2022

Subnational Data to Inform Measles Vaccination Campaigns in Children Under 5 Years in Tanzania

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MPH, Tulane School of Public Health and Tropical Medicine, 1994

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Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Public Health

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Abstract

Measles is one of the most contagious diseases ever known, infecting as high as 90% of susceptible persons encountering the virus, and globally is one of the main causes of disability and death among children. Measles remains an avoidable disease that can be prevented by receiving a measles containing vaccine using supplemental immunization activities (SIA) implementation strategies. Because national-level measles data may not reflect geographic differences, program capacity, or localized outbreaks, SIAs prompted by and geared toward the subnational level may have a greater impact than a nationwide SIA. The purpose of this retrospective cross-sectional study was to examine the patterns of association between using subnational data in children 12–59 months compared to using national-level data as a basis for SIA timing and implementation in Tanzania. Diffusion of innovation and community mobilization theories were used to guide the study. Tanzania Demographic and Health Survey, measles incidence, and SIA data were analyzed for the period 2010–2016. Results revealed SIAs should be implemented sooner, in a specific geographical location, or with strategic changes to the routine immunization program. Results may be used to develop more strategic and cost-effective measles-elimination efforts by countries willing to use the subnational-level approach. Changing the strategy of planning and implementing SIAs based on subnational-level data would be a paradigm shift from the current national-level approach.

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Dedication

This doctoral study is dedicated to my family, friends, and colleagues who motivated and supported me throughout this process. I was inspired by their ongoing presence, quiet words of wisdom, and continued encouragement along the way even when they had to pick up the slack or suffer my absence while I focused on the work necessary to complete my degree.

Acknowledgments

I would like to acknowledge my sons, Ethan and Colin, who started this process with me. I thank them for suffering snack or take-out dinners more often than they were initially used to, and for their exceptional patience when I did not always have time do fun things. Helping them with their schoolwork and ruminating on the most serious of things, or sometimes the most ridiculous of things, motivated me to take that major step and go back to school. Laughing at them thinking they would have to call me "Dr. Mom" was a surprising, motivating notion.

I would also like to acknowledge my chair, Dr. Angela Prehn, who guided, corrected, listened, and cheered me on throughout the prospectus development, change in subject matter, proposal stage, pause in attendance, and finally the study completion. She always provided gentle words of encouragement during the many stages of doctoral work, which so inconveniently sometimes coincided with travel for work, family demands, or "quarantini" time. I could always count on her to embolden me to make those next edits. Onward!

I must also acknowledge my previous supervisor, Dr. Robert Linkins, who helped me to decide on my final subject matter and challenged me to find a way to advance the compelling work that we do in global immunization. Thank you for suggesting, as well as approving, days off so I could focus on my analysis.

I would like to acknowledge my mother, Bettye, and my father, Clifford A. "As-in-Always" Wright. My mother would sometimes try to talk me out of whatever took me away from the easy path or lead to international journeys, though always encouraged me

to help others and supported what I ultimately chose. My father compelled me to act boldly and do what I wanted. Unfortunately, he passed before I completed the doctoral study. Your presence is still felt, Cliff.

Finally, only because of God's grace, mercy and favor was I able to complete this. Merci.

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Section 1: Foundation of the Study and Literature Review

Measles is one of the most contagious diseases ever known, infecting as high as 90% of susceptible persons encountering the virus (Centers for Disease Control and Prevention [CDC], 2015). Globally, measles is one of the main causes of disability and death among children (The Measles & Rubella Initiative, 2015). Measles undermines the immune system and allows the infected person to be more susceptible to secondary health problems such as diarrhea, blindness, pneumonia, and encephalitis (The Measles & Rubella Initiative, 2015). The risk of death and other complications from measles is highest among adults and young children (CDC, 2015). The most common measles-related deaths among children are due to pneumonia, and among adults are due to acute encephalitis (CDC, 2015). Measles, however, remains an avoidable disease that can be prevented by receiving a measles containing vaccine (MCV) such as measles; measles and rubella; or measles, mumps, and rubella. Data showed that for the period of 2000–2014, measles deaths decreased by approximately 79%, down to 114,900 from 546,800 (Perry et al., 2015). The World Health Organization (WHO) model indicated that approximately 17.1 million deaths were averted during this period because of administering the measles vaccine (Perry et al., 2015). However, in the past few years, measles cases saw a resurgence globally through 2019 but then decreased slightly in 2020 due to the COVID-19 pandemic (Dixon, 2021). During the period 2000–2020, the most recent period for which the measles elimination goal was measured, global MCV1 coverage went from 72% to 86% in 2019, but declined to 84% in 2020 due to the COVID-19 pandemic (Dixon, 2021). Reported measles incidence went from 145 to 22

cases per 1 million during this period, averting an estimated 31.7 million measles deaths (Dixon, 2021).

Since 2008, most WHO member states have utilized a two-doses strategy to deliver the MCV: a two-dose schedule through the routine immunization (RI) program, a 1-dose schedule through the RI program plus regular supplemental immunization activities (SIAs), or a onetime catch-up campaign at a designated time. Financial support from Gavi (2017), a global vaccine alliance organization, is assisting some low- and middle-income countries in the global measles elimination endeavor by introducing the second dose of MCV into their RI program rather than the second dose being provided through an SIA (Subaiya et al., 2015).

SIAs are recognized as a strategy to reach never-vaccinated children who have never had measles disease but are also a way to provide the second dose for children in cases of primary vaccine failure when individuals who have received a second dose do not experience serological conversion after vaccination (Pannuti et al., 2004; WHO Regional Office for Africa, 2010). During an SIA, all children in the designated geographic area and target age group receive a dose of the measles vaccine, regardless of immunization history. The second dose of the measles vaccine that is provided through an SIA decreases the proportion of susceptible individuals in that population and prevents measles (Hayford et al., 2013; WHO Regional Office for Africa, 2010). To determine when an SIA should be implemented, countries are encouraged to monitor the accumulation of vulnerable children and base SIA intervals on when the number of susceptibles (those vulnerable to the disease) comes close to the magnitude of one birth

cohort (WHO, 2016a). Susceptibles in this instance are children missed by the RI program or who may be outside of the age range of the RI program, usually over 2 years of age (WHO, 2016a). Accumulation usually takes between 2 and 5 years to occur, and the immunization coverage rate that is used to determine SIA timing is based on the national-level, aggregate figures for this population (WHO, 2016a).

In addition to monitoring susceptible population, countries are expected to monitor vaccination coverage by district or equivalent administrative unit and by the national-level figures (CDC, 2010). Routine vaccination coverage levels signify the current performance of the immunization program and immunity of the population (CDC, 2010). Coverage is often based on the percentage of children receiving a particular number of recommended doses of a particular vaccine during their first year (CDC, 2010). Mass vaccination campaigns or SIAs, in contrast, do not record the administered vaccine doses, and as a result coverage must be estimated by means of techniques such as household surveys, including the Demographic and Health Surveys (DHS) or Multiple Indicator Cluster Survey (CDC, 2010; Hayford et al., 2013). Vaccination coverage generated through household surveys can be based on (a) vaccination cards retained in the household, (b) maternal report, or (c) a combination of the vaccination card plus history, which refers to data from the vaccination card or, if unavailable, by maternal input (Hayford et al., 2013). Administrative vaccination coverage is computed by dividing vaccine doses dispensed to the target group by the total projected target population (CDC, 2010). Administrative data are then combined or aggregated at the national level and used as official national estimates (CDC, 2010). Though national

administrative data provide an estimate for the country, the data are not without flaws: Overestimation of coverage can occur if out-of-date census numbers are used for the target population, or if children outside of the target group are vaccinated and are included in the vaccination figures (CDC, 2010). Alternatively, under- or overestimation can occur if there is under- or overreporting of vaccine doses administered (CDC, 2010).

In the current study, I examined using subnational data as a basis for timing, implementation, and impact on measles SIA outcome. Because national-level administrative data may not reflect geographic differences in immunity profiles (variance in immunization coverage), program capacity (e.g., vaccine stock levels), or localized outbreaks (WHO, 2016a), SIAs prompted by and geared toward the subnational level or community level may have a greater impact because this type of SIA may increase the immunity levels of more susceptibles in a low coverage area (Minetti et al., 2013) or may focus more attention on areas of high population mobility (Haddad et al., 2010) than a nationwide or nonselective SIA.

Implications for positive social change from the current study included the opportunity for more strategic and cost-effective measles elimination efforts by countries willing to use the subnational-level approach. Changing the strategy of planning and implementing SIAs based on local data (i.e., local vaccination coverage), local stock out data, or a combination of the three would be a paradigm shift from the current national-level focus. In Section 1, I present the problem statement, purpose of the study, research questions and hypothesis, theoretical foundations for the study, and a literature review

related to the key concepts of the study. Assumptions, limitations, and significance of potential implications are also described.

Problem Statement

The WHO (2009) recommended that countries with weaker health infrastructures use SIAs to deliver the MCV to reach children outside of the health system, including those who are unreached or unvaccinated through the RI program in the community. The strength of the health system is based on six health system building blocks: health workforce, service delivery, access to fundamental medicines, leadership/governance, financing, and health information systems (Shearer et al., 2012). Weaker health systems may suffer from recurrent and occasionally large variations in vaccination coverage across districts or regions due to a variety of reasons including the occurrence of armed conflict, infant mortality disparities, accessibility of antenatal care and immunization services, and vaccine stock outs (Minetti et al., 2013; Shearer et al., 2012). These differences, often not reflected in national administrative data figures, may call for different approaches for or timing of SIAs (Haddad et al., 2010).

Depending on the measles vaccine coverage of a country and the accumulation of susceptibles, intervals between measles SIAs should range from 2 to 4 years (WHO Regional Office for Africa, 2010). This guideline does not account for region- or district-level immunization coverage or incidence rates, but solely depends on the national figures. National level, or aggregate data, may conceal a large variance at the district level, with administrative data often underestimating or overestimating actual coverage or need, for example due to district level vaccine stock outs (Haddad et al., 2010; WHO,

2013). Haddad et al. (2010) showed that district-level coverage estimates vary between and within regions: more than 54 percentage points difference between the best and worst performing districts in Burkina Faso (33% versus 93% for the third dose of diphtheria tetanus and pertussis vaccine [DTP3] coverage and 34% versus 88% for MCV1 coverage) and a difference of approximately 25 percentage points within each region for DTP3 and measles coverage (Haddad et al., 2010). This shows that when evaluating regional averages or considering the national-leverage figures, substantial interregional variation must be addressed (Haddad et al., 2010). Variability in immunization coverage across districts underlines the limitations of using national averages (Haddad et al., 2010).

