid clinical trial in Benin, India, & Malawi testing the feasibility of STH transmission interruption via community-wide MDA compared to school-based MDA. Each site developed a list of stakeholders engaged in both MDA programs and indicated stakeholders' attitudes towards the intervention as well as influence over intervention delivery. We developed digital sociograms for both MDA networks by site, comparing baseline vs. endline. We descriptively compared changes over time in stakeholder attitudes and influence as well as key SNA measures, including centrality, centralization, and density.

Results: Across sites, we identified an expansive network of stakeholders involved in delivery of school-based (n=139, 162, 63) and community-wide MDA programs (n=65, 136, 60) at endline in Benin, India, and Malawi, respectively. At both timepoints, a majority (>70%) of stakeholders held positive attitudes towards both programs. For both programs, the most connected stakeholders (i.e., with highest degree centrality scores) were those responsible for program implementation, while stakeholders who controlled resource flow (i.e., highest betweenness centrality scores) were responsible for policy-making & program leadership. Low density scores indicated networks had poor overall connectedness due to minimal connectivity across administrative levels, while low centralization scores reflected stable networks where no single individual exhibited high control over resource flow.

Conclusion: During stages of innovation, redesign, or scale-up, analyzing the network of policy makers and implementers provides an opportunity to optimize effectiveness and efficiency of public health programs. Study findings provide useful insight for NTD policy makers and implementers in STH-endemic countries aiming to successfully interrupt STH transmission by transitioning from school-based to community-wide MDA.

INTRODUCTION

Approximately 1.5 billion people globally are infected with soil-transmitted helminths (STH), a group of intestinal worms, predominantly affecting poverty-stricken populations in low- and middle-income countries (LMICs) (1). Chronic or high-intensity STH infection can lead to various nutritional, cognitive or physical morbidities, especially amongst children (1). Current World Health Organization (WHO) STH guidelines thus recommend morbidity control via school-based mass drug administration (MDA) of deworming medicines primarily targeting pre-school age and school-age children (20). These school deworming programs are cost-effective intervention, reaching more than 600 million children annually in 2019 (5). However, untreated individuals, including adults not targeted in school-based programs, continue to serve as an important reservoir of reinfection in many settings. Emerging evidence suggests that expanding deworming to community members of all ages via a community-wide MDA platform may effectively interrupt the transmission of STH, preventing both pediatric morbidity and community reinfection (7,21).

Prior to launching any new intervention, such as community-wide MDA for STH, it is essential to understand the networks of individual who impact intervention delivery and subsequent scale-up through their unique roles in program delivery. Stakeholder networks create pathways for the diffusion of attitudes, knowledge, behaviors, and resources (22). During periods of fundamental innovation, redesign, or scale-up of a health program, analyzing the social network of policy makers, implementers, and other relevant stakeholders provides an opportunity to optimize effectiveness and efficiency of public health programs, particularly those with limited resources. For example, networks that rely on single or few individuals to funnel information or provide supervision can experience intervention delivery bottlenecks through ineffective or harmful resource diffusion, especially if the individual is not well-connected to the rest of the network (18). In contrast, highly-connected networks with numerous influential stakeholders can hasten diffusion and facilitate effective intervention uptake, especially if stakeholders with a positive attitude towards the intervention can be empowered to serve as champions to build trust with recipient populations. In addition to supporting program implementation, social network analyses also provide useful insights regarding the prospects for sustainment at scale.

In this study, we describe and analyze networks of stakeholders for school-based and community-wide MDA for STH in order to identify individuals who influence program delivery and to gain a better understanding of how network dynamics may impact program implementation and scale-up. We describe how networks change over time to understand the fluidity of intervention network structures and assess whether increased intervention exposure may impact intervention acceptability

METHODS

Study Design & Setting

Our study is embedded within the DeWorm3 Project, a multi-country hybrid implementation-effectiveness community cluster randomized clinical trial in Benin, India, and Malawi testing the feasibility of interrupting STH transmission (18). Over three years (2017-2020), all eligible community members in intervention clusters received bi-annual community-wide MDA, while those in control clusters received bi-annual or annual school-based MDA in accordance with national STH guidelines (18). Embedded in the clinical trial are a series of implementation science research aims to evaluate the factors internal and external to the intervention context that impact successful implementation of community-wide MDA for STH i.e., achieving high deworming coverage (19). As part of the DeWorm3 implementation science research, we conducted stakeholder mapping in order to systematically identify and analyze the network of stakeholders involved in MDA delivery (19).

Data Collection

At trial baseline and endline, the Benin and Malawi study teams facilitated stakeholder mapping workshops that included at least one representative each from the Ministry of Health (MOH), the Ministry of Education (MOE), and a community-based or non-governmental organization involved in the delivery of school-based MDA for STH or community-wide MDA programs for other neglected tropical diseases (NTDs) highly-prevalent in the country. At both times points in India, the data collection procedure was adapted to utilize a series of key informant interviews as the single workshop format was not feasible due to the large geographic dispersal of participants and site preferences for data collection.

At baseline, participants developed a list of relevant stakeholders at each administrative level who support delivery of school-based and, separately, community-wide MDA. A stakeholder was typically an individual (e.g., NTD Program Director), although, for large groups of individuals, a stakeholder could also be a discrete group of individuals (e.g., teachers). The following descriptive information was collected for each identified stakeholder: name, organization or Ministry, job title, and administrative level. Participants then designated stakeholder attributes, including attitude towards MDA (positive, neutral, or negative) and influence over successful MDA implementation (high, medium, or low). Attitude and implementation influence were assessed using a consensus approach where, after collaborative discussion, a majority of participants agreed on each rating (23). After building these stakeholder identification lists, participants then developed hand-drawn directed sociograms maps that use arrows indicating the direction of the relationship between two given individuals. Relationships between stakeholders were categorized as: supervisory (i.e., one stakeholder had direct authority of another), financial (i.e., one stakeholder provided budgetary or financial support to another), technical assistance (i.e., one stakeholder provided targeted implementation support to another, excluding financial assistance), or formal communication (i.e., the two stakeholders did not hold any official relationship, yet formally communicate during MDA implementation). At each site, two stakeholder lists and two maps were developed separately for each MDA delivery platform. At study endline, a second round of workshops were conducted where participants were provided with the baseline lists of stakeholders and their relationships and asked to update the baseline data. Updates included adding any new stakeholders or relationships that developed over the past three years, removing any that were non-relevant due to changes in the NTD or STH ecosystem during trial implementation, and reviewing attitudes towards the intervention. For any newly added stakeholders, participants were asked to describe the stakeholder with attributes such as attitude towards the intervention at endline (positive, neutral, or negative) as well as influence over intervention scale-up (high, medium, or low – this data was only collected for community-wide MDA). When a stakeholder left their position and was replaced by another individual in the same role, the role remained on the map as part the MDA program.

Data Analysis

We conducted a series of descriptive analyses, calculating the proportion of stakeholders by administrative level, level of influence over MDA implementation at baseline and scale-up at endline, and their attitudes towards the intervention. We utilized social network analysis (SNA) to examine MDA stakeholder characteristics and evaluate the structures of relational connections within intervention networks (24,25). SNA utilizes network and graph theory to examine structures of relationships between a group of individuals by evaluating the positions of and relationship between stakeholders (24,25). In SNA, each identified stakeholder (i.e., individual or group) represents a 'node' in the network and each relationship is described as an 'edge'. We conducted several node-level analyses, including degree centrality and betweenness centrality (*Table 2.1*) to assess the connectivity of individual stakeholders within the network (25,26). At the network-level, we quantified density and centralization to evaluate overall network connectedness and fragility, respectively (*Table 2.1*) (25,26). These network-level analyses are especially useful for understanding intervention scalability – for example, more decentralized networks suggest interventions may be easier to scale, as the flow and resources are not bound to one stakeholder and are more equally shared across the intervention network (24,27). For each MDA delivery platform, we describe similarities and differences of these values across networks from baseline to endline, by site.

We digitized the hand-drawn maps into sociograms to visually display nodal attributes and edges and describe overall network structure. We visually described the presence of any structural holes, which are defined by a node or without any ties to other nodes or node clusters and are thus isolated from the rest of the network (24,25). All analyses were conducted using RStudio V.1.4.1717 using the *igraph* package (28,29).

RESULTS

Community-wide MDA

Stakeholders in the community-wide MDA networks included a variety of stakeholders at various administrative levels. At the national & regional levels, these included Ministry personnel who define policies and provide program leadership as well as various partners, including pharmaceutical companies, multilateral and non-governmental organizations that support program planning, implementation, and evaluation. The sub-regional & health center levels included MDA program managers who design and oversee program planning & implementation; as well as health facility workers who support program management, manage local supply chains, monitor MDA for adverse events, and supervise community drug distributors (CDDs) and community health workers [CHWs, known as health service assistants (HSAs) in Malawi and accredited social health activists (ASHAs) in India]. Lastly, the community level included CDDs and CHWs who conduct community sensitization and administer deworming; as well as village leaders and community-based organizations who mobilize community members

Across sites, a total of approximately 243 and 288 unique stakeholders were identified in the community-wide MDA networks at baseline and endline, respectively (*Figure 2.1*). The largest number of stakeholders were at the health center/block and community levels, which reflect the nature of MDA programs where a significant number of implementers are necessary for drug administration. Overall, we observed a minimal difference in the number of stakeholders and relationships over time, indicating that the networks remained fairly stable over the study period.

India identified the largest number of community-wide MDA stakeholders at both time points, (137 and 136, respectively), with Benin identifying 52 and 65 unique stakeholders and Malawi identifying 54 and 60 unique stakeholders at baseline and endline, respectively. Changes in the number of stakeholders were primarily driven by the introduction of new individuals into the network. Over a three-year period, India added the most stakeholders at endline (n=26), as compared to 13 in Benin and six in Malawi. In Benin, the number of relationships also remained relatively stable in the networks from baseline to endline (150 vs. 152) as compared to India (483 vs. 433), decrease of 50 relationships) and Malawi (148 vs, 108, decrease of 40 relationships).

We observed a slight decrease or no change in the proportion of stakeholders who had positive attitudes towards community-wide MDA at baseline (82%, 97%, and 72%), as compared to endline (77%, 96%, and 72%), in Benin, India, and Malawi, respectively. Although India and Malawi did not have any stakeholders with a negative attitude towards community wide-MDA at either time point (only positive or neutral), in Benin, the proportion of stakeholders (9.6%) who held a negative attitude towards the intervention remained the same at both time points.

At baseline, a majority of stakeholders in Benin and India (62% and 72%, respectively) were identified as having high influence over successful launch of community-wide MDA, as compared to 17% in Malawi. At endline, the proportion of stakeholders that were identified as having high influence of intervention scale-up were highest in Benin and Malawi (62% and 51%, respectively) and lowest in India (10%). A majority of these influential stakeholders were at the health center or community levels. Across the three sites, the most connected stakeholders (i.e., with the highest degree centrality scores) were CDDs and CHWs, village leaders, as well as community groups such as women's associations, and leadership of NTD and community health programs at the district and sub-district levels. Stakeholders with the most control over the flow of information and resources across the networks (i.e., highest betweenness centrality scores) included national- and district-level NTD and MOH program personnel, district-level governance leadership (e.g., mayors or ward councillors) within the trial implementation area, as well as DeWorm3 site staff. Across sites, we observed low density scores ($\leq$0.06) for community-wide MDA networks over a three-year time period (Figure 2). Centralization scores also remained relatively moderate or low across sites over time, ranging from 0.23 to 0.09 for all networks (*Figure 2.2*).

We visualized six baseline (*Figures 2.3a-c*) and endline (*Figures 2.4a-c*) community-wide MDA sociograms. These sociograms visually display three different network structures for each site. In Benin, we observe "random" shaped sociograms, with a mixture of relationship types, indicated by the various arrow colors between stakeholders. India's sociograms follow a divergent "y-shaped" structure, representative of the separation of the two geographically-distinct trial implementation villages, with a majority of supervisory relationships (i.e., black arrows). The Malawi sociograms appear to have a linear structure with a variety of relationship types. Although we did not observe any structural holes in the baseline networks, two holes (shaded in gray) appeared in the

India endline sociogram due to the removal of one national-level stakeholder (*Figure 2.4b*).

School-based MDA

Most stakeholders in the school-based MDA networks were also included in the community-wide MDA networks. Additional stakeholders unique to the school-MDA networks included: national & regional level stakeholders such as MOH and MOE personnel who define policies and provide program management for school-based MDA programs; sub-regional & health center level stakeholders, such as school deworming program managers who design and oversee program planning & implementation; and community level stakeholders, including school principals who oversee deworming days, health workers that monitor for adverse events, parent and teacher associations who support mobilization of students and non-enrolled children, teachers and CHWs who administer deworming to students at schools and non-enrolled children at child health centers (i.e., *anganwadis* in India).

Across sites, the school-based MDA networks were much larger than the community-wide MDA networks, with a total of 360 and 364 unique stakeholders identified at baseline and endline, respectively (*Figure 2.5*). Similar to the community-MDA networks, most stakeholders were at the health center and community levels. The networks remained fairly stable over the study period, as we observed a minimal difference in the number of stakeholders and relationships over time. Comparing baseline and endline, India had the largest school-based network at both time points (163 and 162, respectively), followed by Benin (139 at both time points), and Malawi (58 and 63, respectively). In Benin and Malawi, the number of relationships also remained relatively stable in the networks from baseline to endline (165 vs. 166 relationships in Benin and 128 vs. 132 in Malawi), as compared to India, which had a decrease of 42 relationships (513 vs. 471). Nearly all stakeholders (93%, 98%, and 88% in Benin, India, and Malawi, respectively) had positive attitudes towards school-based MDA at baseline, though these proportions slightly reduced or remained the same at endline (93%, 99%, and 75%, respectively) across the sites. A majority of stakeholders were identified as having high influence over implementation of school-based MDA at baseline in Benin, India (92% and 72%, respectively), as compared to Malawi (21%).

Across the three sites, the most connected stakeholders (i.e., with the highest degree centrality scores) were school teachers and *anganwadis* workers, as well as health center workers, village leaders (e.g., village heads and religious leaders). Stakeholders with the most control over the flow of information and resources across the networks (i.e., highest betweenness centrality scores) included national- and regional-level STH and school deworming program leadership, district-level educational health program personnel, health facility workers, and school principals, and village leaders. Density scores for school-based MDA networks (*Figure 2.2*) were low across sites over time (all $\leq$0.04). Centralization scores also remained low across sites over time, ranging from 0.15-0.06 for school-base MDA networks (*Figure 2.2*).

Sociograms for baseline and endline school-based MDA are presented in *Figures 2.6a-c* and *Figures 2.7a-c*. Visually, each school-based MDA sociogram is similar to the relevant community-wide MDA sociogram: a random structure in Benin with mixture of relationship types, “y-shaped” structure in India with predominately supervisor relationships, and linear structure in Malawi with mixture of relationship types). The Benin baseline sociogram (*Figure 2.7a*) exhibits two structural holes (shaded in gray), both including health center- and community- level stakeholders. Although there was no change in the number of stakeholders from baseline to endline in Benin, one of the holes in the endline sociogram disappeared due to the addition of relationships at endline at the health center level. The Malawi baseline (*Figure 2.6c*) and endline (*Figure 2.7c*) sociograms included two structural holes that persisted in the endline sociogram, as the additional relationships were in other network areas.

DISCUSSION

An understanding of stakeholder networks is essential for optimizing the launch and scale-up of large, complex public health programs such as MDA. In this study, we applied SNA methods to comprehensively describe and evaluate the dynamics of an expansive network of stakeholders involved in the delivery of school-based and community-wide MDA programs in DeWorm3 trial sites in Benin, India, and Malawi. Our findings may be helpful to STH-endemic countries considering a potential policy transition from school-based to community-wide MDA. Understanding these network characteristics, including network size, connectivity and fragility, as well as stakeholder characteristics, including intervention attitude and influence, may be helpful in supporting important decision-making processes for global and national policy makers.

Network size

Across all sites, school-based MDA stakeholder networks were larger than community-wide MDA networks. This may be because school-based deworming programs are well-established in each country, which makes it easier to identify individuals involved in the delivery platform. The cross-ministerial collaboration (i.e., MOH and MOE) necessary for planning and delivering school-based MDA naturally requires more stakeholders than an intervention primarily implemented by one predominant Ministry (i.e., MOH), such as community-wide MDA. Thus, if countries choose a hybrid implementation approach that requires both delivery platforms, their networks of involved stakeholders would drastically increase. This collaboration, while essential, can become politically and logistically complicated; thus, identifying and galvanizing network connectors prior to launch may be particularly important.

Although we observed a minimal change in the total number of stakeholders over time, the addition or removal of even one highly influential stakeholder could have significant impacts on overall network structure over time, e.g., building connections to bridge any existing structural holes. Identifying these critical actors is essential for developing strategic engagement strategies that can help retain these actors in the network, as they can help maintain the institutional memory that supports high-performing implementation(30). Although we did not investigate the relationship between the change in perceived attitude towards the intervention and the existence of structural holes, structural hole theory discusses how bridging these holes can bring alternative perspectives into a group with homogenous opinions (24,25).

Network connectivity & fragility

Stakeholder-level analyses suggest that individuals with the highest connectivity (i.e., high degree centrality) were not the same as those with greatest control over the flow of information and resources i.e., high betweenness centrality); more highly-connected stakeholders were clustered at community and health center levels while those who controlled resource flow were clustered at national and regional levels. These patterns reflect the ‘pyramid-shaped’ structure of stakeholders involved in MDA implementation; the larger number of implementers at lower levels provide more opportunity for connection due to the integrated nature of MDA delivery that requires close collaboration and communication, while the less-populated upper levels, including policymakers and program managers, serve as gate keepers of information and resource flow. Interestingly, several of the most connected stakeholders were included in both the school-based MDA and community-wide MDA sociograms (e.g., district-level MDA program managers, health facility workers, and village leaders), indicating potential opportunities for leveraging human resource capacity of single individuals and their expertise to support the transition from school-based to community-wide deworming programs. Understanding which stakeholders play critical roles in diffusing innovations in a network is critical for developing engagement strategies to complement the launch of future policy updates (31) or disseminating key sensitization messages to help maximize coverage and compliance rates at scale (24). Inversely, insufficient engagement of these actors could likely result in a more-fragmented network, negatively impacting the cohesion of stakeholders upholding the policy and implementation landscape (32).

For both platforms, we consistently observed low density and centralization scores in each of the intervention networks. Although centrality measures identified individuals with high connectivity, low density is indicative of a network with minimal overall connectivity. Visual maps demonstrate how connections between administrative levels are dependent on one or a few stakeholders, which could result in inefficient diffusion of information or resources and intervention delivery bottlenecks (33).

However, low centralization may also provide an opportunity for network actors with high degree or betweenness centrality who serve as key dissemination agents to expand their influence and facilitate network strengthening strategies by integrating new relationships or providing opportunities for knowledge exchange (30,32). For example, actors with high degree centrality could use their strong connectivity to bring together personnel working across various ministries or organizations to enhance collaboration, while those with high betweenness centrality could help promote complementary cross-ministerial strategies that leverage institutional knowledge and expertise. Low network centralization indicates suggests a more egalitarian distribution of roles across network is not dominated by one or few highly-connected individuals. This is an especially practical trait for scaling-up an intervention as it (26,33,34). These network characteristics could be useful for assessing health system readiness or capacity for effective implementation at scale (35,36). In addition, we observed structural holes in several of the baseline and endline networks. These holes represent opportunities to build connections across administrative levels or implementation units to further improve the flow of information or resources across sub-networks (26), which can further benefit implementation success.

Intervention influence and attitude

Across all administrative levels and all sites, a majority of stakeholders were identified as having positive attitudes towards both MDA platforms at both time points, with a slight decrease at study endline. While we did not qualitatively assess the reasoning for the decrease in positive attitude at baseline, it is possible that over time, stakeholders recognized the additional workload necessary for expanding MDA from schools to the entire community. These perspectives will be assessed in endline qualitative research with implementers. Given that all sites have either ongoing or prior MDA programs for other NTDs, it is possible that the ubiquity of positive attitudes towards both MDA platforms may be an indication of stakeholder priming from exposure to previous NTD programs. This information is useful for assessing the policy transition climate, as stakeholders may be more accepting of a change to standard-of-care STH programming (i.e., transition to community-wide MDA) when the change is aligned with other familiar community delivery platforms.

Interestingly, there was extensive heterogeneity across sites in the proportion of stakeholders influencing successful MDA implementation and scale-up across administrative levels for both platforms. In all sites, a majority of stakeholders with high influence were at the local administrative units. Recent implementation readiness findings from these settings indicate that there is heterogeneity in readiness and capacity to deliver community-wide MDA, with stakeholders at the community levels who are the primary implementation MDA workforce exhibiting particularly low readiness in regard to human resource availability (10). Thus, the high influence of these local stakeholders suggests their readiness should also be prioritized as low preparedness could threaten effective implementation at scale.

This study had several notable strengths. Data were collected systematically across multiple geographies using robust data systems. As a result, these findings provide STH policy makers and program implementers an extensive assessment of the current implementation environment. However, this study also has several limitations. First, this study utilized a sociocentric approach to data collection that aimed to identify a complete network relying on group consensus rather than self-report from a specific individual who appoints others in their network (i.e., an egocentric approach). While an egocentric approach may have more accurately captured stakeholder relationships and attitudes, this approach was a challenge due to the large size of the networks. Thus, it is possible that some stakeholders are missing from the networks. Suggested strategies for strengthening the data collection approach include hosting several rounds of workshops with different key informants, extending the timeline for data collection, or embedding ongoing stakeholder identification within other research activities, such as qualitative data collection. Future research should assess more objective approaches to collecting individual characteristics (i.e., attitudes towards an intervention) and develop robust methods for validating the data in order to develop standardized analytical approaches for conducting SNA of large, complex intervention ecosystems such as ones for MDA delivery.

Despite these limitations, our findings demonstrate the utility of SNA to prepare for potential scale-up of a new policy. Overall, SNA has the potential to improve program implementation by proactively identifying strengths and weaknesses in program coordination or information dissemination (24) and has been used in several implementation studies to monitor intervention delivery (37), measure the impact of network-strengthening intervention strategies on implementation quality (37), and increase collaboration between previously disconnected network members to improve program outcomes (38). In this study, we utilized SNA to assess stakeholders' unique influence on implementation delivery and scale – directly through their position within the network or indirectly via their interaction with other network members (24,27). Although several studies have underscored the utility of stakeholder mapping and SNA within NTDs as it relates to describing transmission of infection, mapping treatment diffusion, and identifying the impact of social relationships on coverage and compliance (39–42), to our knowledge, this is the first application of SNA to evaluate the ecosystem of an NTD program.

CONCLUSION

Our findings provide useful insight to policy makers and implementers in STH-endemic countries considering a transition from school-based to community-wide MDA. Specifically, stakeholder maps and SNA approaches provide the opportunity to identify and quantify the influence of key stakeholders across various administrative levels responsible for MDA planning and delivery, including those who serve as key connectors and brokers of resources or those that can serve as champions for launching and scaling community-wide MDA for STH. At the network level, these approaches identified key strengths (e.g., the networks were not overly dependent on any single individual) and relevant weaknesses (e.g., identifying structural holes where there is no communication across key entities in the network) that are critical for program planning and monitoring. Our findings also demonstrate strategic opportunities to purposefully activate MDA stakeholders to champion different roles based on their position or function within the intervention network. Cultivating these strengths could help the entire network optimally operate in order to drive effective implementation and sustainable impact.

TABLES & FIGURES

Table 2.1: Social network analysis definitions and functions

Analysis Level	Measure	Definition	Function
Node-Level	Degree centrality	Number of outgoing edges for each node	Identifies the most connected stakeholders with the network
	Betweenness centrality	Number of times a node is a bridge along the shortest path between two other nodes	Identifies individuals that serve as critical regulators of resources or information flow from one part of the network to the other
Network-Level	Density	Proportion of number of edges present in a network divided by the total possible number of edges	Reflects the extent to which the nodes in a network are connected with each other
	Centralization	Ratio of the actual sum of differences between the most central node and each other nodes divided by the theoretical maximum possible sum of differences (i.e., assesses how central the most central node is in relation to how central all other nodes are)	Measures the extent to which the connections within a network are concentrated on a single node (i.e., network fragility)

Figure 2.1: Distribution of community-wide MDA stakeholders in DeWorm3 sites, by administrative level

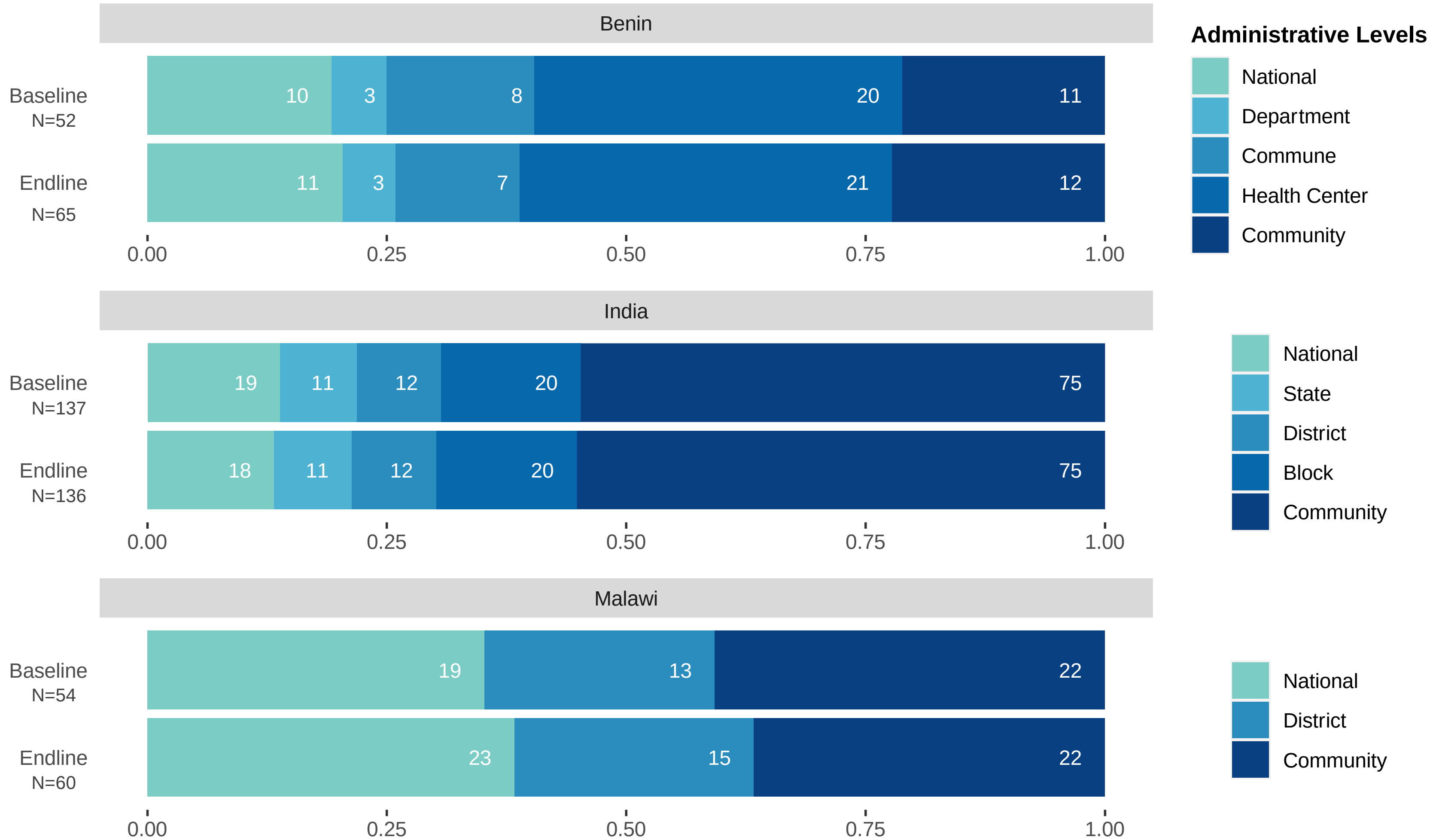


Figure 2.2: Community-wide and school-based MDA network centralization and density scores, baseline vs. endline