In addition to national-level data concealing subnational administrative data, they also mask differences in cold chain conditions at the local level. Outdated or inadequately maintained cooling equipment, weak adherence to cold chain policies, poor comprehension of the risks of vaccine freezing, and poor monitoring of the equipment lead to weak cold chain systems, ultimately affecting the immunity of the population (Wirkas et al., 2007). Emphasis has often been on ensuring vaccines are cold with less consideration for preventing freezing, and in the long run damaging the vaccine (Wirkas et al., 2007). Field confirmation and published reports showed that cold chain freezing of vaccines is routine, possibly causing extensive distribution of potency-compromised vaccines due to the separation of the antigen from the adjuvant (the substance added to a vaccine to enhance an immune reaction to an antigen; Merriam-Webster, n.d.; Oli et al., 2017, Wirkas et al., 2007). Yakum et al. (2015) described the frequency of vaccines

being exposed to adverse temperature ranges and recommended a backup source of power be considered, as well as increased supervision to enforce a contingency plan to reduce the compromising effect it could have on vaccines. Yakum et al. highlighted limitations to their study, including lacking information on any possible fluctuations in temperature during transport, which often is not assessed.

The WHO (2009) recommended implementing national SIAs every 2–5 years to manage the buildup of susceptibles; however, Minetti et al. (2013) described how targeted campaigns geared toward those with minimal access to vaccinations attain higher impact than nonselective campaigns. Though logistically challenging, targeted campaigns, such as those that vaccinate in a limited number of districts or regions with low immunization coverage, can be effective in increasing immunity of susceptibles (Minetti et al., 2013). Nonselective nationwide campaigns that vaccinate all children within an age range result in fewer children whose immunity is bolstered because their prior natural exposure or prior vaccination status is high, thereby resulting in a lower impact from the campaign (Minetti et al., 2013). To address this issue of variation of immunization coverage, measles incidence, immunization services availability, status of the vaccine cold chain, and vaccine stocks across regions, and to attain high-performing campaigns, countries may benefit from local or subnational data or context from which to base their SIA strategies; however, there was a gap in the literature regarding the effectiveness of this approach.

Purpose of the Study

The study's aim was to fill the gap in providing information on whether subnational data can be used to guide the timing, implementation, or impact of measles SIAs in a way that will result in increased MCV coverage. I examined different subnational data variables in the country of Tanzania to determine how they affect MCV pre- and post-SIA. This involved examining national and district-level independent variables (MCV coverage pre-SIA, vaccine stock out data, and cold chain information pre-SIA) with how they compare to the dependent variable (district-level MCV post-SIA).

Research Questions and Hypothesis

Overall research question (RQ): What was the difference in SIA outcome when subnational-level data were used for planning the timing and implementation strategy of SIAs, versus using national-level immunization coverage data alone?

RQ1: What was the difference in SIA outcome when subnational-level immunization coverage data, such as MCV, were used as a basis for SIA timing and implementation compared to using national-level data?

H_o1: There was no difference in SIA outcome, such as MCV coverage post-SIA, when subnational-level immunization coverage data versus national-level coverage data were used for the basis of SIA timing and implementation.

H_a1: There was a difference in SIA outcome, such as MCV coverage post-SIA, when subnational-level immunization coverage data versus national-level coverage data were used for the basis of SIA timing and implementation.

RQ2: What was the difference in SIA outcome when subnational-level vaccine stock out data were used as a basis for SIA timing and implementation compared to using national-level data?

H_o2: There was no difference in SIA outcome, such as MCV coverage post-SIA due to lapse in immunization services, when subnational-level vaccine stock data versus national-level stock data were used for the basis of SIA timing and implementation.

H_a2: There was a difference in SIA outcome, such as MCV coverage post-SIA due to lapse in coverage immunization services, when subnational-level vaccine stock data versus national-level stock data were used for the basis of SIA timing and implementation.

RQ3: What was the difference in SIA outcome when subnational-level cold chain data were used when planning the timing and implementation strategy of SIAs compared to using national-level data?

H_o3: There was no difference in SIA outcome, such as MCV coverage post-SIA for that area, when subnational-level gaps in the cold chain data versus national-level gaps in the cold chain data were used for the basis of SIA timing and implementation.

H_a3: There was a difference in SIA outcome, such as MCV coverage post-SIA for that area, when subnational-level gaps in the cold chain data versus national-level gaps in the cold chain data were used for the basis of SIA timing and implementation.

Theoretical Foundation for the Study

Diffusion of Innovation Theory

The diffusion of innovation theory was one of the theoretical frameworks on which the study was based. The theory has been applied over the years to understand the progression and stages involved in distribution, use, and acceptance of new concepts and programs (Oldenburg & Glanz, 2008). Work in the early 1900s in France by Tarde and in Germany by Simmel helped to explain how system-level consequences compelled individuals to accept novel ideas or actions and how individuals, often connected by social networks, helped to effect change (Dearing, 2009).

For public health products, practices, or programs to be successful, they must be efficiently and widely dispersed for maximum impact, with the goal of improving the public's health (Oldenburg & Glanz, 2008). The diffusion of innovation theory addresses how to implement a novel idea or practice within an organization or network and among and between organizations to resolve issues (Dearing, 2009). Because the current study involved evaluating a different approach to informing and implementing supplemental measles immunization campaigns, this principle aided in recognizing the characteristics of the innovation and, should the result be positive, how to diffuse and implement the strategy.

Assumptions of the Diffusion of Innovation Theory

The diffusion of innovation theory addresses the characteristics of the innovation that influence the pace and degree of acceptance and diffusion. These include (a) relative advantage, or whether the idea is better that what is already in place; (b) compatibility, or

whether the novelty is appropriate for the intended recipients; (c) complexity, or whether the new method is simple to implement; (d) trialability, or whether the novelty can be tested prior to deciding on implementation; and (e) observability, or whether the outcomes are easily measured and visible (Oldenburg & Glanz, 2008). Innovation in this context refers to novel thoughts or ideas, procedures, services, or devices that are valuable or useful to a person or group (Lien and Jiang, 2016). Clear documentation, however, is lacking on the assumption or trigger that the current method under question is suitable for replacement. For example, it is not clear what determines when the current method or current outcomes for a particular issue has need for or room for improvement. This could include making the process more efficient in terms of resource usage or successful outcome indicators. The diffusion element of the theory focuses on the process of how the innovation is carried through certain networks over time (Dearing, 2009). Dissemination is the organized efforts developed to ensure the innovation is accessible (Oldenburg & Glanz, 2008). Diffusion, therefore, is a result of dissemination endeavors (Oldenburg & Glanz, 2008).

Relating the diffusion of innovation theory to the current research question meant looking not only at how subnational-level data can be used to develop and implement measles SIAs, but also at putting into place new systems to communicate the new source of data to be used to all partners involved in the SIAs (e.g., local-, district-, and national-level health staff, nongovernmental organizations, and international partners; Dearing, 2009). These systems or networks may be identified through accessing the subnational data evaluated in the current study. This meant identifying when and how long the cold

chain parameters are exceeded and when and how long measles vaccine and diluent are not present, in which pockets of the target population are non- or underimmunized, and potential reasons why. These variables are identified in the Service Provision Assessment (SPA). This macrolevel, or large-scale, theory emphasizes adopting microlevel, small-scale, or lower level innovations to change behavior.

Community Mobilization Theory

I also looked at the local context in which an intervention may be implemented. As a result, the community mobilization theory was used to inform the study. Based on informative work by Cloward, Ohlin, and Arnstein in the 1960s and Alinsky and Freire in the 1970s, community mobilization efforts aim to recognize the individual–community relationship to better understand the interaction of individual characteristics, environmental factors, and health conditions (Jack et al., 2010). Community mobilization emphasizes using community-based approaches to enhance health results (Jack et al., 2010). This theory emphasizes how all sectors of a community can be engaged to address a health issue (Jack et al., 2010). I evaluated the use of subnational-level data to guide the timing, implementation, or impact of measles campaigns. As a result, a greater emphasis was placed on local information and local efforts to improve health. The theory also views communities not only as a physical setting, such as a neighborhood or village, but also as a group of people with mutual interests, such as health care organizations (Jack et al., 2010).

Community mobilization is “a capacity-building process through which community individuals, groups, or organizations plan, carry out, and evaluate activities

on a participatory and sustained basis to improve their health and other needs, either on their own initiative or stimulated by others" (Howard-Grabman & Snetro, 2003). Shults et al. (2009) highlighted how community-level actions, often using locally available resources or data, may yield other valuable outcomes not necessarily part of the problem to be addressed. By fostering problem-solving capacity and community and individual empowerment, community mobilization principles lay the foundation for improving the health of a community through positive social change (Chen, 2015).

Assumptions of the Community Mobilization Theory

In resource-limited environments, the community mobilization theory is often employed to enhance preparation for and use of health care services (Undie et al., 2014). Encouraging commitment to participate in the planning or implementation of the service may presuppose that all those involved understand their role in the effort and the severity of the problem, and that they will continue to be empowered throughout the implementation and success of the program. The theory also assumes that there are community strengths and qualities that can be improved (Minkler et al., 2008). These assumptions can be addressed in an iterative cycle of discussion of the health issue and problem, and jointly planning, acting and evaluating (Undie et al., 2014).

Applying the Community Mobilization theory to my study means identifying the data documented or collected by local staff in the SPA, such as cold chain information and state of the measles vaccine stock and highlighting how the data can be used to inform SIA planning. This could be used as an empowering tool for local or district-level staff to play a more distinct role in SIA development and implementation (Minkler et al.,

2008). In resource-poor settings, staff often report that they do not recognize the importance of completing records within the recommended timeframe (precisely or entirely) because staff do not see its relationship to the care that they provide (Hammond et al., 2010). However, if the collection of data can be designed to the community's data needs, such as highlighting the unimmunized, this can serve as an incentive for improving the quality and timeliness of the data (Hammond et al., 2010). Staff are a key part of the data collection process, but when they understand the significance of the data and how they will be used, staff can become as vital as the national-level person using the data (Hammond et al., 2010). Both of the selected theories regard communities and organizations as multifaceted, essential elements and mechanisms for development and acceptance of interventions. Use of these theories aided in recognizing the nuances for each aspect of the intervention and the best approach for possible outcomes.

Nature of the Study

A quantitative approach was selected for the study. Quantitative methods are best if a matter meets any of the following conditions: (a) the recognition of factors that may influence an outcome, (b) determining the effectiveness or quality of a program or intervention, or (c) understanding the best outcome predictors (Creswell, 2009). Quantitative methods are also the best approach when testing an explanation or theory. Because I not only looked at items that may influence an outcome but also sought the best outcome predictors, quantitative methods were justified.

Independent variables for the study were the following: MCV coverage pre-SIA, vaccine stock data (measles vaccine or diluent available), and adequacy in cold chain

information (such as number of health facilities lacking adequate quantity of refrigerators, or number of facilities or refrigerators with days of temperatures outside of the recommended temperature range for storage of MCV). The dependent variable for the study was SIA outcome: district-level MCV coverage post-SIA.

Quantitative secondary data analysis was chosen for the study that focused on data between the years 2010 and 2016. Tanzania was selected for the analysis because it was one of the countries with vulnerable or weak health systems, had approximately 730 confirmed cases of measles for 2015, and experienced a decrease of almost 87% (100 cases) by the end of 2016 (WHO, 2016b). Because health planning in the country is decentralized (planning is at the district level where the District Health Management Team plans and distributes resources (Maokola et al., 2011), Tanzania's district-level data were ideal to examine and then use for local decision making. Data from the following resources were combined and analyzed: (a) woman's questionnaire data on vaccination coverage after SIAs from the Tanzania DHS program data (National Bureau of Statistics and ICF Macro, 2011) and (b) child health and infrastructure, resources, and systems information in the Facility Inventory Questionnaire of the Tanzania SPA data (Ministry of Health and Social Welfare et al., 2015). In addition, national-level measles cases and SIA qualitative and quantitative data were used in the analysis. This combination of health facility information and vaccination coverage was expected to provide a comprehensive description of conditions at the subnational level versus a broader, more general description than what national-level vaccination coverage

provides, which is the current basis for determining when an SIA should be conducted (WHO Regional Office for Africa, 2010).

The independent variables (national- and district-level MCV pre-SIA, national- and district-level stock out data, and cold chain information) were compared to the dependent variable (district-level MCV coverage post-SIA). Data analysis included descriptive and inferential analysis of the dependent and independent variables to identify correlation, if present. A multiple regression analysis was performed because there were more than two independent variables that could be related to one dependent variable (see iCreswell, 2009).

Literature Search Strategy

Throughout the-period of January 2016 to April 2017, several databases and literature searches were used to identify relevant articles. Searching databases for English language peer-reviewed literature between the years 2003 and 2017 allowed for inclusion of recent research on the subject, seminal work on the foundational theories, and the current guidelines for SIAs (updated during the literature review process resulting in current information and recommendations for several areas such as using technology during supervision, data collection, and analysis). Search engines and databases included Google Scholar, PubMed, CINAHL & Medline, and ProQuest databases. Search terms contained the following combinations of terms: *vaccination campaign*, *immunization campaign*, *measles vaccine*; *measles immunization campaign and data*; *vaccination campaign and data*; *recommendations and measles vaccination campaign*; *measles data and supplemental immunization(s)*; *measles and mass vaccination campaigns*; *measles*

incidence, data, decision making, and immunization(s); *local data for decision-making*; *local data and decision-making*; *measles data*; *supplemental immunization(s)*; *supplemental immunization activities*; *social marketing and vaccination/immunization campaign*; *promotion or communication and measles campaigns*; and *season/school and vaccination/immunization campaign*.

In addition to the literature search conducted related to SIAs, a search was conducted on potential theoretical frameworks appropriate for the study. The same databases were explored, along with a manual review of theory textbooks. Among the search terms used for this level of research were *research theory, behavioral change theories, health behavior, research foundation, community mobilization (theory),* and *diffusion of innovation (theory)*.

The grey literature was also examined for relevant guidelines, position papers, white papers, and the like. Search terms used on the Grey Literature Report database included *vaccination campaign, immunization campaign, measles prevention*, and *supplemental immunization*. Governing and implementing organizations such as the WHO, CDC, and The Measles & Rubella Initiative were also sources for technical information on the subject.

Literature Review Related to Key Concepts

The following section addresses criteria used for determining timing, implementation, and impact of an SIA (see WHO, 2009). When appropriate, strengths and weakness of the presented articles are examined.

Measles Vaccine and SIAs

Prior to the 1963 licensure of the first measles vaccine in the United States, measles infection was a common childhood disease, resulting in immunity by the age of 15 for more than 90% of the population (CDC, 2015). The measles vaccine, however, is safe, inexpensive, and effective, and provides immunity for life for 95% of children vaccinated at 12 months, which increases to 98% if also vaccinated at 15 months (CDC, 2015). Primary vaccine failure may occur in roughly 2%–5% of children who receive only one dose of MCV (CDC, 2015). This failure to respond may occur due to the vaccine being damaged, incorrect vaccination records, the vaccine recipient possessing a passive antibody, or other causes (CDC, 2015). Most recipients who experience vaccine failure with the first dose will react to a second dose (CDC, 2015). Studies showed that more than 99% of people develop measles immunity after receiving two doses of the measles vaccine (CDC, 2015). The WHO (2016b) advocated immunization for all susceptible children and adults for whom measles vaccination is not contraindicated or is otherwise inadvisable.

The WHO (2009) recommended countries implement SIAs every 2 to 4 years in countries with one dose coverage below 80% , and continue with SIAs until they can attain and maintain $\geq$ 95% coverage with two doses via the RI program (WHO, 2016). This high level of coverage must be upheld consistently throughout the country to prevent measles outbreaks (WHO, 2016a). The type of SIA to be implemented, however, is determined by a number of factors. The following criteria are used for each type of SIA:

- Catch-up SIAs are one-time endeavors, often countrywide, targeted at the main group experiencing disease transmission. This type of effort is utilized to rapidly decrease the number of vulnerable individuals, primary vaccination failures, or nonvaccinated individuals. These SIAs should encompass children aged 9 months to 14 years (WHO, 2016a).
- Follow-up SIAs are intermittent, also nationwide, that are implemented every 2 to 5 years, focused on children born after the last SIA and to reach the nonvaccinated and those who did not gain immunity after the first vaccination. Follow up SIAs should include, at a minimum, children age 9 to 59 months (WHO, 2016a).

Though the WHO (2016a) recommended the continuation of SIAs if national coverage is below 95%, it suggested that pockets of high-risk populations may be obscured and unvaccinated, or undervaccinated children may be missed if only a country-level immunization coverage $\geq$ 95% is used as a guideline for SIA implementation. Other subnational issues may be concealed if only national-level data are used as a basis for SIAs. The current study addressed factors that may contribute to the periodicity of SIAs; therefore the focus of this research was on follow-up SIAs versus catch-up SIAs or a combination of the two. The term SIA referred to follow-up SIAs. The following section addresses studies related to measles vaccine coverage, incidence, and other subnational areas for consideration when determining timing, execution, and impact of measles SIAs. This section includes the current model and studies that addressed other models for planning SIAs.

Timing and Implementation

Timing and implementation of the MCVs differ between countries and regions, but often countries with mature health infrastructures administer both doses later and look to the RI program for delivery versus SIAs (WHO, 2009). In these countries, the MCV1 is often administered around 12 months, and the MCV2 is given between 4 and 6 years of age. The second dose is recommended to generate immunity in those who were unsuccessful in responding to the first dose; that is, those who experience vaccine failure (CDC, 2015; Pannuti et al., 2004).

Countries with vulnerable health infrastructures often use SIAs to deliver MCV2. The variability among countries' measles immunization schedules comes from differences in their health service infrastructure, the goals for measles control, rates of endemic measles transmission, and the program's capacity to reach children at different ages (WHO, 2009). In countries with persistent measles transmission, it is recommended that MCV1 be given at 9 months of age and MCV2 between 15 and 18 months (WHO, 2009).

Areas of high mobility across health districts and migration throughout a country can affect administrative coverage rates because these factors can influence target population numbers, thereby providing an inaccurate perspective when looking at the national level as a whole (Haddad et al., 2010). Haddad et al. (2010) explained that these factors may lead to immunization coverage inconsistencies across districts, which underscores the drawbacks of using nationwide values. If subnational data are used in planning and monitoring immunization programs, Haddad et al. suggested (a) employing

markers that are unaffected by population movement, (b) bolstering the RI system as it relates to administrative data, (c) incorporating surveys into the monitoring process at the subnational level, and (d) actively encouraging local personnel and district-level staff to use coverage data for action.

Local data such as cold chain capacity and vaccine levels can reveal districts that may have compromised measles immunity due to deficits in their minimum service levels. Favin et al. (2012) explained how vaccine stock outs or cold chain problems are elements of service factors that can lead to undervaccination. Favin et al. reviewed the global grey literature, such as journal articles, reports, and field project accounts, focused on information that described children who are under-immunized (i.e., inadequate immunizations for their age or have not received any vaccinations) and what circumstances are linked to their status. Among the most frequently stated causes for undervaccination were false contraindications, health staff demeanor and attitudes, concern over side effects, and access to and reliability of services (Favin et al., 2012). Studies that cited problems with service resources indicated vaccine stock outs or cold chain problems as the causes of unavailability of vaccinations (Favin et al., 2012). Vaccine stock outs reflect lack of storage capacity or funding, or inadequate requisitioning and delivery systems and skills (Favin et al., 2012). With service being denied or unavailable, parents are less likely to return for vaccinations (Favin et al., 2012). Favin et al. did not, however, differentiate between national-level versus subnational-level stock outs. Favin et al. referenced other factors such as lack of incentives for conducting outreach, which may be difficult to document or predict

countrywide but may be ascertained locally, thereby highlighting region-specific elements that could be vital to conducting SIAs.

Erchick et al. (2017) looked a bit deeper at the issues surrounding immunization program effectiveness, including accountability. Erchick et al. defined *accountability* as the connections or interactions between political, technical, and managerial staff within the government as they relate to immunization service delivery, governance, finance, logistics, human resources, and data management. Erchick et al. interviewed 17 government health care workers and health officials in the state of Niger, one of Nigeria's 36 states. Health care workers cited shortages of vaccines as reasons why children and their caregivers are turned away. Government officials described difficulties with powering and maintaining cold chain equipment that affect the ability to maintain vaccines in health facilities, thereby reducing availability of the vaccines when the target population comes to be vaccinated. Erchick et al. highlighted timing of financing as another contributing factor to not vaccinating children, and therefore low immunization coverage. Because vaccines are secured months in advance, a delay in the release of funds for vaccine purchase can lead to vaccine stock outs (Erchick et al., 2017). A delay at any level can be propagated to all levels below (Erchick et al., 2017). The outcome of reduced chances of parents returning later due to stock outs echoes the findings of Favin et al. (2012). Limitations of the explaratory study included the fact that health officials from only one state were interviewed, their experiences may not have been representative of others around the country, and understanding of accountability may have been dependent on the level of government in which one is employeed (Erchick et al., 2017).