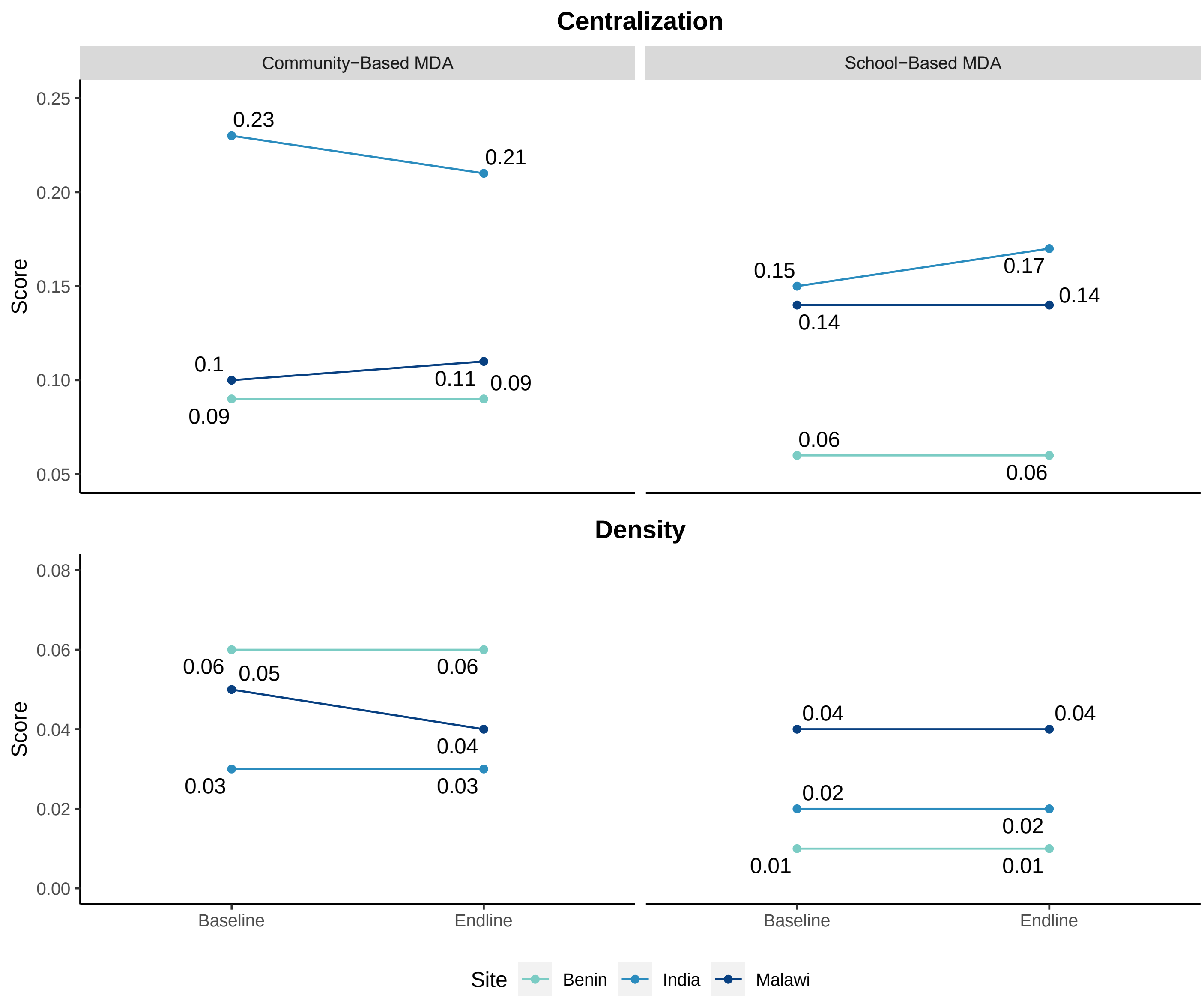
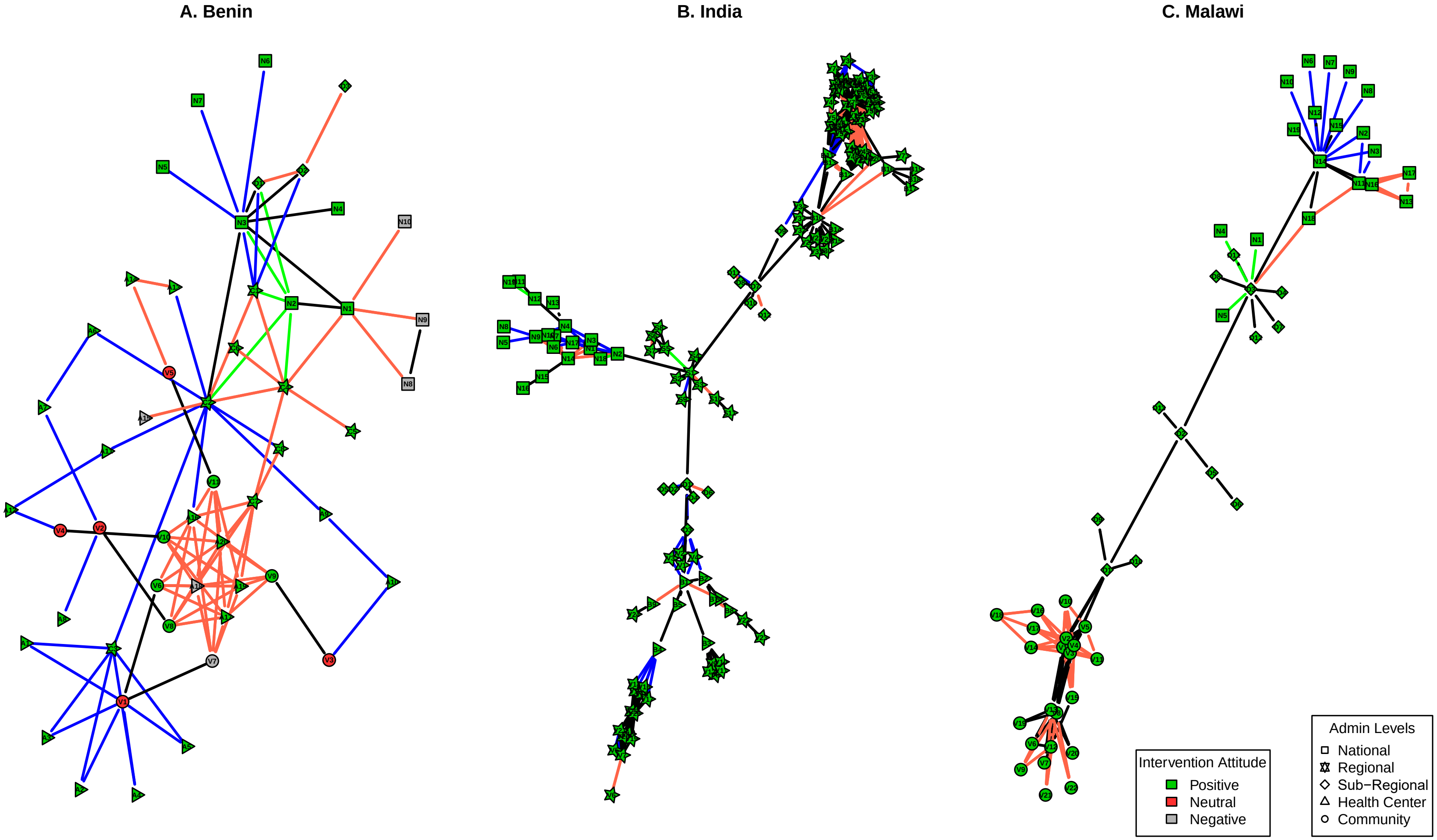
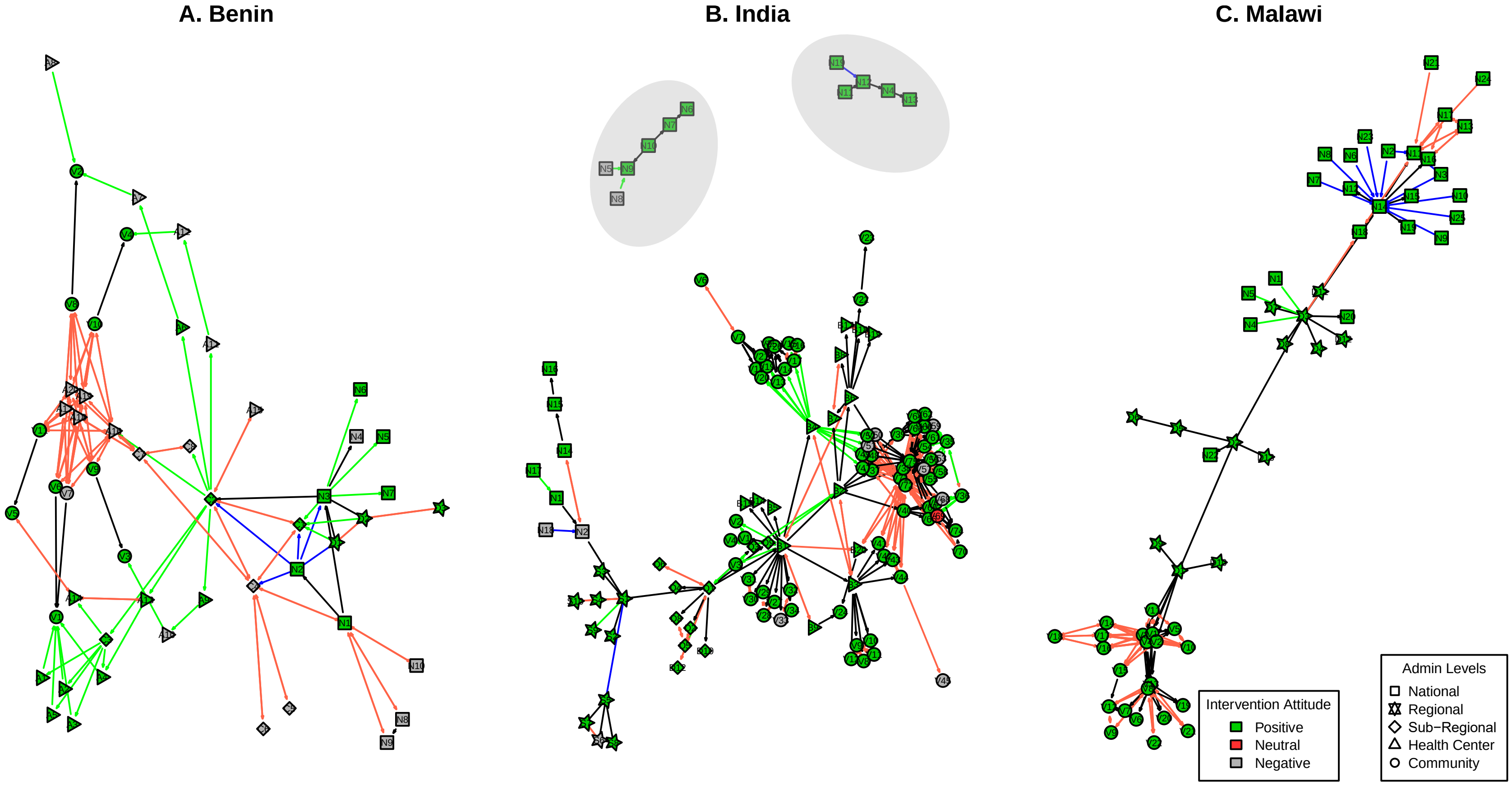


Figure 2.3: Baseline community-wide MDA sociograms, by site



Note: Regional levels per site: Benin=department, India=state, Malawi=district. Sub-regional levels per site: Benin=commune, India & Malawi =district

Figure 2.4: Endline community-wide MDA sociograms, by site



Note: Regional levels per site: Benin=department, India=state, Malawi=district. Sub-regional levels per site: Benin=commune, India & Malawi =district

Figure 2.5: Distribution of school-based MDA stakeholders in DeWorm3 sites, by administrative level