The strategy of basing SIAs on local measles incidence data has been utilized to varying degrees by countries for a variety of reasons such as limited budgets. Haddad et al. (2010) identified not only high population mobility as a factor in using local data, but also the use of local measles incidence data to implement SIAs. Zhuo et al. (2011) described how SIAs were implemented in select districts of Guangxi Province in China. These high-risk districts were chosen due to their high measles incidence and multiyear SIAs executed to decrease susceptible populations and inhibit epidemics (Zhuo et al., 2011). This was in contrast to the WHO (2016a) recommendation of implementing campaigns over a short period of time simultaneously throughout an administrative unit or country. Zhuo et al. found that using a selective strategy to carryout SIAs could be an efficient method to reduce susceptibles and prevent epidemics. A limitation of their approach, however, was that the RI data collection system was intended to support China's unique political organization to transform national and international measles elimination obligations into actual local action. Though the system was found to be effective in identifying high-risk areas and areas for building capacity in this particular province in China, it was uncertain whether it would be successful in other parts of the country or in other countries. Guangxi developed and implemented their SIA strategy according to the circumstances of their province, per the central government's stipulation.

Timing of SIAs in response to incidence data may identify areas for an outbreak response. Minetti et al. (2013) described how select models suggested more focused or localized SIAs can be of greater benefit but should be implemented according to local context. Minetti et al. found that these types of nonselective campaigns favored those

already accessing the health system and those who are willing to be vaccinated. A strength of this approach is campaigns targeting those outside of the health system or hard-to-reach individuals because selective or targeted campaigns appear to be of greater benefit, especially for those areas of higher vaccination coverage. Minetti et al. explained that the selection of campaigns should be based on attaining a practical balance of cost, expected impact, and feasibility, and basing the strategy on local epidemiologic data. A weakness associated with this model was that Minetti et al. looked at the proportion of cases prevented as the single measure of the intervention impact, whereas the WHO (2016a) described the primary objective and a successful campaign as reaching at least 95% national coverage.

Vaccination campaigns triggered by the specific type of epidemiologic situation hold promise to prevent or reduce measles epidemics. Lessler et al. (2016) examined possible triggers, such as degrees of population immunity and case detection. Lessler et al. developed a stochastic age-structured model to evaluate strategies based on the number of reported measles cases on a biweekly basis ($N = 10$ and $N = 25$) or a measles seroprevalence of less than 85% in a selection of a sentinel population (children 24–36 months of age and those 2–5 years of age). Lessler et al. found that case-based campaigns prevented an average of 28,613 cases over 15 years in the setting with highest numbers of measles cases and 599 in the lowest occurring settings. Serologically prompted campaigns, or those prompted by a certain level of susceptibility in children, prevented the most at 89,173 cases in highest incidence settings (triggering annual campaigns) and 744 cases averted in settings with the lowest incidence. Serologically prompted

campaigns can help prevent epidemics beforehand and prevent more cases per campaign, thereby highlighting the benefits of susceptibility monitoring. One limitation of the study was the cost associated with annual campaigns; having resources readily available may be out of reach for countries with weak health systems. A major benefit of serological monitoring is that it can be used to trigger control activities for other vaccine preventable diseases; however, more research is needed in this area (Lessler et al., 2016). A limitation of the study was that the settings represented a country as a whole and did not recognize the nuances or distinctions that regional or district-level data can reveal.

Basing SIA strategy on regional administrative coverage versus national level coverage has been supported by Lakew, et al. (2015) and Haddad et al. (2010). In addition to regional data highlighting areas of population mobility, Haddad et al. (2010) recognize that overestimation of measles coverage often occurs in remote areas, whereas underestimation occurs in high population areas (Haddad et al., 2010). Recognizing these tendencies can direct execution of SIAs in these areas by focusing resources in one area or redirecting resources to another (Haddad et al., 2010).

Even within regions of high vaccination coverage, a large number of under-immunized children can be concealed (Dawson and Apte, 2015). For example, in an area of Sydney, Australia, the under-five immunization rate was 92.5%, but there still was still a group of 3,400 children that were not completely immunized (Dawson & Apte, 2015). The researchers identified pockets of vaccine hesitancy that contributed to practices of parents outright refusing to allow their children to be vaccinated, but also there could be parents who did have their children vaccinated though they may be apprehensive about

possible harms (Dawson & Apte, 2015). In these instances, the parents delayed introduction of vaccines or selectively modified their child's vaccination schedule with the belief that this would lessen harm (Dawson & Apte, 2015).

SIA Models Based on Coverage, Incidence, and Other Data

A country-specific approach to SIA timing has been suggested by some researchers. Verguet et al. (2014) proposes that this strategy would be most successful when the length of time between SIAs was dependent on RI coverage and local demographics, but more importantly, high SIA coverage. The interval between SIAs differs within and between countries and should be established by the current RI coverage and demographics of the population, such as the birth rate and under-five population (Verguet et al., 2014). Verguet et al. (2014) proposed a model that considered numerous combinations of coverage levels for MCV1 and SIAs (barring the WHO recommended 2-4 year frequency and including MCV1 coverage below 80%) that would permit countries to recognize more locally suitable SIA planning in line with operational and financial capability. The researchers developed a model of measles infection transmission based on age-stratification in unvaccinated and vaccinated persons (Verguet et al., 2014). The individuals used in the model can be infected with measles, recovered from measles (resulting in lifelong immunity) or susceptible to measles (Verguet, et al., 2014). The infection rate of the susceptible population depended on the effective contact rate among the various age groups and the existing ratio of the population already infected (Verguet et al., 2014). Ferrari, et al. (2013) also used a model that found by evaluating patterns across the globe, which differ in demographic characteristics and

measles vaccination coverage, they could detect both the overall manner of measles infection response to vaccination and the scale at which local demographics affects those general patterns (Ferrari et al., 2014). The model used by Verguet et al. (2014) examined countries with the highest measles mortality burden and found that for countries such as Nigeria and Ethiopia with less than adequate MCV1coverage (42% and 66%, respectively) SIAs would need to occur approximately every 2 years (Verguet et al., 2014). India, with an MCV1 coverage of 74%, would require an SIA every 3 years (Verguet et al., 2014). This national level coverage, however, may mask differences at the sub-national level (Verguet et al., 2014). Two Indian states, Bihar and Uttar Pradesh, with MCV1 coverage of 58% and 53%, respectfully, would require an inter-SIA period of 2 years to achieve measles control, compared to the 3 years estimated at the national level (Verguet et al., 2014). Weaknesses associated with this model include not considering local variability in the measles transmissions strength and variations in birth and immunization rates in the short-term (Verguet et al., 2014). The model, however, generally supported global guidance but could be used to tailor a country's SIA planning and timing to their situation because RI coverage and demographics of the local population are key variables in controlling measles and identifying timing of SIAs (Verguet et al., 2014).

WHO's (2015) Strategic Advisory Group of Experts (SAGE) on immunization recommended further research on an algorithm to guide countries on when to implement measles SIAs. In addition to the model proposed by Verguet et al. (2014) based on local demographics and MCV1 coverage through the RI program, Bishai et al. (2011) proposed

a model that incorporated a stochastic model of measles transmission with an economic model of administrative data for planning and implementing SIAs. A stochastic model "predicts a set of possible outcomes weighted by their likelihoods or probabilities" (Pinsky and Karlin, pg. 1, 2011). The stochastic model included district-level measles data; the economic model included costs associated with SIAs, routine MCV1, outbreak control, measles treatment, and surveillance (Bishai et al., 2011). The recommended model for Uganda included triennial implementation of SIAs aimed at covering 95% of children 12-59 months of age (Bishai et al., 2011). This cost-effective strategy was expected to yield fewer and less intense measles outbreaks; however, as vaccination coverage and routine services improve, the cost-effectiveness of these mass vaccination campaigns would diminish (Bishai et al., 2011). Johri, et al. (2012) suggested a broadened SIA strategy, such as integrating health services into the SIA, to fit a state or district's needs versus one approach for the whole country.

Regional differences related to transportation and some of the building blocks of the health system, such as demand barriers, staffing challenges, or health facility quality or management differences (Shearer et al., 2012) can influence how an SIA should be implemented. Lakew et al., (2015) cited these regional disparities as factors that could affect the administrative coverage, but also the way the intervention is implemented. However, the authors did not address the reality that regional data may reflect vaccine stock outs, cold chain issues, or community communication challenges, often not apparent in national level data (Lakew et al., 2015; WHO, 2013). The researchers believe that by improving access to vaccinations throughout country it would have a multilayered

effect on the delivery of healthcare by strengthening health worker output and immunization coverage in addition to increasing the effectiveness of their interventions, which may include SIAs (Lakew et al., 2015).

Health system effects on measles cases and coverage have been identified as a contributing factor to regional differences. Perry et al. (2015) considered measles cases as a marker for the scope and effectiveness of the health system as underserved populations reveal themselves during measles outbreaks. Established immunization program practices and policies may be reconsidered during these outbreaks, such as not opening a vial if insufficient numbers of children are present to be vaccinated, restricting measles vaccination to only monthly sessions, or not vaccinating children less than 12 months of age (Perry et al., 2015). The authors, however, did not address the issue of coverage estimations being affected by imprecise documentation of doses dispensed, inclusion of MCV doses given during an SIA to children outside the target age range, and imprecise target population estimates (Perry et al., 2015).

In line with Perry et al.'s (2015) suggestion that MCV coverage may be a reflection of the healthcare system, Hardt et al. (2016) provided evidence that weaknesses in the system lead to differences in implementation strategies and missed vaccination opportunities. These problems included inadequate understanding and therefore incorrect implementation of current immunization schedules on the part of the healthcare staff, not immunizing children at all well-child clinic visits, inefficient vaccination records documented by healthcare professionals, and a shortage of vaccines (Hardt et al., 2016). In addition to these training issues, suspicion of the motives of outside organizations

involved in immunization activities, public trust, and politics could undermine sufficiently strong healthcare systems, highlighting the complexity of the factors that could influence implementation and impact at both the local and national level (Hardt et al., 2016).