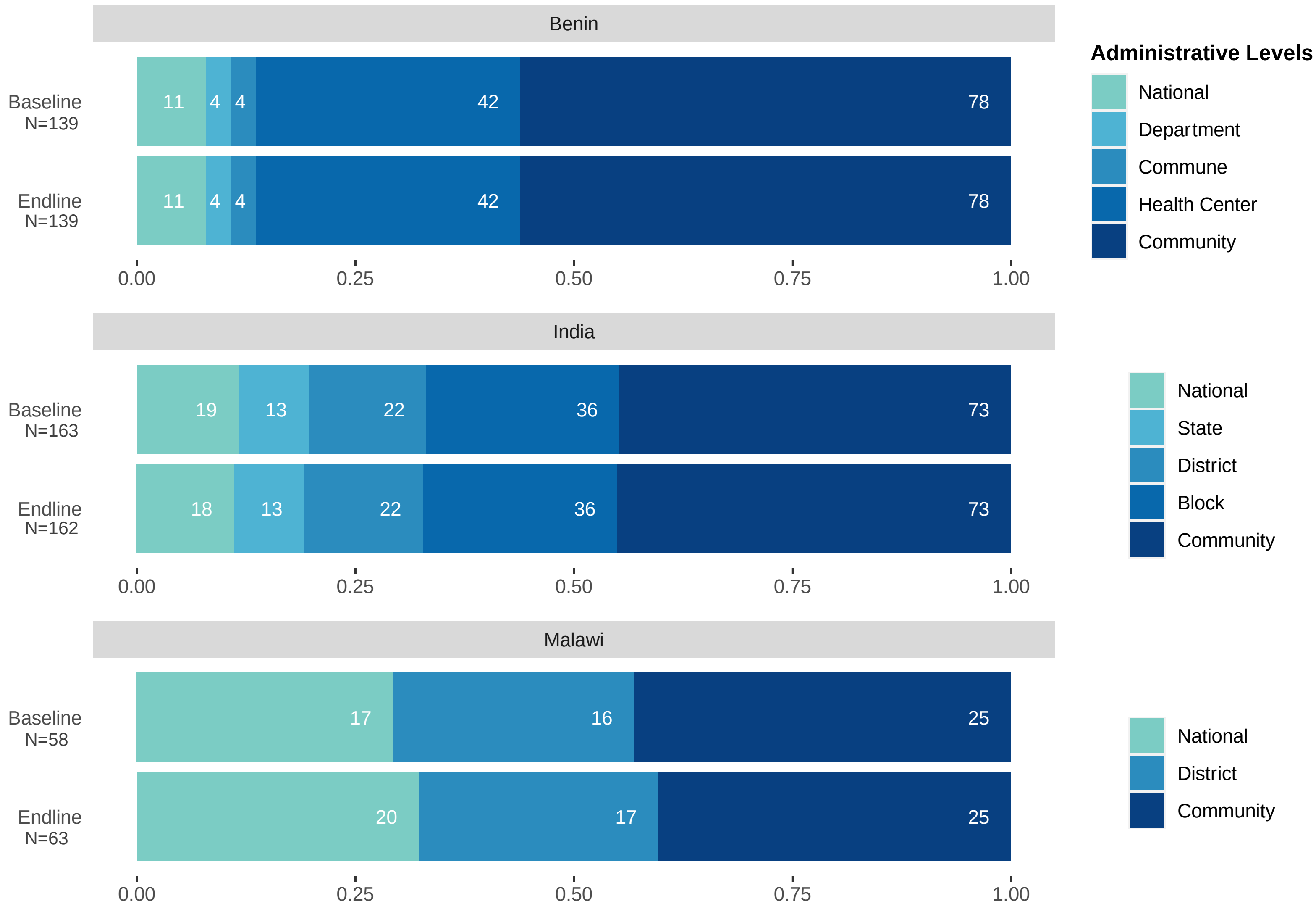


Figure 2.6: Baseline school-based MDA sociograms, by site

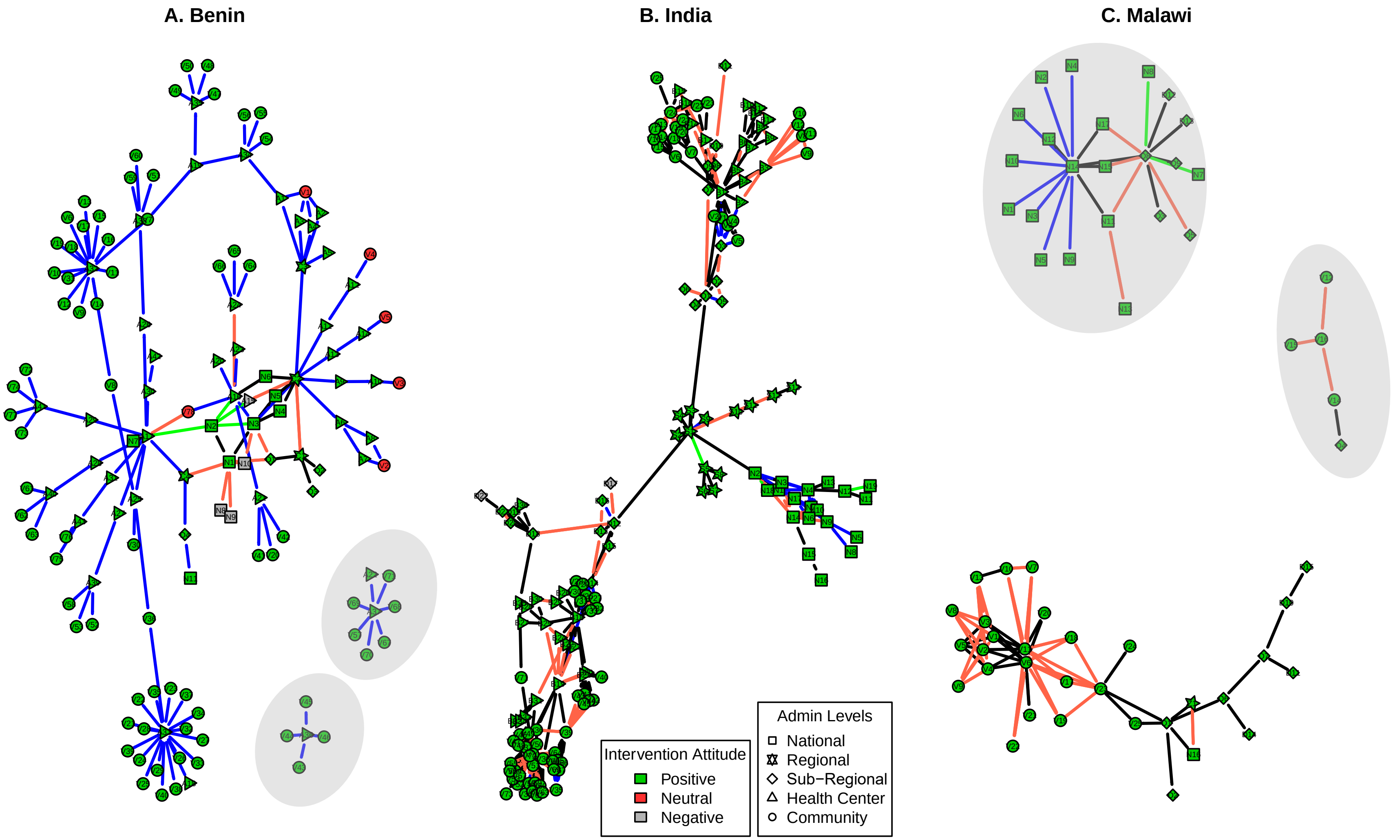
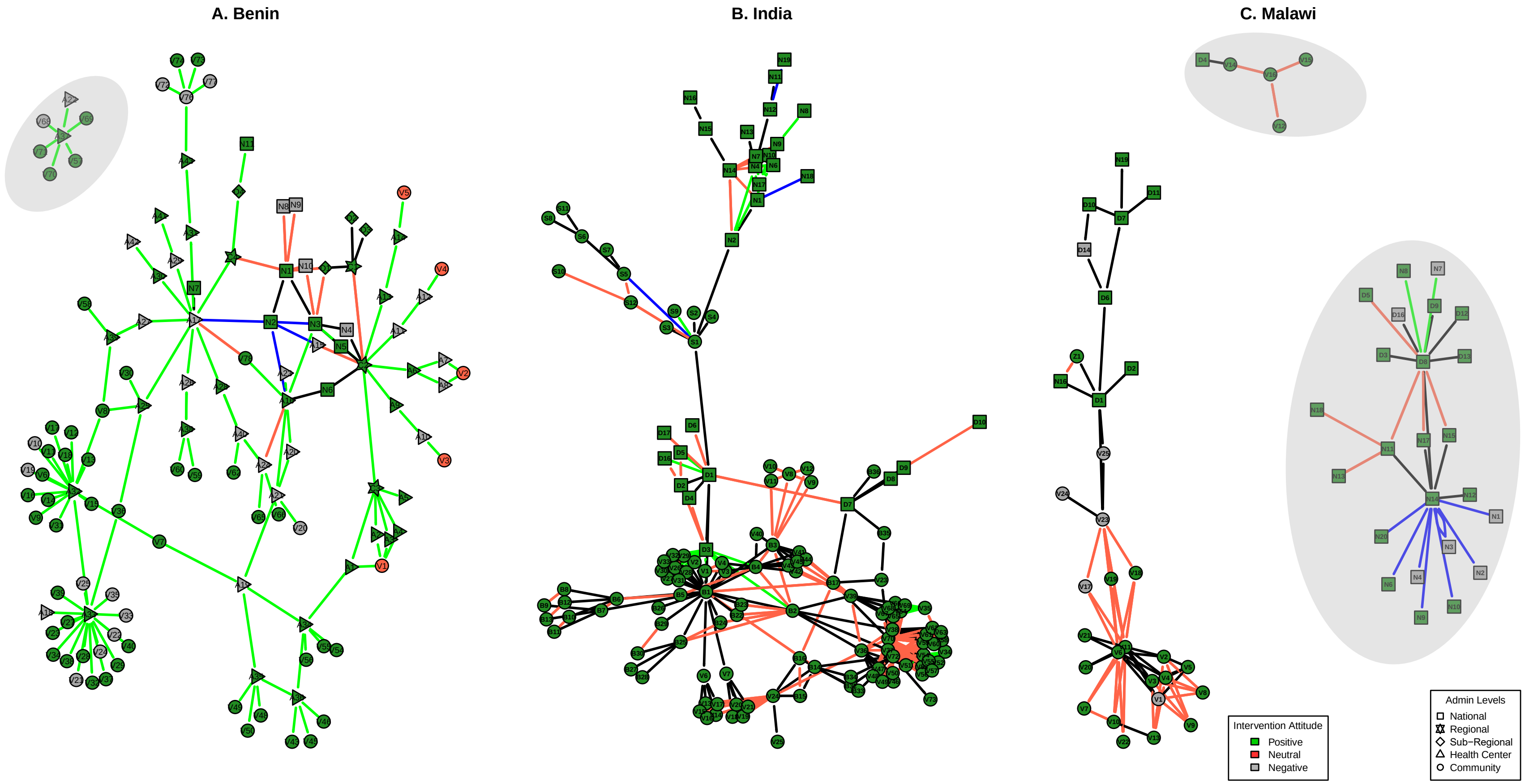


Figure 2.7: Endline school-based MDA sociograms, by site



CHAPTER 3. Defining optimal implementation packages for delivering community-wide mass drug administration for soil-transmitted helminths with high coverage

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ABSTRACT

Background: Recent evidence suggests that community-wide mass drug administration (MDA) may interrupt the transmission of soil-transmitted helminths (STH), a group of intestinal worms that infect 1.5 billion individuals globally. Although current operational guidelines provide best practices for effective MDA delivery, they do not describe which activities are most essential for achieving high coverage or how they work together to produce effective intervention delivery. We aimed to identify the various packages of influential intervention delivery activities that result in high coverage of community-wide MDA for STH in Benin, India, and Malawi.

Methods: We applied coincidence analysis (CNA), a novel cross-case analytical method, to process mapping data as part of the implementation science research of the DeWorm3 Project, a Hybrid Type 1 cluster randomized controlled trial assessing the feasibility of interrupting the transmission of STH using bi-annual community-wide MDA in Benin, India, and Malawi. Our analysis aimed to identify any necessary and/or sufficient combinations of intervention delivery activities (i.e., implementation pathways) that resulted in high MDA coverage. Activities were related to drug supply chain, implementer training, community sensitization strategy, intervention duration, and implementation context. We used pooled implementation data from three sites and six intervention rounds, with study clusters serving as analytical cases (N=360). Secondary analyses assessed differences in pathways across sites and over intervention rounds.

Results: Across all three sites and six intervention rounds, efficient duration of MDA delivery (within ten days) singularly emerged as a common and fundamental component for achieving high MDA coverage when combined with other particular activities, including

a conducive implementation context, early arrival of albendazole before the planned start of MDA, or a flexible community sensitization strategy. No individual activity proved sufficient by itself for producing high MDA coverage. We observed four possible overall models that could explain effective MDA delivery strategies, all which included efficient duration of MDA delivery as an integral component.

Conclusion: Efficient duration of MDA delivery uniquely stood out as a highly influential implementation activity for producing high coverage of community-wide MDA for STH. Effective MDA delivery can be achieved with flexible implementation strategies that include various combinations of influential intervention components.

BACKGROUND

Policymakers and implementers are often challenged with making decisions regarding the implementation of complex interventions to ensure high coverage and uptake (90–92). Complex interventions, by definition, have numerous interrelated elements that impact both implementer processes and recipient responses, including their intervention components, implementation strategy, and contextual features (93,94). Therefore, there is a critical need for approaches that evaluate the relationships between these elements and determine their influence on effective intervention delivery in order to identify under what circumstances complex interventions are successful (90,95,96). Outcomes from these assessments can support evidence-based decision-making for policymakers and implementers, especially those working within health systems in low- and middle-income countries (LMICs) who often face issues of limited resources and capacity (97–100).

One such complex intervention is mass drug administration (MDA) for neglected tropical diseases (NTDs) – a group of parasitic, viral, and bacterial diseases that affect billions of individuals, with disproportional prevalence in LMICs across sub-Saharan Africa, South Asia, and Latin America (3,4). Untreated NTD infections negatively impact health, learning and productivity outcomes, diminishing quality-of-life and reinforcing cycles of poverty amongst the world's most disadvantaged populations (3,4). Worldwide, the most prevalent NTDs are soil-transmitted helminths (STHs), a group of parasitic intestinal worms that infect approximately 1.5 billion people globally – of these, an estimated 900 million are pre-school and school-age children (1–3). Current World Health Organization (WHO) guidelines recommend geographic areas that meet pre-defined STH prevalence thresholds to implement MDA, with a particular focus on deworming pre-school and school-age children in schools. In these programs, all at-risk children receive anti-helminthics, such as albendazole, regardless of their infection status (3,4). This school-based MDA approach is the standard-of-care for STH control across numerous LMICs, reaching hundreds of millions of children annually (1,3,6). However, this approach does not target adults who serve as infection reservoirs in communities, thus contributing to rapid pediatric reinfection (4,6). A community-wide MDA approach that targets community members of all ages shows promise of interrupting the transmission of STH (7–9). However, even with this intensified treatment strategy, MDA must be delivered with high coverage, with at least 80-90% of the targeted population dewormed, to achieve transmission interruption (7–9,101,102).

Significant evidence suggests best practices for delivery of MDA with high treatment coverage include: a reliable drug supply chain to ensure the adequate allocation and distribution of anthelmintic drugs; a robust training cascade to build implementer capacity; a far-reaching community sensitization strategy to inform and mobilize recipients about MDA; and a well-executed, yet rapid distribution strategy (2,103–110). Thus, effective MDA delivery requires a significant investment of material, financial, and human resources as well as adaptable implementation strategies that are feasible, appropriate, and acceptable for heterogeneous implementation settings. However, current MDA operational guidelines issued by the WHO and national Ministries of Health in NTD-endemic countries lack context-specific recommendations that take into account variation in key implementation factors, such as disease epidemiological profiles, community preferences, and health system capacities (6,104,105,109,111). Furthermore, guidelines do not distinguish which implementation activities are most essential for achieving MDA delivery with high coverage. This information is necessary for implementers who are planning MDA at scale in resource constrained environments, and who may not be able to incorporate all best practices into an implementation plan.

Using coincidence analysis (CNA), a cross-case analytical method, we systematically identify the various configurations of intervention delivery activities – known as implementation pathways – that result in high coverage of community-wide MDA for STH. This analysis aimed to characterize the "core components" of MDA delivery – activities that are necessary for achieving high coverage and need to be implemented with fidelity (112). Such evidence may help policymakers define the required resources for implementing MDA with high coverage as well as shape implementer decisions regarding implementation that balances fidelity with flexibility.

METHODS

CNA is a type of configurational comparative method (CCM) based on Boolean algebra that determines specific combinations of conditions called configurations whose presence or absence "makes a difference" (i.e., are difference-makers) as to whether an outcome of interest occurs (113,114). CCMs are based on regularity theories of causation that utilize cross-case comparisons to identify these difference-makers. Thus, in comparison to regression-based analyses, these approaches fundamentally identify different properties of causal structures (113,115). Of particular utility is the ability to model Boolean conjunctivity, where multiple conditions must be jointly present to bring about an outcome, and equifinality, where multiple pathways lead to the same outcome (113,115). These two principles are of particular interest to implementers and policymakers, as interventions delivered in real-world settings are often complex and feature numerous interdependent activities that can produce various outcomes based on the selected implementation strategy (116).

CNA enable the complex modeling of the relationships between influential factors that cannot be captured with traditional statistical approaches (113,115); thus, it is gaining traction as an additional approach for evaluating program implementation (116–121). The aim of CNA is to identify the minimal set of necessary and/or sufficient configurations to achieve an outcome of interest (113,114). A necessary condition/configuration must be present for the outcome to occur (but does not produce the outcome by itself), while a sufficient condition/configuration can produce the outcome alone (122,123). Certain conditions, called "INUS" conditions, are neither sufficient nor necessary alone, but as part of a configuration, play an influential role in producing the outcome of interest. INUS represents a condition that is Insufficient (not sufficient by itself to produce an outcome) but a Necessary component of a configuration that is itself Unnecessary (due to multiple pathways) but Sufficient for the outcome to occur (122,123). In real-world implementation, it is rare that any single program activity produces the outcome of interest; thus, identifying these INUS conditions is especially relevant for evaluating intervention delivery (115).

Study Background & Setting

We applied CNA to process mapping data from the DeWorm3 Project, a Hybrid Type 1 cluster randomized controlled trial conducted in three sites – Benin, India, and Malawi – that aim to assess the feasibility of interrupting the transmission of STH, defined as weighted cluster-level prevalence $\leq$2% measured 24 months after the final round of MDA (18,19). The primary study objective is to evaluate the impact of bi-annual community-wide MDA as compared to school-based MDA on STH infection prevalence (18). Over three consecutive years, 40 clusters per site, which consisted of one or more administrative villages, settlements or zones, were randomized to receive bi-annual community-wide MDA delivered by trained community drug distributors (CDDs) or school-based MDA delivered by trained teachers, in accordance with WHO recommendations and national Ministry of Health guidelines (18). Embedded in the trial is a robust implementation science research component – including stakeholder mapping, qualitative research, structural readiness assessments, process mapping, and economic evaluation methods – that aims to contextualize trial findings, optimize intervention delivery, and identify strategies for successful intervention scale-up (19).

Sampling & Data Collection

Data from this analysis comes from the process mapping component of DeWorm3 implementation science research, which details the required inputs for effective intervention delivery (19). During each round of MDA, routine process mapping exercises were conducted in each intervention cluster. Trained implementation science research staff tracked the completion and timing of key intervention delivery activities in five domains: *drug supply chain* (e.g. quantity and timing of albendazole arrival), *training* (e.g. timing and proportion of implementers trained prior to delivery), *community sensitization* (e.g. type of community sensitization activities conducted), *intervention duration* (e.g. number of days of MDA delivery), and *implementation context* (e.g. presence of ongoing community interventions or events that may have impacted MDA delivery). Data were recorded on paper copies of standardized process mapping worksheets (Appendix 1) and subsequently entered into the DeWorm3 SurveyCTO database (124).

Measures & Analysis

Our analytical process was adapted from Whitaker et. al. (116). Intervention clusters served as analytical cases. Our primary analysis aimed to identify configurations that led to high coverage of community-wide MDA across all sites and intervention rounds using one pooled dataset including 360 cases (20 intervention clusters across six MDA rounds for three sites). The primary outcome of interest was high coverage (> 90%) of community-wide MDA, as per trial protocol (18). The initial dataset included 11 possible factors based on the five MDA implementation domains included in the process mapping exercise (*Table 3.1*). Each factor was previously identified as a key variable that impacts effective delivery of community-wide MDA for various NTDs (2,103–108,110,125). With configurational approaches, factors with insufficient variability cannot be difference-makers as they do not distinguish cases with and without the outcome (113). In order to make this determination, we used plots to visualize the distribution of all 11 factors, removing two forms of mass media sensitization strategies (newspaper and television) that had very low (<1%) variation, leaving nine factors suitable for further analysis. In CNA, conditions are the specific values a factor takes on based on data calibration choice. We used crisp-set (i.e., dichotomous) calibration for the outcome and all conditions as it is straightforward to interpret and operationally actionable as compared to other calibration choices (126).

CNA models have two overall measures of fit: consistency and coverage. Consistency indicates the “reliability” of a CNA model by measuring the number of cases identified by the overall model with the outcome of interest over the total number of all cases identified by the overall model (113,122,123,126). Coverage is an indicator of the “relevance” of a model by measuring the number of cases identified by the overall model with the outcome of interest (i.e., the same numerator as for consistency) over all cases with the outcome present (113,122,123,126). Consider an analysis conducted within a hypothetical dataset of 100 high-coverage clusters and 100 low-coverage clusters. If 80 clusters across the dataset had the same configurations, and 75 of these 80 had the outcome present, the overall consistency and coverage scores for this model would be 0.94 (75/80) for consistency and 0.75 (75/100) for coverage. Depending on the dataset and the thresholds set for consistency and coverage, CNA may yield several candidate models that fit the data equally well (i.e., similar consistency and coverage scores), a situation known as model ambiguity (42,48). In this scenario, it is not possible on mathematical grounds alone to select one model as the “correct” one; rather, theory, background knowledge, and case familiarity may need to be called upon in order to choose one model over the others. Another strategy when faced with model ambiguity is to identify common elements that appear across all model possibilities. Even if it cannot be absolutely determined which single model is the correct one, if all candidate models contain the same identical component, then it follows that this component directly relates to the outcome of interest.

Using a data reduction approach described previously in the configurational literature (119,120,127), we first aimed to select the most influential factors to include in iterative model development and analysis. We used the “minimally sufficient conditions” (*msc*) function in the R *cna* package (128) to simultaneously consider all nine factors and 360 cases at once to identify configurations with the strongest relationship to the outcome, as measured by coverage scores. We set the initial consistency threshold at 1.0, reducing it by increments of 0.05 until we observed configurations at the specified threshold. We then ranked these configurations by coverage score, considering all one-, two- and three-condition configurations with the highest coverage scores and aligned with theory, background knowledge and case familiarity.

With this subset of factors, we then iteratively developed models using the R *cna* package (128). We selected a final model with consistency and coverage score thresholds of $\geq$0.85 and $\geq$0.50, respectively, without model ambiguity. Model interpretation followed conventional Boolean analysis with conditions in uppercase/lowercase representing the presence/absence of a condition, the asterisk "*" symbolizing the logical operator *AND* (i.e., a conjunct), plus sign "**+**" symbolizing the logical operator *OR* (i.e., a disjunct), and the one sided-arrow "→" expressing sufficiency (116,129).

Our primary analysis aimed to identify configurations – or implementation pathways – that led to high MDA coverage across all three sites and six intervention rounds. This analysis was conducted with one pooled implementation dataset including 360 cases (20 intervention clusters across six MDA rounds for three sites). We also conducted two secondary analyses to assess differences in pathways: a cross-site analysis to consider contextual variation in implementation across countries, and a longitudinal analysis to evaluate potential changes in pathways over MDA rounds. The longitudinal analysis was conducted using six MDA round-level datasets, each including 60 cases (20 intervention clusters for three sites) and the cross-site analysis was conducted using three site-level datasets, each including 120 cases (20 intervention clusters over six MDA rounds). All analyses were performed using RStudio v.1.3.959 using the *cna* package (128).

RESULTS

Descriptive Statistics

High MDA coverage was achieved 171 times across all six intervention rounds – 94 times (55%) in India, 39 times (23%) in Malawi, and 38 times (22%) in Benin (*Table 3.2*). Across MDA rounds, round three had the highest number of clusters (n=43) that achieved high coverage across sites, while round one had the lowest (n=17). Across sites, India had the highest median MDA coverage in nearly all MDA rounds (*Figure 3.1*). Across all sites and over six rounds, the median number of days of MDA delivery was 11 days (range 4-18 days).

CNA Analysis

The data reduction process identified seven factors to use in subsequent model development at 0.80-0.50 consistency-coverage score thresholds: drug supply chain (DRUG), printed sensitization materials (PRINT), intervention duration (MDADAYS), door-to-door sensitization (DOOR), public address announcements (PUBLIC), community meetings (MTG), and implementation context (CONTEXT). No single condition alone was sufficient for achieving high MDA coverage. Our analysis revealed four possible models sufficient for attaining high MDA coverage:

1. MDADAYS*PRINT + MDADAYS*PUBLIC*CONTEXT → COVERAGE
2. MDADAYS*DRUG + MDADAYS*PRINT → COVERAGE
3. MDADAYS*DRUG + MDADAYS*PUBLIC*CONTEXT → COVERAGE
4. MDADAYS*PRINT + MDADAYS*PUBLIC*DOOR → COVERAGE

For clarification, we include a plain-language interpretation for Model 1. In this model, there are two pathways for clusters to achieve high MDA coverage: (a) PRINT*MDADAYS: distribution of printed health education materials *AND* delivery of MDA within 10 days *OR* (b) PUBLIC*CONTEXT*MDADAYS: public address announcements *AND* a conducive implementation context *AND* delivery of MDA within 10 days.

Note that across the four possible models, there are only a total of four specific configurations represented; each candidate model is a disjunct of those configurations. Although the similar consistency and coverage scores across models (*Figure 3.2*) indicate model ambiguity, the analysis successfully identified one INUS condition – MDADAYS (efficient MDA delivery duration) – which was observed not only across all four possible models, but was part of every configuration within those four solutions. Although MDADAYS alone was insufficient for the outcome to occur, it was a necessary component of each of the four observed pathways across the models:

(a) PRINT*MDADAYS,

(b) DRUG*MDADAYS,

(c) PUBLIC*CONTEXT*MDADAYS, and

(d) PUBLIC*DOOR*MDADAYS).

Although the cross-site and longitudinal analyses revealed several possible models, they did not meet the pre-specified analytical consistency and coverage score thresholds and were not reported.

DISCUSSION

This analysis indicates that, while insufficient or necessary by itself, efficient duration of MDA delivery (within 10 days) in combination with at least one other influential implementation activity – including a conducive implementation context, early arrival of albendazole before the start of MDA, or a flexible community sensitization strategy – consistently led to high coverage of community-wide MDA for STH.

Thus, our results suggest that efficient MDA delivery duration was one of the most influential implementation activities for producing high treatment coverage and MDA delivery within 10 days appears to be an optimal delivery timeframe for community-wide MDA for STH. Current evidence shows that the number of scheduled MDA days plays a significant role in the ability of implementers to meet necessary MDA targets, with overly brief durations negatively impacting treatment coverage (104,130–132). However, these studies do not determine a definitive timeframe for effective delivery. To our knowledge, this is the first study to assess the effectiveness of a specific duration of MDA delivery.

Our findings mark an important addition to the NTD evidence base, as MDA duration has several implications for policy makers, NTD program managers, and implementers. Primarily, decision-making regarding program duration affects financial and material resources allocated for implementation. Thus, having clarity around the adequacy of scheduled MDA duration may support implementers to more effectively plan for MDA and maintain cost-effectiveness of the intervention, which is a key policy consideration for transitioning to community-wide MDA for STH (133,134). Specific to planning, it is critical that implementers allocate a sufficient number CDDs for the target population size for the given campaign delivery schedule (104,135). Notably, there may be an important relationship between campaign duration and size of the available workforce; a larger number of CDDs may be necessary to deliver MDA over a shorter duration of time as compared to the amount of CDDs needed to deliver MDA to the same target population over a longer period of time. While these results do not directly call for implementers to deliver MDA faster than necessary, they do provide additional consideration for the potential diminishing returns if the number of days are over-extended, given the additional financial and opportunity costs of community-wide MDA as compared to school-based MDA (133,136). These findings also provide novel evidence for an intervention component that is not currently highlighted in NTD operational manuals. A potential area of future CNA research could further examine what specific factors distinguish areas that deliver MDA more efficiently to further strengthen these findings.

Although were ultimately unable to single out a single model to explain high MDA coverage due to model ambiguity, the pathways within the candidate models demonstrate how high MDA coverage could potentially be accomplished in various ways, reflecting the utility of flexible implementation strategies, especially for sensitization strategies. Our results indicate that in addition to efficient MDA duration, three components – community sensitization, drug supply chain, and implementation context – consistently appeared across the models, suggesting their influence in achieving high MDA coverage. These three components are heavily outlined in the existing evidence base as key factors that influence the delivery of and demand for community-wide MDA for various NTDs, as summarized below.

Community Sensitization: It is critical that community members are aware of upcoming MDA campaigns and have trust in their efficacy and safety. Sensitization helps build awareness, demand, and trust amongst recipient community members and also builds buy-in from key political, civic, and community stakeholders (105,106). Numerous studies have demonstrated the importance of well-designed, multifaceted community awareness strategies on MDA coverage (106,108,130,135,137–139). Our findings further demonstrate the strong influence of various sensitization approaches and indicate the importance of flexibility when designing sensitization strategies – in some areas, distribution of written materials may be more effective, while in other areas door-to-door sensitization may be more appropriate.

Drug Supply Chain: Another critical component of STH MDA delivery is having sufficient amounts of deworming drugs. Shortage of drugs is a potential consequence of late drug arrival, as the delay forces implementers to rely on stocks of deworming drugs in local health clinics to initiate MDA, which are likely in inadequate amounts to reach all targeted populations. Thus, timely drug arrival is an indication of adequate planning as well as a functional supply chain, which are both predictors of MDA coverage (140–142). Therefore, late drug arrival often serves as a barrier to achieving high MDA coverage (140–142). Our results further illustrate how timely drug arrival serves as a facilitator for effective MDA delivery. These findings define the importance of effective planning to mitigate supply chain issues and the need for robust supply chain management to help ensure timely and adequate receipt of necessary drugs.

Implementation Context: The implementation context plays a significant role in intervention delivery (91,93,94). There are a number of contextual challenges that may impede MDA implementation and result in fewer individuals being dewormed. In our study, clusters identified several contextual issues that affected MDA delivery, including other ongoing community health programs, heavy rainy seasons, local cultural festivals and religious events. Our analysis suggests that clusters without these contextual challenges positively influenced MDA coverage. Existing evidence highlights the importance of scheduling MDA around other community events that may negatively affect treatment coverage, or reduce the availability of implementers to deliver MDA, including ongoing public health priorities and programs, important religious or cultural events, community activities, or weather periods (104,135). Our findings emphasize the importance of careful planning and cross-sectorial collaboration and communication that in turn, could increase the likelihood of an optimal implementation context.

Overall, our findings illustrate important findings for inclusion in future operational guidelines for delivering community-wide MDA for STH and other NTDs. Policymakers and national-level NTD program managers can utilize these findings when developing MDA budgets and implementation strategies to ensure there are sufficient financial, human, and material resources. Additionally, implementers can use these findings to ensure they sufficiently invest in intervention planning before intervention delivery.

Our analysis has several strengths. Primarily, we included a large amount of implementation data covering six intervention delivery rounds and three distinct geographic settings. These data were pulled from a multi-country study that followed a comprehensive data collection process. We also applied a rigorous analytical process involving the use of CNA within implementation science (116). However, these results have several limitations. Primary is our use of data from an ongoing hybrid trial; therefore, our findings may not be completely generalizable to MDA programs implemented under routine practice. Other limitations of generalizability are specific to the CNA methodology. Specifically, our results are directly affected by our calibration choices and might have differed with other calibration thresholds. Additionally, although we were able to identify key operational variables that influence MDA coverage, there were other contextual factors that could have impacted intervention delivery that were not included as part of our analysis, including: degree of community trust or acceptability towards the intervention, implementer satisfaction and motivation (e.g., with workload or incentives), and level of community migration over time (105). The candidate models we reported each had coverage scores around 0.50, indicating a role for other factors and additional pathways to successful intervention delivery. The influence of these factors will be assessed in other planned DeWorm3 coverage analyses. Despite these limitations, we further demonstrated the utility of CNA in modeling complex causality for complex intervention delivery. Thus, our results have substantive implications for the future implementation of community-wide MDA to interrupt the transmission of STH across various low-resource settings.

It is also important to note the impact of the COVID-19 pandemic on study implementation activities. Sites were under country-wide lockdown during a significant portion of the last year of planned MDA delivery (i.e., MDA rounds 5 and 6), and all MDA planning and delivery activities were suspended until as late as July 2020. When field activities resumed, sites captured the impact of the pandemic on MDA implementation on the routine process mapping worksheets, e.g., noting how the pandemic negatively impacted the implementation context in some clusters. Thus, this analysis does capture some of these pandemic-specific challenges. However, we acknowledge the need for additional quantitative and qualitative research that directly assesses the impact of the COVID-19 pandemic on MDA planning and delivery and subsequent transmission interruption progress (143). Currently, there are several ongoing DeWorm3 evaluations assessing these impacts and understanding how the study's existing community-wide infrastructure could be utilized to facilitate rapid community responses to COVID-19.

CONCLUSION

Using an innovative analytic approach, we identified that efficient duration of MDA delivery within 10 days was a highly influential implementation activity for achieving high coverage of community-wide MDA when co-implemented with other key implementation factors such as a conducive implementation context, early arrival of albendazole, and a flexible community sensitization strategy. These findings can be used by STH-endemic countries implementing MDA programs to develop appropriate operational guidelines and support effective implementation planning. Similar methodological approaches may be extended to evaluate other community-based primary care programs implemented in LMIC health systems.

TABLES & FIGURES

Table 3.2: Description and calibration of CNA variables

Outcome/Condition	Description	Factor	Calibration
High coverage of community-wide MDA	≥90% (per-protocol) [1]	COVERAGE	0 < 90% coverage 1 ≥ 90% coverage
Drug supply chain	Timing of when albendazole arrive in each cluster	DRUG	0 Late arrival of albendazole (on first day of MDA) 1 Early arrival of albendazole (at least one day before MDA)
Implementer training	Proportion of community drug distributors (CDDs) trained prior to MDA in cluster	TRAIN	0 Not all CDDs trained 1 All CDDs trained
Community sensitization type	Type of community sensitization activity conducted in cluster [2]	MTG, PUBLIC, PRINT, DOOR, RADIO, TV, NEWSPAPER	0 Sensitization activity not conducted 1 Sensitization activity conducted
Intervention duration	Number of days of MDA delivery	MDADAYS[4]	0 MDA delivered in > 10 days 1 MDA delivered in <= 10 days
Implementation context	Presence of ongoing interventions or events in the community that may have negatively impacted MDA delivery or uptake	CONTEXT	0 Non-conducive implementation context (at least one ongoing community intervention or event) 1 Conducive implementation context (no community interventions or events)

[1] Per-protocol coverage defined as: the percentage of censused and eligible individuals treated with a single dose of albendazole
[2] Sensitization activities incudes: community meetings (MTG), public address announcements (PUBLIC), distribution of printed education materials e.g., posters and banners (PRINT), door-to-door sensitization (DOOR), or mass media (RADIO, TV, NEWSPAPER).
[3] Television (TV) and news (NEWSPAPER) were removed from final dataset due to limited variation across cases
[4] CDDs who participated in DeWorm3 were given 10 days to deliver community-wide MDA

Table 3.3: Number of clusters that achieved high MDA coverage, by site and MDA round

Site	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	All Rounds
Benin	1	4	15	7	3	8	***38***
India	16	16	20	20	4	18	***94***
Malawi	0	0	8	5	18	8	***39***
All Sites	***17***	***20***	***43***	***32***	***25***	***34***	***171***

Figure 3.8: Median community-wide MDA coverage rates, by site and intervention round