Providing more evidence of the health system as a marker for MCV coverage, Colson et al. (2015) observed extreme coverage levels within the same states and demographic groups. Colson et al. (2015) found that the difference between children whose vaccination card identified them as immunized against measles and those whose lacked measles antibodies ranged between 5 and 96%. This suggested that health system-level causes rather than individual causes pushed the disparity between coverage rates (Colson et al., 2015). Colson et al. (2015) suggested that disruptions in the cold chain, for example, could be the cause of low antibodies against the measles virus in children with documented vaccination coverage. Breaks in the cold chain while the vaccines were being shipped, stored, or delivered could lead to the vaccines being ineffective (Colson et al., 2015). Significant challenges of not only insufficient cold chain capacity occur at subnational levels (WHO, 2016a), but also differences in compliance with cold chain procedures, improper refrigerator maintenance or outmoded refrigeration equipment, lack of understanding of the risks of vaccine freezing and weak supervision and monitoring all add to the weakness of the existing cold chains (Wirkas et al., 2007). In the study by Colson et al. (2015) the authors were unable, however, to explain why no measles outbreaks occurred in these areas of extremes in coverage.

In the preceding section, I described how the timing of a measles SIA could be influenced by a number of factors. WHO (2016a) suggested scheduling SIAs every 2-5 years as this is the approximate time needed for the number of susceptibles to equal one birth cohort on the national level. Research suggests, however, that timing could be based on district-level considerations such as vaccination coverage, measles incidence, the strength of the local health system, and mobility of the local population (Bishai et al, 2011; Haddad et al., 2010; Lakew et al., 2015). These factors vary within and between districts and regions and should be considered when planning an SIA. These factors also come into play when deciding on how to implement an SIA. Local measles incidence, for example, may call for more of an outbreak response model that is focused on high incidence of disease areas and hard-to-reach populations, resulting in a selective or targeted campaign (Minetti et.al, 2013). The next section will examine the impact of SIAs on these various factors.

Impact of SIAs

The impact of an SIA can be multifaceted - from reducing incidence of the disease by increasing measles immunization coverage and immunity, to affecting the health system, to ultimately increasing health equity (Colson et al., 2015; Hurtado et al., 2013; Khetsuriani et al., 2011; Lessler et al., 2016; Minetti et al., 2013; Perry et al., 2015).

The first set of outcomes, rapidly reducing immunity gaps in susceptible populations and reducing measles incidence, are recognized by many countries as potential outcomes of an MCV SIA (Khetsuriani et al., 2011). Khetsuriani et al. (2011)

reviewed information of WHO European Region Member States who conducted SIAs between 2000 and 2009. During this period, over 57 million individuals were vaccinated against measles in 16 of the 53 Member States (Khetsuriani et al., 2011). Nationwide catch-up campaigns were primarily conducted, with subnational catch-up SIAs being conducted in only three Member States. The diversity of the region and diversity of how SIAs were implemented did result in measles incidence decreasing, but the traditional concept of a short-term mass campaign was found to be less successful than an SIA carried out through routine services or rolling campaigns (Khetsuriani et al., 2011). As many western European countries have chosen to decentralize governance, supervision and implementation of their mature health systems, this may result in low priority given to measles, vaccine safety fears, supervision and logistical issues (Khetsuriani et al., 2011). As the European Region, in general, does not suffer malnutrition, it avoids the life-threatening effects measles can create, with their resulting cases being mild (Khetsuriani et al., 2011). Consequently, the public, as well as some health care providers, associate a low priority with the vaccine and the region has faced challenges when it comes to realizing their measles elimination goal (Khetsuriani et al., 2011). This situation is ripe for using subnational data, such as areas of susceptibles and underserved individuals, and for local input driving the implementation of their measles elimination efforts (Haddad et al., 2010). SIAs implemented through the routine program or rolling campaigns might be a successful substitute in areas of ongoing outbreaks, with remaining susceptibility among the older population, or in areas of high measles incidence (Khetsuriani et al., 2011). In concert with Haddad et al. (2010) recommendation of using

local data for action, Khetsuriani et al.'s (2011) description of longer-term strategies reflecting the region's diversity will impact measles incidence.

In addition to MCV coverage reflecting the strength of a health system and identifying the need for or where to implement an SIA, SIAs can contribute to strengthening the RI system. The mutual benefits of each effort on the other is described in the research of Fields et al., (2013). The additional planning involved in SIA preparation, such as updating target population numbers and costs related to accessing difficult to reach populations, can be used to update RI program information (Fields et al., 2013). This information could be used for programmatic enhancements that can help maintain elevated population immunity for each succeeding age cohort between SIAs (WHO, 2016a). The additional training to bolster health worker skills during an SIA benefits the RI system (Fields et al., 2013). Procuring and delivering extra cold chain equipment to healthcare facilities for an SIA was listed as another example of a possible benefit the SIA could render onto the RI program (Fields et al., 2013). Fields et al., 2013 caution that in resource-limited health systems, however, the additional cost for fuel may not be easily absorbed into the RI system and may outweigh the benefits to the system.

The resulting impact of a measles SIA is expected to be the rapid decrease of susceptibles in the population and the prevention or spread of measles (Hayford et al., 2013). However, SIAs may have other impactful outcomes, such as strengthening the RI program by updating target population numbers and identifying defaulters, increasing or improving the cold chain, and decreasing inequity of service delivery by reaching across economic levels and reaching the underserved (Fields et al.; Haddad et al., 20102011;

Vijayaraghavan et al., 2007). In addition to these benefits, SIAs may bring positive marketing for the RI program in general by enhancing community awareness of the disease and services offered in nearby health facilities (Uddin et al., 2016).

Though SIAs have been found to strengthen health systems, in some countries they may negatively impact the system during the duration of the campaign. Verguet et al. (2013) found that SIAs disrupted the normal operation of the system by redirecting staffing or funding from other activities during the SIA. The researchers analyzed district-level service headcounts, such as RI indicators (for example, number of children under 5 years visiting a facility for primary healthcare, number of children under 1 year immunized with the first or second dose of routine measles vaccine), in 52 districts of South Africa during the period of 2001–2010 (Verguet et al., 2013). The researchers found that use of not only child health services, but also maternal health services, were reduced during campaigns (Verguet et al., 2013). Fewer children received the first dose of the routine measles vaccine, finished their basic course of immunizations (13% and 29% respectively), and a smaller number of women participated in their first prenatal care visit (12%) and accessed reproductive health services (a reduction between 7% - 17%) at the district level during an SIA than during non-SIA periods (Verguet et al., 2013). Looking closer at the data, Verguet et al., (2013) suggested that the issue of fewer immunizations being provided in the routine program during the campaign are compensated for in SIA coverage which also includes ages outside of the standard age range of an under 2 years during campaign. Verguet et al. (2013) described how use of routine services in the months following the SIA increase; that is, there may be

rescheduling or maneuvering of certain visits from the SIA period to post-SIA, that could possibly reflect better efficiency in the health system. Though the outcome of the study established the negative impact of SIAs on health systems, the authors suggested that SIA's impact may also include bringing equity in access to fundamental health services as SIAs can be used as a way to deliver health interventions that tackle the primary causes of mortality in children, especially those not normally reached by routine services (Verguet et al., 2013; Vijayaraghavan, et al., 2007). SIAs may also impart negative effects, such as redirecting funding or staffing from other activities in the health system during an SIA (Verguet et al., 2013). Fewer immunizations may be provided through the routine program during this time, though further analysis shows that months following an SIA, an increase in RIs may result from rescheduled vaccinations (Verguet et al., 2013).

With the previously mentioned outcomes in mind, basing SIAs on subnational data can identify and improve program utilization, that is, decrease inequity of service delivery and measles immunization coverage, as encouraged in WHO's SIA field guide (WHO, 2016a) and by Vijayaraghavan et al. (2007). SIAs target these inequities by seeking high vaccination coverage in the targeted population, therefore reducing the disparity in immunity between the poor and the rich in the population (Vijayaraghavan et al., 2007). Vaijayaraghavan et al. (2007) described how measles vaccination coverage equity during SIAs was comparable across economic levels (Vijayaraghavan et al., 2007). Along with speaking to matters of social fairness, securing equity in measles vaccine coverage was important for controlling disease (Vijayaraghavan et al., 2007). As has been described earlier, in the presence of high national measles vaccine coverage,

measles outbreaks may still arise in areas of susceptible sub-populations, such as lower socioeconomic communities where many may live in overcrowded conditions making them more likely to die from measles (Vijayaraghavan et al., 2007). Though the researchers were able to describe the increase in equity gained by the measles SIA, they were unable to explain these differences within provinces, or at the district level (Vijayaraghavan et al., 2007). This is the level at which practical interventions would be most effective.

Along with the indirect impact of increasing health services and measles immunization coverage equity, SIAs have the potential to bring more and different attention to the immunization program. An increase in the public's awareness and understanding about the importance of the intended vaccines and acceptance of the actual vaccines during not only the campaign, but also through the RI program was a potential byproduct of SIAs (Uddin et al., 2016). This feeds into one of the five components for the strategy to eliminate measles, rubella and congenital rubella syndrome as described by the Measles and Rubella Initiative (WHO, 2012). Community awareness of health services, benefits of the vaccine, as well as safety concerns can encourage public approval and uptake of the intended interventions (WHO, 2012).

In addition to the direct benefits of increased MCV coverage from an SIA, indirect benefits can also be garnered. Hanvoravongchai et al. (2011) described the prospect of locating and vaccinating defaulters or dropouts that SIAs offer, thus strengthening the recommendation of strategically implementing SIAs or narrowing the campaign area to yield higher campaign impact. Focused resources in a narrowed

campaign can also be used to support increased outreach activities focused on hard-to-reach populations (Hanvoravongchai et al., 2011). Uddin et al. (2016) goes on to explain how some campaign staff take the opportunity to distinguish those children needing additional vaccines or who have fallen behind on the vaccination schedule (Uddin et al., 2016). Catching up on other vaccines was another benefit of SIAs (Uddin, et al., 2016).

In addition to ways that SIAs are impacted by using subnational data during the planning and implementation phase, one must be cognizant of other factors that may affect the SIA's outcome. Confounding factors, or elements that could influence an outcome due to their involvement or connection with other factors influencing the outcome (Porta, 2014), may also play a role. Confounding factors associated with the study could include social marketing, or communication strategies for the SIA (for example, which could help increase participation during the SIA), and the time of year during in which the SIA is conducted (e.g., if during the school year and during school hours, more school-aged children could be vaccinated in schools). As well as the previously mentioned factors, national level measles incidence, without subnational level illumination, could influence the outcome of the SIA, and can thus also be identified as a confounding factor.

Communication should be an essential part of disease elimination plans, such as polio and measles (Mbabazi et al., 2015). Communication strategies include house-to-house visits, radio and television marketing, phone calls, short text messages, word of mouth and personal communication between service providers and caregivers during the preparation phase of the campaign (Mbabazi et al., 2015;Uddin et al., 2016). Experience

from the polio eradication program shows immunization coverage increases between 12–20% when communication was integral to efforts to strengthen RI (Mbabazi et al., 2015). More importantly, the approaches to and types of communication channels must be evidence-based, interactive, community owned, locally appropriate, and should capture all households prior to the start of the campaign (Mbabazi et al., 2015).