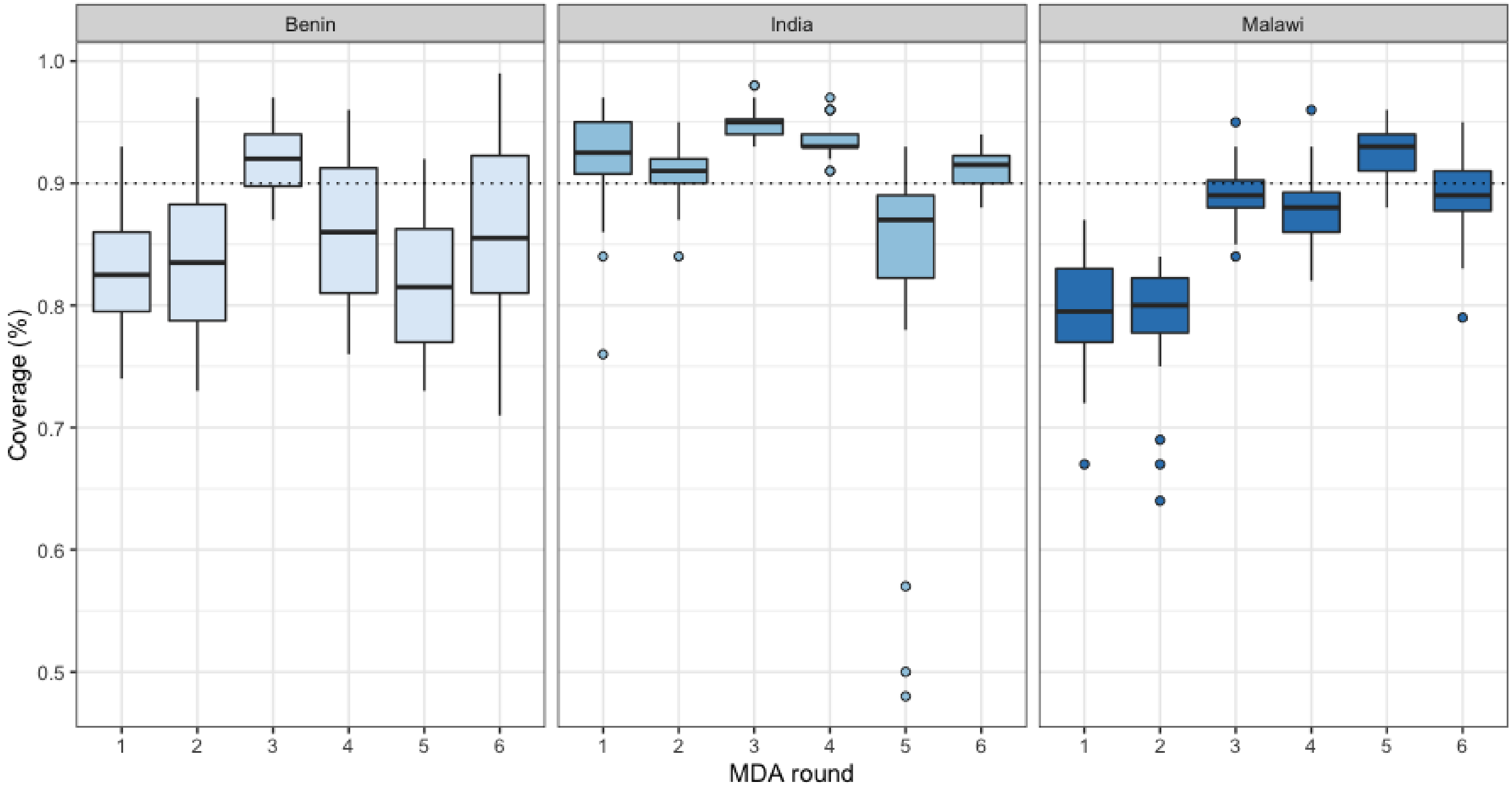

Figure 3.9: Conditions represented within CNA models for achieving high coverage of community-wide MDA for STH

Models	Conditions in CNA Model							Consistency	Coverage
	DRUG	PRINT	MDADAYS	PUBLIC	DOOR	MTG	CONTEXT		
1		●	●	●			●	0.90	0.50
2	●	●	●					0.89	0.52
3	●		●	●			●	0.89	0.51
4		●	●	●	●			0.85	0.50

CHAPTER 4. Psychometric evaluation of an instrument assessing health system readiness for scaling up mass deworming programs: a Mokken analysis

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ABSTRACT

Background: Globally, approximately 1.5 billion people are infected with soil-transmitted helminths (STH), a group of intestinal parasites with disproportional prevalence in school-age children. School-based mass drug administration (MDA) programs effectively control STH-associated morbidities in children. However, recent evidence suggests that STH transmission interruption may be feasible using a community-wide MDA strategy. Transitioning from a control to elimination strategy requires significant health system infrastructure changes. Thus, the *Structural Readiness for Scale-up Survey* was developed to assess health system readiness to scale-out school-based MDA to community-wide MDA as part of the DeWorm3 Project, an ongoing implementation-effectiveness study assessing the feasibility of interrupting STH transmission. In this study, we aimed to confirm the instrument's dimensionality and scalability and evaluate the survey's overall measurement properties.

Methods: In a sample of 343 MDA stakeholders identified during stakeholder mapping exercises, we examined the 36-item *Structural Readiness for Scale-up Survey* measuring five hypothesized readiness constructs: change commitment, change efficacy, capacity, organizational structure, and flexibility. Data were analyzed using Mokken scale analysis, a nonparametric item response theory (IRT) method, using a multi-step analytical approach examining scale unidimensionality, monotonicity of response probabilities, conditional independence, and invariant item difficulty.

Results: A majority of respondents (83%) were community-based MDA implementers with an average of 8.5 years of service in their positions. Two unidimensional Mokken scales were confirmed from 8 of the 36 items – change efficacy and organizational

structure – with moderate (H=0.43) and strong scalability (H=0.52), respectively. Other hypothesized readiness constructs failed to meet analytical assumptions and thus, were not endorsed as Mokken scales.

Conclusion: Mokken scale analysis identified two unidimensional subscales within the adapted *Structural Readiness for Scale-up Survey* that demonstrated acceptable scalability – change efficacy and organizational structure. These findings provide a potential starting point for investigating health system readiness to scale-up mass deworming programs, yet highlight the challenges with defining and measuring readiness of health system stakeholders in low- and middle-income settings.

Background

Globally, approximately 1.5 billion people are infected with soil-transmitted helminths STH), a group of intestinal parasites predominantly found in tropical settings with poor sanitation and hygiene infrastructure (1,2). Chronic or severe STH infections are associated with malnutrition and iron deficiency anemia, as well as cognitive and growth delays in children. Global STH control efforts prioritize large-scale distribution of preventative chemotherapy, known as mass drug administration (MDA). MDA programs primarily focus on school-based deworming of pre-school and school-age children, who are most at risk of experiencing adverse outcomes associated with STH infections (1–3). Although school-based MDA campaigns reach hundreds of millions of children annually (5), they fail to reach older community members who continue to serve as community infection reservoirs (4,6). Recent studies have demonstrated that a community-wide MDA approach that targets community members of all ages may be more effective than school-based MDA in reducing STH prevalence and could potentially interrupt STH transmission (7–9). However, transitioning from a control to elimination strategy requires significant health system infrastructure changes to reach a much broader population of program participants (43). This transition is a type of intervention scaling referred to as "scaling-out", where an effective intervention is delivered to a new population or using a new delivery system that is similar to, but distinct from, previous implementation (44). Prior to scaling-out, it is critical to assess the readiness of implementing organizations to help ensure effective intervention delivery and subsequent health impacts.

Organizational readiness assessments aim to measure the psychological motivation and infrastructural capacity to launch or scale new interventions such as community-wide MDA for STH (45,46). For implementing organizations, readiness is a necessary precursor for effective intervention delivery (47–50). and is an important determinant for assessing implementation success (51). Presently, there are several tools that measure organizational preparedness to launch new public health policies and programs (52,53). One commonly-used tool is the Organizational Readiness for Implementing Change (ORIC), which measures the collective commitment and efficacy of organizations to implement ‘change’ i.e., a new intervention or novel delivery model of an existing program (45,54). Although originally developed and validated in the Unites States, the ORIC has subsequently undergone various cultural adaptations and psychometric evaluations in several high-income contexts (54–56). While the ORIC has predominantly been used in primary health care settings to assess readiness to implement innovative models for various clinical practices, more recently it has been used to assess health system readiness to implement new public health programs in various low-and-middle-income countries (LMICs) (43,57–59). The usage of the ORIC in these contexts is a significant departure from the tool’s original intended purpose of assessing implementation readiness of single organizations, as intervention delivery in LMICs is often reliant on health systems, which are comprised of partnership between multiple organizations, including governments (e.g., Ministry of Health) multilateral, bilateral, non-governmental, and private organizations (52). Thus, it is essential that instruments applied in different contexts than originally developed undergo intentional cross-cultural adaptation followed by rigorous psychometric evaluation to ensure that they are appropriate for the intended audience and accurately reflect the constructs that they aim to measure (60). Inaccurate measurement can lead to spurious results and misguided implementation, causing implementers additional burdens to their already resource-constrained settings (61,62).

As part of an ongoing study assessing the feasibility of interrupting STH transmission using community-wide MDA (18,19) a novel instrument – the *Structural Readiness Survey* – was recently developed to assess health system readiness to transition from school-based to community-wide deworming (43). In addition to assessing the cognitive and behavioral drivers of readiness detailed in the ORIC, the *Structural Readiness Survey* also evaluates the infrastructural characteristics of health systems in LMICs that influence capacity to implement new policies and programs (43). The instrument aims to measure five hypothesized domains of readiness (*Figure 4.1*), including the two "readiness for change" ORIC constructs: change commitment and change efficacy (54) as well as capacity, organizational structure, and flexibility, newly-developed domains of readiness that encapsulate "capacity for change" developed from several change management theories (63–65).

The instrument underwent a rigorous adaptation process and subsequent face validity assessments to maximize its interpretability and applicability for use in LMIC settings (43) and has since been further adapted as the *Structural Readiness for Scale-up Survey* to assess health system readiness to scale-out school-based MDA to community-wide MDA in three LMIC settings in sub-Saharan Africa and South Asia (43). However, the tool has yet to undergo any psychometric evaluation. Thus, in the present study, we utilized a confirmatory Mokken scale analysis, a non-parametric item response theory (IRT) model (66–69), to investigate the dimensional structure and measurement properties of the hypothesized five-domain *Structural Readiness for Scale-up Survey*.

Mokken scaling is a non-parametric item response model (IRT) that aims to evaluate the relationship between individual items and a latent variable (66–69). IRT approaches are growing in popularity in clinical and pub. Unlike parametric IRT, Mokken scaling does not assume normality of the latent variable, thus providing a more flexible analytical approach (70). Although IRT approaches are used less often than classical test theory (CTT) methods such as factor analysis, they offer important advantages. First, by modeling the relationship of individual items to the underlying construct, IRT approaches provide deeper insights into understanding the psychometric performance of survey items (71–74). Second, IRT models have superior score comparability traits, as defined by two important item characteristics – item difficulty, which describes the level at which an item is likely to be endorsed along the underlying construct (i.e., “easier” items have lower difficulty and are expected to be endorsed at lower construct levels), and item discrimination, which describes how well an item can differentiate between respondents at varying levels of the latent construct (66,75). Unlike CTT approaches, where these parameters are limited to the study population, IRT models provide sample-free estimates of these parameters, thus promoting cross-sample comparisons of total scores (71). This feature is especially critical for health systems research that often compares outcomes across heterogeneous contexts. Lastly, IRT approaches are better suited for survey items with categorical responses, as is the case for our instrument (74). Given these valuable analytical properties, we utilized an IRT approach to investigate the measurement properties of the *Structural Readiness for Scale-up Survey* with the aim of developing a psychometrically sound tool to support scale-out STH MDA programs in various settings.

METHODS

Study Setting & Sampling

This study is embedded within the DeWorm3 Project, a hybrid type I cluster-randomized control trial testing the feasibility of interrupting the transmission of STH using community-wide MDA in Benin, India, and Malawi (18,19). Primary trial outcomes compare MDA coverage and STH prevalence between clusters randomized to biannual community-wide MDA or standard-of-care school-based MDA over three years. Secondary implementation science research aims to assess factors that influence effective intervention delivery, including the present readiness research (18,19). Following the last round of MDA delivery, sites conducted stakeholder mapping exercises with policy makers, implementers, and implementation partners to identify all individuals, groups, or organizations who influence or would be influenced by a change in standard of care delivery of MDA for STH from school-based to community-wide MDA and would also influence intervention scale-out (*Table 4.1*). These stakeholder maps provided the sampling frame for this analysis. We used purposive sampling methods to ensure survey respondents were representative of the STH MDA delivery population, recruiting all identified stakeholders to complete the survey with the intent of maximizing our sample size for Mokken analysis (76).

Measures

The instrument of interest in this study, the *Structural Readiness for Scale-up Survey*, is an adapted version of the previously described *Structural Readiness Survey* (10). The survey adaptation process comprised of several modifications, including plain-language revisions to simplify language throughout the instrument for ease of administration across stakeholder groups (e.g., replaced “interrupt STH transmission” with “stop STH transmission” and edited item language to reflect survey intention (e.g., changing from “ready to implement” to “ready to scale”). All revisions were made in collaboration with site-level implementation science teams prior to survey administration. After item adaptations were approved by sites, the survey was then translated into French (Benin) and Tamil (India), while the Malawi site retained the survey in English.

The survey included 36 items using a 5-point Likert scale (using “strongly disagree” to “strongly agree” or “never” to “always”) with varying number of items within each of the five hypothesized readiness domains: change commitment (n=8 items), change efficacy (n=13 items), capacity (n=5 items), organizational structure (n=6 items), and flexibility (n=4 items). In addition to the readiness items, the survey included several items to collect demographic characteristics, including: position, years of service in position, administrative level, age, and gender.

Data Analysis

We calculated descriptive statistics for the demographic characteristics as well as for the items, including mean score and response frequency prior to conducting the Mokken analysis. Mokken scaling entails a multi-step analytical process, as four key assumptions must be met before a set of items are endorsed as a Mokken scale (77–79). First, unidimensionality assumes that all items measure a single latent dimension and is assessed by two coefficients: the item scalability coefficient *Hi*, which calculates the correlation between item *i* and the total score, and the item-pair coefficient H*ij*, which calculates the covariation between the item pair item *i* and item *j* (77–79). Unidimensionality is confirmed if items demonstrate $Hi \geq 0.3$ and $Hij \geq 0$ (77–79). Any item that did not meet these thresholds were iteratively removed, starting with the lowest values, until only those within the appropriate limits remained. The strength of the unidimensional scale was then assessed by the scale coefficient *H*, the weighted sum of all *Hi*, determined by the following thresholds: weak $<0.3H<0.4$, moderate $\leq 0.4H<0.5$, and strong $H \geq 0.5$ (77–79). Second, monotonicity assumes that as the level of θ increases, the probability of a "correct" item response also increases i.e., the higher a respondent's readiness increases, the more likely they are to select a higher response option denoting greater readiness for that item on the given Likert scale. We assessed monotonicity by calculating each item's *crit* statistic, which is the frequency of assumption violations, using the threshold *crit*$\leq$40 indicating no serious violations (77). Third, local independence assumes that the response to an item is independent of the response to any other item, given θ (77–79) and is assessed using a conditional association procedure that flags items with relatively large residual dependence, as indicated by high values of the dependence index $W2$ (79). Lastly, invariant item ordering (IIO) assumes that the order of items based on their difficulty estimate is constant along the θ continuum for all respondents (68,69,79). A scale with stronger IIO lends more meaning to the interpretation and comparison of inter-respondent total scores e.g., if comparing two respondents and one has a higher score, it is likely that the higher-scorer has answered more difficult items and thus exhibits a higher level of θ (80).

We first assessed whether the IIO property holds for each item set using the *manifest IIO* function to identify and sequentially remove items that violate the assumption before calculating the scale coefficient H^T, which estimates item ordering accuracy, designating weak, moderate, and strong item ordering at the following thresholds:

$0.30<0.40$, $0.40\leq0.50$, and >0.50, respectively (81). To maximize the sample size necessary for Mokken analyses (76) we pooled data from the three sites, accounting for site-level clustering with a multi-level analytical approach (82). At each stage of the analysis, any item that violated the specific assumption was removed in a backwards stepwise function to improve final scale fit (77,78), retaining scales with at least three endorsed items (83). All analyses were conducted in RStudio v2021.09.2 using the *mokken* package (84).