Social marketing is the application of commercial marketing techniques, such as population segmentation, and relates them to influence the behaviors of the target audience; and whose results ultimately benefit the individual and society (Nowak et al., 2015). Central to social marketing and marketing are the four "P's" – product, price, place and promotion (Nowak et al., 2015). These categories were used to generate, convey, and produce importance to each target group, by allowing components within each category to be altered in a way to make the idea, the adoption of a behavior, service, recommendation, or offering more appealing and attractive (Nowak et al., 2015). The product included the benefits received or derived from the offering and qualities of the offering (Nowak et al., 2015). The price incorporated the costs related to the behavior or offering such as, time, money, physical efforts, whereas place coverered convenience, accessibility, access, and distribution (Nowak et al., 2015). Finally, promotion involved the creative strategy and persuasive communication factors employed to emphasize the product's benefits, its costs, and how or where to take advantage of the offering (Nowak et al., 2015). For immunizations, this includes determining the benefits and attributes of the immunization program's products as seen through the eyes of their target audience (Nowak et al., 2015). In the case of measles SIAs, the target audience are the parents of

children for whom the vaccine is recommended; the product would be the MCV; ease of access and convenience to the vaccine during the SIA is the price; a health facility or outreach location is the place; and messages, conveyed through promotion materials (e.g. public service advertisements, brochures, posters), key informants in the community, and communication between providers and parents would fall within the promotion category (Nowak et al., 2015). Further segmentation of this target audience would consider how psychographic and demographic characteristics, their intention to perform the advocated behavior, cultures, and possibly their subjective experiences with immunization (Nowak et al., 2015). Social marketing focuses on how the message is delivered and the response by the recipient (Opel, et al., 2009). A major strategy for provoking emotion is through the use of narratives and stories (Opel et al., 2009).

Social marketing and marketing methods can be successful, but their effectiveness differs and is not assured (Nowak et al., 2015). Cates, et al. (2011) implemented social marketing into an HPV vaccine campaign by targeting not only mothers of girls 9-13 years of age, but also the media and healthcare providers as they are key influencers in health behavior. Cates et al. (2011) used the following social marketing principles in the campaign: recommendation of the vaccine against HPV – product; perception of efficacy and safety and where to get the vaccine – price; brochures, posters, doctors' recommendation, and news releases – promotion; and place (retail outlets, pharmacies, and doctors' offices – place. The authors surveyed 1000 women with a response rate of 28.9%, resulting in a total of 225 mothers answering the survey (Cates et al., 2011). Those mothers indicating some campaign awareness (n=85) were more prone to take

action than those mothers who claimed to be unaware (n =18) (Cates et al., 2011). Actions most commonly conveyed were: talking to their doctors (38%), discussions with their daughter (36%), speaking with friends and family (33%), and getting their daughter vaccinated (27%) (Cates et al., 2011). These actions did not vary by age of the daughters (Cates et al., 2011). Though the social marketing campaign was found to be effective at increasing uptake of the HPV by reaching mothers of 11–12-year-olds and their healthcare providers, the participant numbers were low, and replication of campaign components should be further investigated (Cates et al., 2011). Obregon and Waisbord (2010) suggests the media, local associations, political and religious leaders, as well as informal social networks should not be viewed only as conduits for improving awareness of the SIA or altering perceptions about immunization, but they can also be viewed as channels for expressing local politics and needs of the community. As such, communication strategies should depend on an accurate understanding of the plans and motives of all partners involved (Obregon & Waisbord, 2010). Mbabazi et al. (2015) found that in high-density communities, house-to-house visits that provided standard messages (including the basis for the campaign, the target population, nearest vaccination campaign location, interventions to be provided, and expected reactions after the vaccinations) reached more households than media messages. However, additional studies and analysis concerning local communication channels for expressing local needs and politics should be conducted (Obregon & Waisbord, 2010).

The second confounder, time of year, could have an effect on the SIA (WHO, 2016a). WHO guidance describes generally agreed upon timing issues that should be

considered when planning an SIA: a) executing the SIA during the school year to avail services to school-age children (Cates et al., 2011); b) scheduling the SIA during the low seasonal transmission period to disrupt prevailing chains of transmission; c) conduction of the SIA during seasons with less severe weather, such as not during or limited conduction during heavy snowfalls or the rainy season; and d) being aware of local events and occasions that may interfere with the SIA (WHO, 2016a). Though these timing issues have been recognized as issues that can affect an SIA, additional evidence on their actual impact on SIAs was lacking.

Finally, national level measles incidence can mask the level of incidence in regions and districts and subsequently effect how and when an SIA is implemented and thus its outcome. Haddad et al. (2010) described how these resulting over- or underestimations may redirect funds away from the area needing an SIA of longer duration; an SIA requiring a variety of outreach activities; or an area that could benefit from a different age range; start or duration for the SIA versus the age range designated for the nationwide SIA (Haddad et al., 2010).

Data for Decision Making

Encouraging the use of subnational data to guide SIAs can bolster use of local data for decision making. Health staff, especially local health staff, play a role in collecting data, but may need help in recognizing the importance of their data as well as their role in capturing data to be used for regional and national-level efforts (Hammond et al., 2010). In settings with limited resources, staff may not appreciate the need to complete data collection forms in a timely matter, or to finish them accurately as they do

not see the link between the data and clinical care they provide (Hammond et al., 2010). Staff need guidance in understanding how to achieve agency and local health goals through the use of information and data (Hammond et al., 2010). Giri et al. (2010) highlighted the strength of implementing micro-planning from the bottom up to acquire local ownership of adjusting the nation's strategy for measles, and subsequently rubella, elimination. Using local data for decision making enhanced commitments at all levels (Giri et al., 2011). Giri et al. (2011) found that a successful MCV campaign in Bhutan was based on a number of factors, including local level planning; health worker dedication; social mobilization; including public support and an understanding and accurate estimate of the target population at all levels.

In summary, MCV SIAs can be influenced by timing and implementation factors such as the point at which susceptibles approximate a new birth cohort; local-level characteristics of the health system: gaps in cold chain capacity and deficiencies in health services; and identifying and addressing features of the local population, such as measles incidence, MCV coverage and population mobility (Bishai et al, 2011; Haddad et al., 2010; Lakew et al., 2015). Additionally, outcome factors of an SIA included increasing MCV1 coverage; decreasing susceptibles; as well as strengthening the RI program by identifying defaulters and vaccinating them, informing target population numbers; improving community awareness of the need for immunizations; and using local data for decision making at multiple levels of the planning, implementation, and dissemination process (Fields et al., 2013; Haddad et al., 2010; Hanvoravongchai et al. 2011; Vijayaraghavan et al., 2007; Uddin et al., 2016). The next section will provide a brief

description of Tanzania's health system, their measles elimination approach and incidence, as well as the rational for choosing this country for the study.

Tanzania's Background

In 2016, Tanzania's population was 52,482,726 with 97% of the population living on the Mainland and the remainder living on the island of Zanzibar (CIA, 2022.; MoHSW et al., 2015). The majority of the population lives in rural areas (68.6%) with approximately a third (31.6%) living in urban areas (CIA, 2022). The country is separated into 30 regions: 5 in Zanzibar and 25 are on the Mainland (MoHSW et al., 2015). The regions are partitioned into districts, which are then further divided into local government units. The District Health Management Team designs and implements health strategies for the districts (Maokola et al., 2011), however, the local government units, or councils, govern and deliver public services at the lowest governing level (MoHSW, et al., 2015).

Over the past few years, Tanzania has made progress in reaching some of their Millennium Development Goal targets: in 2012, deaths from under-5 mortality decreased from 147 per 1,000 live births in 1999 to 67 deaths per 1,000 live births, as well as infant mortality deaths – 99 deaths per 1,000 live births in 1999 dropping to 46 deaths per 1,000 live births in 2012 (MoHSW, et al., 2015). Despite experiencing some gains in the health sector, Tanzania's health system continues to undergo challenges in the six health system building blocks mentioned earlier: health workforce; service delivery; access to fundamental medicines; leadership; financing; and health information systems (Shearer et al., 2012). Shortages in equipment and drugs, as well as the workforce, particularly health workers in rural areas, causes delays or possibly gaps in the delivery of health services

(Baker et al., 2017). For those health workers in the field, many were insufficiently trained while they work in remote settings providing fundamental public service (Baker, et al., 2017). Some were also subject to irregular supervision and thus inadequately supported to do their work (Baker et al., 2017).

Despite health system challenges described above, measles cases in Tanzania have undergone progressive improvement over the past few decades (Goodson et al., 2009). Routine measles vaccination was introduced to children in Tanzania in 1975 (Goodson et al., 2009). At the time of the newly introduced Expanded Program on Immunization in Tanzania, MCV1 coverage was estimated at 46% in 1980 and rose to approximately 80% in 1990 (Goodson et al., 2009). Coverage fluctuated in the 1990s between 72% and 83% and went from 78% in 2000 to >90% in 2003–2007 (Goodson et al., 2009).

The Tanzanian Ministry of Health (MOH) adopted WHO/UNICEF's strategic plan for measles mortality reduction in 2001 and implemented their first phased, wide age-range catch-up SIA from 2001 to 2002 (Goodson et al., 2010). The phased method left out age groups covered in previous SIAs, though, also neglected approximately one and a half birth cohorts, that is, children aged 6–7.5 years in July 2006 (Goodson et al., 2010). Broader target age range SIAs have continued, such as the 2014 SIA targeting children 9 months to 14 years of age, resulting in an MCV coverage of 97% (WHO, 2017c). As a result of increased MCV coverage through SIAs and RI, measles cases fell 95%, from 14,649 in 2000 to 727 in 2005 (Goodson et al., 2010). In 2018, the most

recent year for which complete data was available, Tanzania reported 800 measles cases (WHO, 2018b).

Tanzania was chosen for this study as it represented a peculiar case in duality: a country able to make impressive advancements in measles control (Goodson et al., 2010) while being a mainly rural health system facing ongoing infrastructure challenges (MoHSW, et al., 2015). Additionally, multiple types and years of data were available to review and triangulate, such as MCV coverage (National Bureau of Statistics and ICF Macro, 2011; National Bureau of Statistics and ICF Macro, 2011), and health services and SIA information (MoHSW et al., 2015; WHO, 2017c) and disease incidence (WHO, 2018b).

Definitions

Administrative vaccination coverage/administrative data: "calculated by dividing vaccine doses reported to have been administered to the target population by the total estimated target population" (CDC, 2010).