RESULTS

Descriptive Statistics

In total, 343 individuals completed the survey, with India having the highest number of respondents (n=166) followed by Malawi (n=95) and Benin (n=82). A significant proportion (83%) of all respondents (n=286) were at the community level with an average of 8.5 years of service in their positions. A majority of respondents were female (65%) with a mean age of 38 years. Item response frequencies and means are presented in *Table 4.2*. Across all subscales, most items had mean scores $\geq$ 4.0. Several items in the change efficacy subscale had lower mean scores below 3.0, specifically those assessing sufficiency of funding to implement community-wide MDA (items 11 and 13) and need for additional implementer training (item 14), as well as one item in the flexibility subscale assessing comfort in sharing innovative ideas between colleagues (item 27). Response frequencies demonstrated that for most items, a majority of respondents only answered at the highest categories.

Mokken Analysis

None of the eight items in the hypothesized change commitment subscale initially met the unidimensionality (*Hi* and *Hij* coefficient) thresholds. Five items (items 3-7) were iteratively removed, leaving three items (items 1, 2, and 8) for further analysis. These items met the unidimensionality assumption (all $Hi \geq 0.3$ and $Hij > 0$) with strong scalability ($H=0.51$). Subsequent assessment for the monotonicity assumption revealed no significant violations, as all three items exhibited $crit \leq 40$. Additionally, none of the items were flagged for having high values of the dependence index $W2$, thus meeting the local dependence assumption. Finally, IIO failed for the three items, as they demonstrated weak item ordering ($H^T=0.13$).

Similar to the change commitment analysis, none of the 13 items in the hypothesized change efficacy subscale initially met the *Hi* and *Hij* thresholds. During the iterative unidimensionality analysis, nine items (items 9, 12, 14, 15, 17-21) were removed. The remaining four items (items 10, 11, 13, and 16) met the assumptions for unidimensionality (all $Hi \geq 0.3$ and $Hij > 0$) with moderate scalability ($H=0.43$). Assessments for monotonicity and local dependence revealed no significant violations for these items and subsequent IIO calculations revealed strong item ordering ($H^T=0.65$).

Although all of the five items in the hypothesized capacity subscale met the *Hij* thresholds, they all exhibited $Hi<0.3$. Despite the iterative removal of items with the lowest *Hi* values, none of the items were able achieve the necessary threshold of $Hi \geq 0.3$ and thus, were not suitable for further analysis as they could not be confirmed as a unidimensional scale.

Two of the six items (items 35 and 36) in the hypothesized organizational structure scale were removed, as they did not meet the *Hi* thresholds. The remaining four items

(items 31-34) met the unidimensionality (*H*=0.52), monotonicity, local dependence and IIO assumptions (H^T=0.64).

For the hypothesized flexibility subscale, none of the four items met the *Hi* and *Hij* coefficient thresholds. After iteratively removing two items (items 27 and 28), the two remaining items (items 28 and 29) exhibited unidimensionality with moderate scalability (*H*=0.41); however, the subscale did not have a sufficient number of items suitable for further analysis (n<3).

The initial scalability coefficient *Hi* for all items and their assumption violations are presented in *Table 4.2*. Final scalability coefficients *Hi* and *H* after the iterative Mokken analysis are presented in *Table 4.3*.

DISCUSSION

Our Mokken scale analysis identified two unidimensional subscales within the adapted *Structural Readiness for Scale-up Survey* including the domains of change efficacy and organizational structure. These findings do not provide a final endorsed scale structure; however they do provide a potential starting point for investigating health system readiness to scale-up mass deworming programs. Although we expected that all five hypothesized domains of readiness would perform well under the Mokken analysis, three domains – change commitment, capacity and flexibility were not endorsed as subscales of readiness as they failed to meet the required Mokken assumptions. Across these three hypothesized subscales, 83% (19 items) failed to meet the unidimensionality assumption. Inherently, unidimensionality implies that a single construct dimension is being measured with a set of items. A lack of unidimensionality suggests that items are not functioning as intended, as they are measuring different constructs and thus, the survey's total score provides minimal information about the latent variable it aims to represent (85). Items that violate this assumption are recommended to return to the item construction phase, undergoing additional revisions to their language, followed by subsequent qualitative content validation approaches with context experts to evaluate their content relevance, representativeness, and technical quality as well as target respondent populations to evaluate whether items are representative of actual respondent experiences (86).

Within the ORIC, change commitment encompasses motivation, which is a relevant indicator for readiness of LMIC health systems, given the simultaneous delivery of various health programs that may impact program prioritization and implementer determination (52). Surprisingly, the three items in the change commitment subscale that met the unidimensionality, monotonicity and local dependence assumptions did not demonstrate sufficient item ordering, thus eliminating the entire subscale from Mokken endorsement. IIO is a critical scale property, especially for hierarchical instruments that rank items by difficulty in order to measure progressive levels of a latent variable (i.e., readiness); however, it is unclear whether IIO is a realistic property for a majority of scales used in health settings, particularly those measuring more subjective constructs such as attitude or personality (87). Furthermore, in the IRT literature, IIO is often considered an elusive characteristic for IRT analyses with polytomous items, despite recent developments in IIO analytical procedures (81,87–89). In our analysis, it is plausible that the removal of five items that were situated between those that met the three Mokken assumptions may have impacted the precision of the subscale's item ordering; however, their removal was necessary as they did not support scale unidimensionality. While item ordering may be a challenging characteristic for survey developers, it is critical that researchers designing instruments consider its importance during item development stage (79,80).

A key difference between our instrument and the ORIC is that the ORIC items uses the collective "we" to ensure items are group-referenced and signal collective, rather than individual or self-referenced, readiness (54). Our adaptation from using group- to self-referenced language was due to qualitative feedback from our initial readiness validation study, where health workers noted a discomfort in reporting upon the collective readiness of their peers due to the hierarchical nature of LMIC health systems (43). It is plausible that continually switching from "I" to "we" language across the items may have impacted item ordering; thus, it may be necessary to revise items and consistently group items using self-referenced language followed by those using group-referenced language. Future work should develop practical item development techniques to maximize IIO that would be invaluable for survey designers and evaluators.

Collectively, these findings signify the challenge of assessing motivation within health systems. It is plausible that distinct organizations that have more rigid team structures may have a clearer understanding of the collective “we”, as compared to multi-organizational health systems. Findings from recent ORIC validation studies conducted in LMICs hypothesized that implementers within these settings have low agency in decision-making regarding program implementation and thus, further demonstrating the difficulty of measuring collective motivation in these settings (58). Generally, there is a dearth of literature investigating collective motivation as a construct of implementation readiness in LMIC health systems; therefore, further research within these settings is warranted to understand how to improve the definition and measurement of this construct, which remains an important indicator for implementation success.

Although the items within our hypothesized capacity and flexibility domains were intended to assess important readiness capacity elements, we were unable to sufficiently analyze their performance as they appeared to have insufficient inter-item correlation, which suggest they are not measuring a common concept. These findings suggest that these items have poor measurement performance for their intended domains. Thus, we recommend further qualitative evaluations with key stakeholders to further refine and assess the items’ cognitive functioning prior to any additional psychometric or descriptive evaluations (86).

During the item development stage of the *Structural Readiness for Scale-up Survey*, extra care was taken to ensure that items went through a rigorous cultural adaptation and face validity process; however, approximately 70% of items were not endorsed within the Mokken analysis. Although other studies that aimed to validate the ORIC in LMICs were able to replicate the findings of the original ORIC validation study, it is important to note that these studies used factor analysis, and thus employed a different evaluation approach than this Mokken analysis. Future ORIC validation work should re-analyze the surveys assessed with factor analysis using IRT techniques to compare findings from the two methodological approaches.

The alterative instrument structure confirmed by our Mokken analysis aligns with findings from a recent global health literature review which concluded that publicly available tools assessing organizational readiness for implementation and scale prioritize assessment of capacity over motivation (19). Although the authors were not able to find data regarding whether any of the tools underwent validity assessments, they describe the key elements of readiness commonly captured across the 30 evaluated tools, including organizational management/governance and organizational attributes (52). which align with several of the endorsed items within our instrument's change efficacy and organizational structure subscales. For example, the authors designate the organizational attribute of financial resources as a key capacity element (52), which aligns with two of the endorsed items in the change efficacy subscale that aim to define the sufficiency of financial resources for community-wide MDA implementation. Additionally, in our organizational structure subscale, all four endorsed items aim to assess health system governance and management structure from national to local levels. Although the items within our hypothesized ‘capacity’ and ‘flexibility’ domains were intended to assess other identified capacity elements highlighted in the review, our inability to sufficiently analyze their measurement performance does not negate their status as critical elements of health system readiness (52).

Overall, our findings highlight the difficulty of measuring readiness in complex health systems. We offer three key recommendations for future readiness validation work. Namely, organizational psychologists, health systems researchers, and global health implementation scientists should collaborate and develop new theories that accurately assess how readiness within health systems differs from that of organizations. Subsequently, psychometricians with qualitative and quantitative expertise can support these initial efforts during item development processes, utilizing cultural adaptation techniques and qualitative content validation approaches to further refine and approve survey items interpretability and functionality. Lastly, further validation studies – using both CCT and IRT approaches, should be conducted concurrently to continue to improve measurement properties of adapted tools.

Strengths & Limitations

The present study demonstrates a number of strengths. To our knowledge, this is the first study using IRT methods to validate a tool assessing LMIC health system readiness to scale-up an intervention. We applied Mokken analysis, using a pragmatic approach especially developed for applied health researchers (77,78). Our analysis used respondent data from nearly 350 health system stakeholders involved in the delivery of MDA programs who accurately represent the network of STH policymakers and implementers relevant for understanding the dynamics of transitioning from school-based to community-wide MDA.

We also recognize some study limitations. Data for the analysis were pooled across three heterogenous contexts to ensure sufficient sample size for Mokken analysis. Given our pooled analysis, we aimed to ensure measurement invariance by accounting for inter-site clustering using a multi-level modelling approach. However, the respondent population had minimal heterogeneity, as nearly 90% were community drug distributors; thus, we suspect marginal bias in our analysis. Additionally, given our limited sample size within each site, we were unable to comparatively assess item measurement properties by site. Despite these limitations, we present Mokken scale analysis as a valuable, rigorous method for exploring the measurement properties of existing tools used in global health program delivery.

CONCLUSION

Using a rigorous IRT-based analysis, our findings identified two unidimensional subscales within the *Structural Readiness for Scale-up Survey*, specifically change efficacy and organizational structure, that may be a starting point for assessing health system readiness to scale-up mass deworming programs. Future efforts should continue to clarify important constructs, refine survey items, and investigate item properties using qualitative content validation methodologies to develop an instrument that more accurately represents health system readiness to scale community-MDA for STH. The current research supports the application of IRT methods to rigorously evaluate the measurement properties of implementation science tools, especially those used in LMIC settings. These assessments continue to be critical for health systems that are preparing to launch new programs, as they help investigate the perceived skills, resources and infrastructure necessary for effective intervention delivery, especially at scale.

TABLES & FIGURES

Table 4.4: Description of readiness survey respondents

Administrative Level	Description & Role	Example Stakeholders
National and Regional	*Policymakers & program leaders:* Government officials and external implementation partners who set national STH control guidelines and provide funding or technical support (e.g., donate deworming medications)	• MOH health secretaries • NTD program directors • Non-governmental organizations (NGOs) • World Health Organization (WHO) representatives • Pharmaceutical companies
District & sub-Regional	*Mid-level managers & supervisors:* Governmental officials who manage MDA planning and supervise MDA delivery (e.g., facilitate training, manage drug supply chain, compile coverage data, monitor for adverse events)	• District health officers • Regional NTD managers & coordinators • Regional health facility workers (e.g., nurses, pharmacists) • Health information officers
Community	*Implementers:* Governmental officials and non-governmental personnel who supervise MDA delivery teams; sensitize communities; administer deworming medications; and record coverage data	• Community-based health facility workers • Community drug distributors (CDDs) and community health workers • Community-based organizations (e.g., youth or women's groups) • Community leaders

Table 4.5: Item response frequency, mean scores, & Mokken assumption violations

Construct	Item No.	Item Language	Mean score	Response Frequency (%) for Likert Response Categories					Mokken Criteria Met			
				1	2	3	4	5	A	B	C	D
	1	I believe that [COUNTRY] needs to stop the transmission of STH (intestinal worms).	4.53	7.6	0.3	2.6	10.2	79.3	✓	✓	✓	x
	2	My colleagues believe that [COUNTRY] needs to stop transmission of STH (intestinal worms).	4.59	4.7	0.3	2.6	16.3	76.1	✓	✓	✓	x
	3	I believe that community-wide MDA can stop the transmission of STH (intestinal worms) in [COUNTRY].	4.75	0.6	2.0	0.9	14.6	81.9	x	x	x	x
	4	My colleagues believe that community-wide MDA can stop transmission of STH (intestinal worms) in [COUNTRY].	4.65	0.6	2.0	3.8	19.2	74.3	x	x	x	x
Change Commitment	5	I am supportive of scaling up community-wide MDA for STH (intestinal worms).	4.94	0.3	0.3	0.3	3.2	95.9	x	x	x	x
	6	My colleagues support the scaling up of community-wide MDA for STH (intestinal worms).	4.74	0.9	0.3	3.5	14.3	81.0	x	x	x	x
	7	In my experience, community drug distributors are given sufficient incentives for administering community-wide MDA.	3.53	22.7	6.7	5.0	25.7	39.9	x	x	x	x
	8	Ministry of Education personnel that I work with on school or child interventions will support transitioning from school-based to community-wide deworming.	4.29	9.0	2.3	5.8	16.6	66.2	✓	✓	✓	x
	9	I know of at least one community health programme that could be used to deliver community-wide MDA for STH at scale.	4.31	6.1	6.1	3.5	19.5	64.7	x	x	x	x
Change Efficacy	10**	How often are community members resistant to community-wide MDA programs?	3.90	1.7	5.8	20.4	44.6	27.4	✓	✓	✓	✓
	11*	There is often not enough funding to implement community-based programmes at scale.	2.70	33.2	26.2	5.0	8.5	27.1	✓	✓	✓	✓
	12**	There have been difficulties with having enough funding at the Commune level to implement	3.79	13.7	4.4	17.5	17.8	46.6	x	x	x	x

Construct	Item No.	Item Language	Mean score	Response Frequency (%) for Likert Response Categories					Mokken Criteria Met			
				1	2	3	4	5	A	B	C	D
		community-based programmes in [COUNTRY].										
	13*	I am worried about whether [COUNTRY] has sufficient future funding for scaling community-wide MDA programmes in [COUNTRY].	2.73	28.6	30.3	4.1	13.1	23.9	✓	✓	✓	✓
	14*	My colleagues will need additional training to effectively deliver community-wide MDA for STH at scale.	1.53	73.8	15.7	1.2	2.0	7.3	x	x	x	x
	15*	It will be challenging to recruit enough supervisors of community drug distributors needed in [COUNTRY] to deliver community-wide MDA for STH at scale.	3.37	17.5	23.9	3.5	14.3	40.8	x	x	x	x
	16	Supervisors of community drug distributors (CDDs) provide sufficient support to CDDs on how to deliver community-wide MDA.	4.71	2.6	1.5	2.3	9.3	84.3	✓	✓	✓	✓
	17	[COUNTRY] can develop high-quality IEC materials for community-wide MDA programmes.	4.64	3.5	1.7	1.5	13.4	79.9	x	x	x	x
	18	[COUNTRY] can develop high quality training materials for community-wide MDA programmes.	4.53	4.7	2.3	2.0	17.5	73.5	x	x	x	x
	19	There is a collaborative network of external stakeholders (NGOs or technical/financial partners) that would support scaling up community-wide MDA for STH in [COUNTRY].	4.55	1.7	2.6	3.2	24.2	68.2	x	x	x	x
	20	There is an effective programme in [COUNTRY] for training community drug distributors on how to deliver community-wide MDA.	4.42	6.1	4.4	1.7	17.2	70.6	x	x	x	x
	21	My colleagues have experience delivering other community-wide MDA programmes (ex. lymphatic filariasis) with high coverage.	4.53	3.5	1.7	2.0	23.9	68.8	x	x	x	x
Capacity	22	Community drug distributors currently have the skills to effectively deliver community-wide MDA for STH at scale.	4.60	4.1	2.9	1.5	12	79.6	x	x	x	x