Clinically confirmed case: Any individual that meets the clinical case definition of suspected measles who does not have a laboratory-confirmed and epidemiologic linkage to another confirmed measles case (WHO, 2016c).

Cold chain: Sometimes denoted as the immunization supply chain, or the vaccine supply chain; The system consists of a sequence of connections devised to keep vaccines within WHO suggested temperature ranges, from the time of production to the time of administration to a patient; Major equipment includes freezers, refrigerators and cold boxes used during SIAs (WHO, 2015).

Covariate: “A continuous variable that is expected to change or vary with the outcome of a study. Generally speaking, a covariate can refer to any continuous variable that is expected to correlate with the outcome variable of interest. They are included in the analysis to increase precision or rule out alternative explanations for the findings but are not the focus of analysis.” (Ruppel, 2018).

Data triangulation (immunization): “an approach for critical synthesis of existing data from two or more independent sources to address relevant question for program planning and decision making. The data triangulation process identifies and aims to address limitations of any one data source and/or data collection methodology. Data triangulation also encourages deeper insight into the phenomena of interest through making sense of complementary information and integrating knowledge of the broader context and underlying process(es)” (Stashko, Gacic-Dobo, Dumolard, & Danavaro-Holliday, 2019); “the synthesis of two or more existing data sources to address relevant questions for programme planning and decision-making” (CDC et al, 2020).

Epidemiological (epi)-link: A patient who has direct contact with another laboratory-confirmed measles case and also meets the clinical case definition whose onset of rash was during the preceding 21 days (WHO, 2016c).

Expanded Program on Immunization (EPI): The WHO unit, created in 1974, that provides technical support to Member States and country immunization programs focused on accelerating disease control, increasing access to exceptional immunization services, and connecting to other health services that can be offered at the same times as immunization services (WHO, 2010).

Immunity: Resistance to a foreign substance or pathogen either by acquisition (vaccine or infecting agent) which results in active immunity; or previous exposure or infection which results in acquired immunity (Porta, 2014).

Immunization/vaccination campaigns: A delivery tactic used to rapidly reach a large number of children or individuals with at least one vaccine. These can be conducted either at the sub-national or national level, single antigen or combined dependent on the purpose and country needs. There are different types of vaccination campaigns: Supplementary Immunization Activities (SIAs) and Periodic Intensification of Routine Immunization (PIRI) (WHO, n.d.).

Lab confirmed: A person who has laboratory-confirmed measles virus infection and matches the clinical case definition (WHO, 2018b).

Local data: An assortment of community information collected at the community or lowest regional level (Porta, 2014).

Measles incidence: The number of occurrences of measles at the start, or of persons becoming ill, during a certain time period in a particular population or group (Porta, 2014).

Measles vaccination/immunization coverage: The projected percent of individuals in a target group who have received the measles vaccine; Used to pinpoint zones or regions and units of individuals with low vaccination coverage so health organizations or schools can take action in assisting to increase coverage and safeguard populations from the disease (CDC, 2016; Subaiya, et al., 2015).

MCV1: first dose of measles-containing vaccine (WHO, 2016b).

MCV2: second dose of measles-containing vaccine.

Microplanning: Preparation for an SIA starting at a lower level of administration and distributed up to the next level for their awareness; local needs, availability of resources, and gaps for an SIA are decided at the lower level to ensure a satisfactory and uneventful implementation; a "bottom-up" approach to SIA planning and implementation (WHO, 2016a).

Outreach: Any service delivery approach that necessitates that the health facility workforce leaves their institution or building to provide immunizations (WHO, 2017a).

Periodic Intensification of Routine Immunization (PIRI): A term used to describe a range of time-limited, occasional activities or campaigns employed to dispense routine vaccinations to under-vaccinated populations and to promote the benefits of vaccination. PIRIs include Child Health Days, National Vaccination Weeks, and Child Health Weeks. Vaccine doses delivered through a PIRI activity are considered routine, rather than supplemental as children are screened for eligibility based on immunization history and age and the doses are documented on in immunization registers and on vaccination cards and included in the national administrative coverage data (WHO, n.d.).

Routine immunization program (RI): The appropriate, consistent and sustainable interface between the vaccine, staff that deliver it and recipients of the vaccine to ensure everyone is appropriately vaccinated against vaccine-preventable diseases (WHO, 2017b).

Social marketing: the application of commercial marketing techniques, such as population segmentation, and relates them to influence the behaviors of the target

audience; and whose results ultimately benefit the individual and society (Nowak et al., 2015).

Social mobilization: a holistic method that involves all pertinent sectors of society: technical experts, policymakers, opinion leaders, the media, administrators, professional associations, the private sector, religious groups, community members, NGHOs, and individuals; It takes the collective needs of the people into account, encompasses the principle of community participation, and empowers groups and individuals for action (Chimpololo & Burrowes, 2019).

Subnational: "Of, relating to, or designating a region or group within a nation; below a national level" (Oxford Dictionaries, 2016).

Susceptibles: Individuals that are vulnerable or do not have resistance to a disease; the active condition of being more liable or likely to be affected by a health factor (Porta, 2014).

Suspected case: An individual in whom a clinician suspects measles OR any individual reporting a fever, AND widespread rash, AND runny nose, cough, or conjunctivitis (WHO, 2018b).

Supplemental immunization activity (SIA): A successful tactic for bringing vaccination to children who may be missed or underserved by the RI program or to older vulnerable persons who are not part of the target population of the EPI services; also known as mass-immunization campaigns (WHO, 2016a).

- *Catch-up campaign*: a onetime SIA, often nationwide, used to vaccinate the main target population involved in disease transmission; the strategy is used to rapidly decrease the number of susceptible individuals (WHO, 2016a).
- *Follow-up campaign*: an intermittent SIA, usually countrywide, implemented every 2 to 5 years, aimed at those children born since the last SIA to reach those previously missed and those who did not acquire immunity after their first vaccination (WHO, 2016a).
- *Mop-up campaign*: sometimes refrered to as House-to-house – SIA strategy recommended in areas where there is indication of vaccination refusals (WHO, 2016a).

Vaccine supply stock out: Deficiency in quantity of a vaccine (Subaiya, et al., 2015) or diluent, i.e., liquid used to reconstitute a freeze-dried vaccine such as MCV (Each vaccine has a specific diluent that should not be used to reconstitute any other vaccine) (OpenLearn Works, n.d.).

Assumptions

As in most research, there were assumptions associated with the study that are basic to the foundation that are unable to be proven and are unverified (Frankfort-Nachmias and Nachmias, 2008), but without them, the research question could not exist (Leedy and Ormond, 2010). In this study, it was assumed that the DHS data includes at least two sets or years of SIA data to compare and that each set will be complete, that is, contain information for all variables, such as vaccine stock out information and measles vaccine coverage. DHS Surveys have sizeable sample sizes and representative of the

national, regional and urban-rural levels and normally are implemented roughly every 5 years, allowing for comparisons over time (ICF, n.d.). One can safely presume that the two sets of DHS data will have the needed two years of data as they are from two distinct years. Further, the data sets should contain the same needed variables as pertinent questions will be analyzed from the Woman's Questionnaire from both years, which stays relatively consistent from year to year, to allow comparability within and across countries (ICF, 2007a). It is also assumed that measles incidence data captured most cases of the disease. Data submitted to WHO contains information on all types of measles cases: suspected, clinically confirmed, epi-linked, and lab confirmed (WHO, 2018b). However, some cases may not have sought health care or may not have been reported for a variety of reasons, and that during outbreaks, some countries may only report a small portion of all measles cases through WHO's case-based system (WHO, 2018b). The WHO-UNICEF Joint Reporting data was assumed to be comparable to data utilized in Tanzania as Tanzania is the source of the WHO-UNICEF data and WHO and UNICEF created the Joint Reporting Form (JRF) as a way to strengthen partnerships and reduce reporting burden (WHO, 2013c). Through the JRF, Member States submit information on national immunization coverage estimates, vaccine-preventable disease cases, national immunization schedules, in addition to performance markers of the immunization system (WHO, 2013c). Finally, was assumed that the data sets can be combined and analyzed, or triangulated, to effectively determine differences and similarities in immunization coverage and other variables identified for the study. As all of the data sets have similar

or the same variables, little to no manipulation of the combined data will need to be performed.

Assumptions identified above were essential to the foundation of the study as they strengthen the reliability and validity of the study results (Leedy & Ormond, 2010), and within the context of the study, provides some perspective on the completeness, generalizability, and compatibility of the data sets to be used.

Scope and Delimitations

The study was designed to address what resources can be used for the planning of measles SIAs. Specifically, using subnational level versus national-level data to guide the timing, implementation, and impact of a measles mass vaccination campaign. Multiple data sources were triangulated to determine if there was a difference between subnational and national-level data sources with regards to SIA outcome.

Delimitations, or features of the study that define the limits and scope of the study but are not within the purview of this researcher (Simon, 2011), include the fact that the study used secondary data sources and as such, was limited to the questions posed, variables present, and time period of the data sets. As the data was intended to be merged, limitations surrounded compatibility and quality of the different data collected. Using data collected at different points in time by the same primary researchers, thus the same data collection procedures and variable naming conventions, should have reduce certain limitations of the data. The age range for the study will be children 12 months to 5 years, however, limitations will be according to age or age groups identified in each data set.

Another limitation of the study was its generalizability. Generalizability of study results is reliant on internal validity - whether an experimental program or intervention leads to a difference and whether there is adequate proof to support the assertion (Fink, 2013). Research results cannot be generalized to other settings and populations without knowing if the results are due to other factors or the experimental program itself (Fink, 2013). As the current study was conducted with secondary data analysis of existing data as opposed to utilizing a random sampling method, which offers the greatest likelihood of being internally valid, the results may not be generalizable to other populations or settings (Fink, 2013). Additionally, secondary data is often collected years prior to a study. Researchers should use caution when making inferences on the older data as current circumstantial applications, e.g., COVID-19 implications, may need to be tempered. (Sullivan, et al., 2020).

Significance, Summary, and Conclusions

SIAs have been recognized as a cost-effective service delivery method as they enhance equity in vaccine coverage among populations and often bring other health services, such as albendazole, insecticide-treated bed nets, and vitamin A (Goodson et al., 2012). In times when SIAs are often supported with limited funds or funds could have alternate uses, cost-effective and strategic decisions are of greatest concern (Bishai et al., 2011). Successful SIAs demand detailed micro-planning at the community level where local level data on vaccine storage, vaccination sites, vaccination coverage and disease incidence varies (Goodson et al., 2012). Often, districts collect and submit subnational data to the national level without fully utilizing their data for local action. Encouraging

the use of subnational data to guide SIAs may bolster use of local data for decision-making. Helping local health staff to recognize the role they play in collecting data, as well as helping them recognize the importance of their data that will be used for regional and national-level efforts may help compel buy-in from multiple levels, but more importantly, will show the value national level places on local level counterparts (Hammond et al., 2010).