Construct	Item No.	Item Language	Mean score	Response Frequency (%) for Likert Response Categories					Mokken Criteria Met			
				1	2	3	4	5	A	B	C	D
	23*	It will be challenging to recruit enough community drug distributors needed in [COUNTRY] to deliver community-wide MDA for STH at scale.	3.31	20.4	23.6	3.2	10.5	42.3	x	x	x	x
	24**	I have observed delays in the arrival of drugs for MDA programmes due to supply chain problems	4.62	1.5	1.5	9.0	9.9	78.1	x	x	x	x
	25	[COUNTRY]'s National Master Plan for Neglected Tropical Diseases is currently being implemented as intended.	4.58	1.5	3.2	1.7	22.7	70.8	x	x	x	x
	26**	How often are treatment data incorrectly recorded during delivery of community-wide MDA programmes?	3.93	9.9	5.0	9.9	32.9	42.3	x	x	x	x
Flexibility	27	It is challenging to present new ideas to my supervisor.	2.24	55.4	10.8	3.2	15.2	15.5	x	x	x	x
	28	MOH leadership at the National level generally accept new ideas.	4.11	9.3	3.8	5.2	29.7	51.9	x	x	x	x
	29	My supervisor (the person I report to) usually accepts feedback on how to improve the delivery of interventions.	4.61	2.9	2.9	1.5	15.7	77.0	✓	x	x	x
	30	My subordinates (people who report to me) feel comfortable providing feedback on how to improve the delivery of interventions.	4.49	2.9	2.9	5.2	20.1	68.8	✓	x	x	x
Organizational Structure	31	Neglected Tropical Disease programme leadership at the National level is effectively implementing community-wide MDA programmes in [COUNTRY].	4.38	5.8	3.5	2.6	23.3	64.7	✓	✓	✓	✓
	32	Neglected Tropical Disease (NTD) programme leadership at the Department level is effectively implementing NTD programmes in [COUNTRY].	4.45	3.5	2.9	3.8	24.8	65.0	✓	✓	✓	✓
	33	Neglected Tropical Disease (NTD) programme leadership at the Commune level is effectively implementing NTD programmes in [COUNTRY].	4.51	4.4	1.7	2.6	21	70.3	✓	✓	✓	✓

Construct	Item No.	Item Language	Mean score	Response Frequency (%) for Likert Response Categories					Mokken Criteria Met			
				1	2	3	4	5	A	B	C	D
	34*	There have been difficulties distributing deworming medicines to local levels.	3.13	28.0	14.0	9.9	12.8	35.3	✓	✓	✓	✓
	35	[COUNTRY]'s national policy for Neglected Tropical Diseases supports community-wide mass drug administration (MDA).	4.69	1.2	1.5	3.5	15.5	78.4	x	x	x	x
	36	The current National Master Plan for Neglected Tropical Diseases provides enough guidance for delivering community-wide MDA programmes (e.g., deworming or malaria).	4.69	0.3	1.5	2.0	21.0	75.2	x	x	x	x

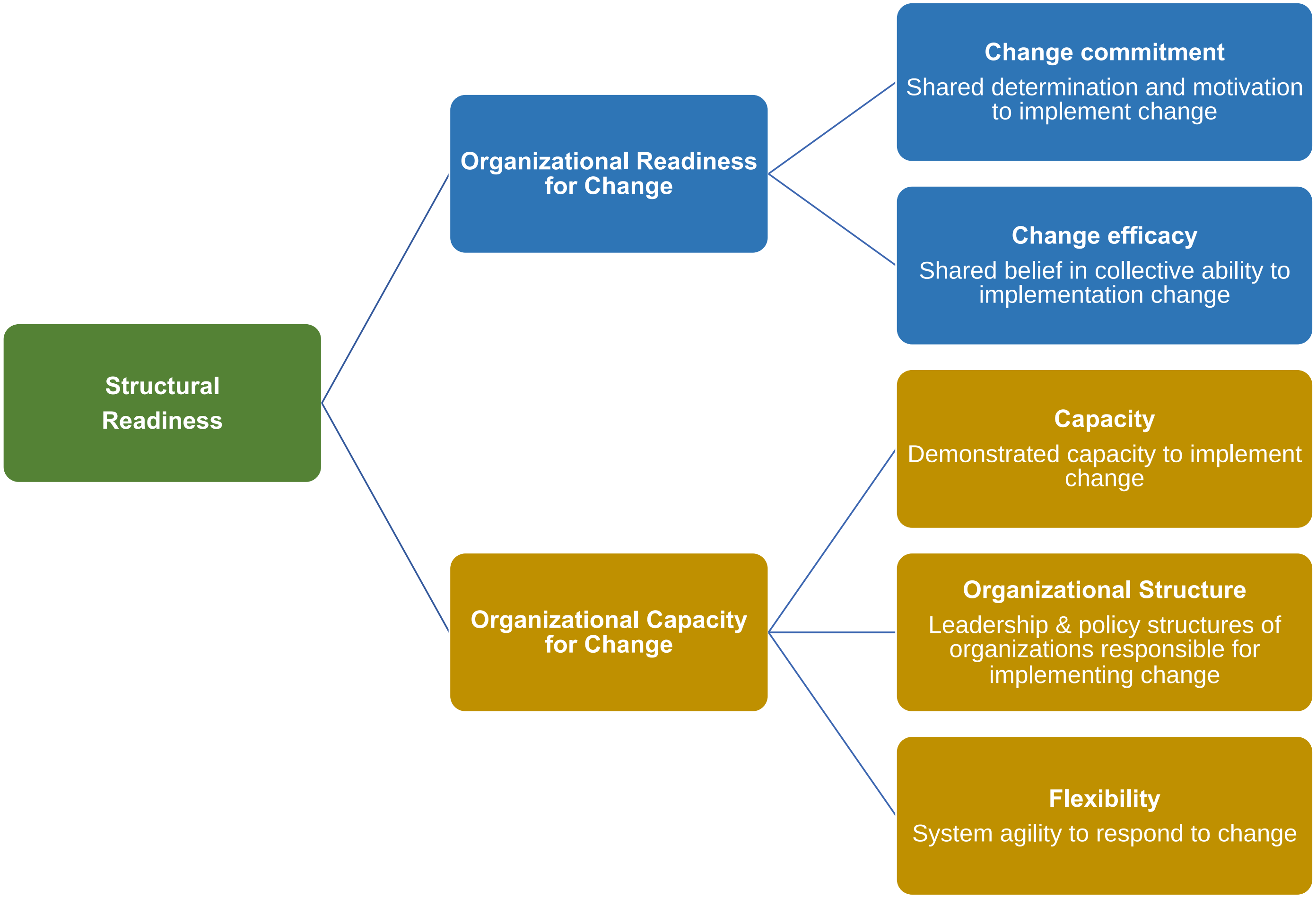
NOTE: Most items used 5-point Likert scale with response options 1 Disagree - 5 Agree. Items with (*) indicate reverse response option: 1 Agree - 5 Disagree. Items with (**) indicate reverse response option: 1 Always - 5 Never

Table Key: Mokken criteria: A – Unidimensionality B – Monotonicity C – Local Dependence D – Invariant Item Ordering
(✓) indicates the criteria was met and (x) indicates the criteria was not met

Table 4.6: Final scalability coefficients after multi-step Mokken analysis

Scale	Item no.	Item Language	*Hi*	*H*
Change Commitment	1	I believe that [COUNTRY] needs to stop the transmission of STH (intestinal worms).	0.50	0.51
	2	My colleagues believe that [COUNTRY] needs to stop transmission of STH (intestinal worms).	0.59	
	8	Ministry of Education personnel that I work with on school or child interventions will support transitioning from school-based to community-wide deworming.	0.45	
Change Efficacy	10**	How often are community members resistant to community-wide MDA programs?	0.49	0.43
	11*	There is often not enough funding to implement community-based programmes at scale.	0.47	
	13*	I am worried about whether [COUNTRY] has sufficient future funding for scaling community-wide MDA programmes in [COUNTRY].	0.30	
	16	Supervisors of community drug distributors (CDDs) provide sufficient support to CDDs on how to deliver community-wide MDA.	0.40	
Capacity	*None of the items met the Hi threshold after iterative analysis*		*N/A*	*N/A*
Flexibility	29	My supervisor (the person I report to) usually accepts feedback on how to improve the delivery of interventions.	0.41	0.41
	30	My subordinates (people who report to me) feel comfortable providing feedback on how to improve the delivery of interventions.	0.41	
Organizational Structure	31	Neglected Tropical Disease programme leadership at the National level is effectively implementing community-wide MDA programmes in [COUNTRY].	0.35	0.52
	32	Neglected Tropical Disease (NTD) programme leadership at the Department level is effectively implementing NTD programmes in [COUNTRY].	0.55	
	33	Neglected Tropical Disease (NTD) programme leadership at the Commune level is effectively implementing NTD programmes in [COUNTRY].	0.63	
	34*	There have been difficulties distributing deworming medicines to local levels.	0.56	

Figure 4.10: *Structural Readiness Survey* domains



CHAPTER 5. CONCLUSION

This dissertation highlights the usefulness and importance of utilizing implementation science approaches to investigate how various implementation factors influence the scale-up of community-based interventions such as MDA for STH.

From our stakeholder analysis, we found that community-wide MDA will require an extensive network of stakeholders who, based on their network position, can be leveraged to serve as key connectors, brokers of resources and intervention champions to promote effective intervention delivery. Outcomes from our psychometric evaluation provide a basis for investigating health system readiness for intervention scale-up, yet highlight the challenges of measuring readiness in LMIC contexts using existing tools and suggest that further development of such tools for use in these settings should be prioritized. Our cross-case analysis of implementation strategies used during MDA identified that efficient duration of MDA delivery (within 10 days) was a highly influential implementation activity for achieving high coverage of community-wide MDA when co-implemented with other impactful elements, such as a conducive implementation context, early arrival of deworming drugs, and a flexible community sensitization strategy. Taken together, these findings provide a robust analysis of the deworming implementation landscape, providing critical evidence for an STH climate primed to transition to community-wide MDA.

We provide novel evidence regarding the dynamics that impact LMIC health systems and provide opportunities for future research to expand upon our findings to enhance intervention delivery in these settings. Additionally, we make several important contributions to global health implementation science by promoting methodological approaches suitable for evaluating scale-up processes.

Following this dissertation, I would like to work with global STH policymakers and implementers to explore various options for transitioning to community-wide MDA, specifically synthesizing and appraising the epidemiology and implementation evidence produced by DeWorm3 and other ongoing STH interruption studies. Furthermore, I intend to conduct additional qualitative research to understand how to better define and measure ‘health system readiness’ for intervention scale-up and use those findings to further refine our structural readiness instrument. These proposed objectives are especially relevant for STH-endemic countries, given the potential shift in disease priority from control to transmission interruption that is being driven by global policymaking bodies and their technical partners.

Given the evolving global agenda for STH, our dissertation findings will support effective delivery of community-wide MDA and support the elimination of STH as a public health problem, reducing the global STH burden for billions of people within vulnerable communities.

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APPENDIX

Appendix 1: DeWorm3 Routine process mapping worksheet

deworm3

Routine Workflow Tracking Worksheet: Community-Wide MDA

Country:______________ **MDA Round:** ____ **Cluster ID** _________ **Submission Date**: ______________

Instructions: Please complete this form for every cluster that delivers community-wide MDA (20 clusters).

Activity		**Completion Data**	
Drug Supply Chain			
Date albendazole arrived in cluster		____- ____ -______ *DD-MM-YYYY*	
First day that community drug distributors (CDDs) collected albendazole and total number of tablets collected		____- ____ -______ *DD-MM-YYYY*	______ *tablets*
Number of days of albendazole collection by CDDs		___________ *days*	
Number of tablets returned		__________ *tablets*	
CDD Training			
Number of CDDs trained		__________/ __________ *(No. CDDs trained/Total no. of CDDs)*	
Date of CDD training *If training occurred on more than one day, write all dates*		____- ____ -______ *DD-MM-YYYY* ____- ____ -______ *DD-MM-YYYY* ____- ____ -______ *DD-MM-YYYY*	____- ____ -______ *DD-MM-YYYY* ____- ____ -______ *DD-MM-YYYY* ____- ____ -______ *DD-MM-YYYY*
Community Sensitization			
For each sensitization activity: 1. Indicate which activities occurred in the cluster prior to this round of MDA (tick all that apply) 2. Indicate the quantity of the sensitization activity 3. Indicate the date when the activity started in the cluster	☐ Community meetings	___________ *No. of meetings*	____- ____ -______ *DD-MM-YYYY*
	☐ Public dialogue event *(e.g. drama or town crier)*	___________ *No. of events*	____- ____ -______ *DD-MM-YYYY*
	☐ Distribution of printed IEC materials *(e.g. pamphlets or posters)*	___________ *No. distributed*	____- ____ -______ *DD-MM-YYYY*
	☐ Door-to-door sensitization	___________ *No. of houses visited*	____- ____ -______ *DD-MM-YYYY*
	☐ Mass media (circle one): Radio TV Newspaper Other	___________ *No. of media spots*	____- ____ -______ *DD-MM-YYYY*
	☐ Other (please specify): ___________________________	___________ *Specify no.*	____- ____ -______ *DD-MM-YYYY*
MDA Delivery			
Dates of first and last days of MDA		____- ____ -_____TO ____- ____ -_____ *DD-MM-YYYY DD-MM-YYYY*	
Dates of first and last days of MDA mop-up		____- ____ -_____TO ____- ____ -_____ *DD-MM-YYYY DD-MM-YYYY*	
Monitoring & Evaluation			
Please note any community activity that took place in the cluster <u>one month</u> prior to first day of MDA that may have affected treatment coverage. Include the date of the first and last days of the activity (DD-MM-YYYY). *(If you need more space, please write on the back of this page)*			

Please write your name on this worksheet to confirm accuracy of data:

Implementation Science Supervisor: ______________________________

Cluster Lead ________________________________

VITA

Marie-Claire Gwayi-Chore is a global health specialist and implementation scientist with a decade of experience implementing mass drug administration programs for soil-transmitted helminths and other neglected tropical diseases. She holds a Master of Health Science from the Johns Hopkins Bloomberg School of Public Health as well as a Master of Science from The London School of Hygiene & Tropical Medicine.

This dissertation is a product of five years of collaboration with implementing partners in the Benin, India, and Malawi DeWorm3 trial sites, as well as study coordination partners in United Kingdom and United States. Marie-Claire supported the development of all implementation science research protocols and instruments and co-led training activities of site implementation science teams. For all dissertation aims, she led the data cleaning, data analysis, interpretation, and manuscript writing.

She is passionate about promoting diversity, equity and inclusion (DEI), antiracism, and anticolonialism within global health education, research, practice & mentorship and is an emerging expert bringing an implementation science lens to the practice of decolonizing global health.