Cultural changes that affect individual's worth as well as improves the health of a community are positive social changes that may result from the study (Chen, 2015). In addition to the individual-level social change proposed by the study above, a broader level social change or implication is intended by the study. The strategy of planning and implementing SIAs based on local vaccination coverage, stock out data, or a combination of the three, may result in more strategic and cost-effective measles elimination efforts by countries willing to use the possible new recommendations. These efforts may identify pockets of susceptibles, or actual measles cases, strengthen the health system by providing additional training, monitoring and supervision to health staff, and improve access to health services to those normally outside of the health system (Colson et al., 2015; Hurtado, Grais, & Ferrari, 2013; Khetsuriani, et al., 2011; Lessler et al., 2016; Minettie et al., 2013; Perry et al., 2015).

The WHO Stretegic Advisory Group of Experts (SAGE) recognized the need to identify effective strategies in bolstering SIA coverage, specifically in different epidemiologial settings as well as recommending further research on an algorithm to guide countries on when to implement measles SIAs. (Goodson et al., 2012; WHO 2015).

Revealing the utility of subnational information will fill the research gap by providing descriptive information on whether and possibly how subnational data can be used to guide the timing, implementation, or impact of measles SIAs. If changes in SIA planning and implementation result from this research, and improvements in immunization coverage and measles incidence are effectuated, reduced mortality and spread of measles will indeed be the positive social outcome. The next section will include an explanation of the research design, methodology, data analysis and possible threats to the validity of the study.

Section 2: Research Design and Data Collection

Timing of the SIAs is currently based on national immunization coverage for the measles vaccine and is more of a "one size fits all" or general strategy for all countries implementing SIAs (WHO, 2015). Current guidelines recommend that countries with vulnerable health systems implement SIAs every 2–4 years with children who were born since the last SIA, usually children between 9 months and 5 years of age (WHO, 2009; Weldegebriel et al., 2011). This approach does not take into account the variability of immunization coverage between regions or districts, or for stock outs that may occur at various levels within a country. The current study was aimed at filling the gap on whether subnational data can be used to guide the timing, implementation, or impact of measles SIAs.

Research Design and Rationale

The research design was a retrospective cross-sectional study using secondary data. In retrospective cross-sectional designs, investigators use data previously collected

for other objectives to assess individuals at one point in time (Creswell, 2009; Mann, 2003). The focus is typically a series of questions regarding previous experiences, attitudes, or backgrounds with the purpose of describing the study population at one point in time (Fink, 2013; Mann, 2003). Because the current research question addressed the difference in SIA outcome when district-level data are used for planning and implementation of SIAs versus using national-level immunization coverage data alone, a cross-sectional study was appropriate because retrospective cross-sectional studies address relationships between characteristics and outcomes but are unable to differentiate between cause and effect (Frankfort-Nachmias & Nachmias, 2008; Mann, 2003). Identifying associations and determining prevalence are key objectives in cross-sectional studies (Frankfort-Nachmias & Nachmias, 2008; Mann, 2003). Because the current study was retrospective in nature, looking at the study population at one point was the limiting constraint. There were no resource constraints associated with secondary analysis of data that had already been collected. Independent variables for the study included MCV pre-SIA, stock out data (measles vaccine or diluent stock out), and the adequacy of the cold chain. The dependent variable was district-level SIA outcome, or the MCV coverage post-SIA. Potential confounding variables included social marketing related to SIA and the time of year during which the SIA was conducted (dry versus rainy season; school year versus vacation).

Methodology

The target population of the study was children 12 months to 5 years of age because this is often the targeted age range for SIAs (WHO, 2016a) and the group with

the highest risk of complications or fatality from measles (CDC, 2015). The population was the country of Tanzania during the time period 2010–2016.

Sampling Strategy and Procedures Used to Collect Secondary Data

The study sample was drawn from a combination of three databases: the 2010 Tanzania DHS data of 10,139 households, the 2015–2016 Tanzania DHS data of 13,266 households, and the 2014 SPA containing 1,200 facilities plus measles incidence data and measles SIAs for the same time periods. Inclusion criteria for the study were children between 12 months and 5 years of age, specifically children whose birthdate was between January 1, 2005, and December 31, 2014, for the 2010 TDHS data and between January 1, 2010, and December 31, 2015, for the 2015–2016 TDHS data. All facility information from the 2014 SPA data was included. Because the focus of the study is examining subnational data, all records were organized/filtered and analyzed by district and region except measles incidence and SIA data. Exclusion criteria were children outside the birth time frame and records missing a district or region designation.

The 2010 TDHS sample was planned to offer estimates for the entire country, for Zanzibar, and for the rural and urban areas in the Mainland (National Bureau of Statistics and ICF Macro, 2011). To approximate geographic differences for certain demographic markers, the mainland Tanzania regions were folded into seven geographic zones. Though not official administrative zones, the Reproductive and Child Health Section of the MoHSW uses these classifications. To reduce sampling error and to have a comparatively large number of cases, I used zones in each geographic area (National Bureau of Statistics and ICF Macro, 2011).

The 2015 TDHS sample design was conducted in two stages to deliver estimates for the whole country: Mainland and Zanzibar, urban and rural [Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) et al., 2016]. Sample points, or clusters, were selected in the first stage containing enumeration areas defined for the 2012 Tanzania Population and Housing Census (MoHCDGEC et al., 2016). A total of 608 clusters was chosen. The second stage entailed a systematic selection of 22 households from a line listing of all 608 selected clusters. Finally, to estimate geographic differences, the researchers divided Tanzania into nine geographic zones. Grouping the regions this way allowed a relatively sizable number of participants in the denominator, thereby reducing sampling error (see MoHCDGEC et al., 2016).

Power Analysis

Because I used previously collected data, the sample size was already established (see Doolan & Froelicher, 2009). However, to ensure the data set had an adequate sample size to respond to the research question, or to reduce the chances of properly rejecting a false null hypothesis with the available sample, I performed a power analysis (see Doolan & Froelicher, 2009). Statistical power helps to ensure the chances that a study will obtain a statistically significant variation between groups or interventions when a difference is present (G. Sullivan & Feinn, 2012). If the power is high enough, the chances of determining that there is an effect is high (G. Sullivan & Feinn, 2012). A power analysis includes four values: effect size, variability, alpha level, and the number of subjects (Doolan & Froelicher, 2009). Effect size, or the main outcome or finding of the study, is generally classified as small (0.2), medium (0.5), and large (> 0.8) (G. Sullivan & Feinn,

2012). A medium effect has been described as being noticeable to the naked eye of a thorough observer; this level of effect was used for the current study (see G. Sullivan & Feinn, 2012). The most frequently determined alpha level, also referred to as the significance level, is .05 (5%), but other levels often used are .01 and .10 (Mertler & Vannatta, 2010).

Because the data were analyzed by district and region, the maximum number of records from the health facility data set was 1,200; however, the maximum number of households was 13,266 (from the 2015 TDHS data set) with an unknown number of eligible children within the designated age range. Once approval for the study was received, these considerations were implemented to examine the data and determine the resulting sample size using a small effect size of 0.2 and an alpha level of .05. I anticipated that these statistical analysis measures would be strong enough to reveal a minimal yet significant effect (see Mertler & Vannatta, 2010). A researcher must be aware that effect sizes have supplementary value beyond actual difference if a research question is specified in terms of effect sizes and then explained alongside the actual differences (Leppink et al., 2016). Of the studies addressing similar local data triggers for SIAs, none reported effect size (Lessler et al., 2016). For the current study, G*Power Statistical Power Analysis tool was used to compute the power analysis (see Faul, 2007), resulting in a minimum sample size of 260. For each data set, the sample size was calculated a priori (prior to the study taking place) and post hoc (atter the study was conducted) to confirm the sample had the likelihood of rejecting the false null hypothesis, or not providing strong enough evidence that the null hypothesis is false (see Mayr,

2007). Table 1 presents data sets used for the study, their total sample size, and their sample size based on a 0.2 power calculation.

Table 1

Secondary Data Sets and Sample Sizes

Data set	Total sample size	Statistical power analysis size					
		t test		ANOVA		Chi-square	
		A priori	Post hoc	A priori	Post hoc	A priori	Post hoc
2010 TDHS 2015 TDHS 2014 SPA	10,139 households 13,266 households 1,200 health facilities	262	260	858	858	495	325
Data setss based on actual cases or events							
Tanzania Measles Incidence/cases Data – WHO (2020 & 2016)	One figure per year	N/A		N/A		N/A	
WHO Summary Measles SIAs 2000-2016	Yes/no variable	N/A		N/A		N/A	
Tanzania Administrative data – WHO (2010-2016)	One figure per year	N/A		N/A		N/A	

DHS Data

The DHS program has been recognized worldwide since 1984 for its accurate collection and dissemination of representative data on child health, gender fertility, malaria, family planning, nutrition maternal, and HIV/AID (ICF, 2007b). Country surveys are used to gather evidence on health and basic demographic topics allowing flexibility to meet local needs and conditions. The model questionnaires, including the health, woman's, men's, and household questionnaires, of the DHS program emphasize basic indicators and flexibility (ICF, 2007b). Although the questionnaires contain the

same information from one country to another, they vary in some questions posed and how the information is used (ICF, n.d.). DHS data are available and encouraged to be used for additional analysis through comparative studies, journal publications, and trend reports (ICF, n.d.).

The 2010 TDHS was the eighth DHS conducted in Tanzania (National Bureau of Statistics and ICF Macro, 2011). The sample for the 2010 TDHS was designed to produce distinct estimations on important markers for the national level, seven zones, and urban and rural areas (National Bureau of Statistics and ICF Macro, 2011). For selected indicators, estimates can be calculated at the regional level. The TDHS comprises three questionnaires: the women's questionnaire, the household questionnaire, and the men's questionnaire. The women's questionnaire was the only one used in the current study because this questionnaire contained the pertinent variables. Variables from the women's questionnaire included in the study were current age of child, vaccination card available, date of measles vaccination, and vaccinations received through immunization campaign in the last 2 years (see National Bureau of Statistics and ICF Macro, 2011).

The 2002 Population and Housing Census was used to draw 475 clusters, or sampling points, in the first stage. Eighteen sample points in 20 mainland regions were identified plus 25 in Dar es Salaam (National Bureau of Statistics and ICF Macro, 2011). Each region of Zanzibar identified 18 clusters resulting in 90 total sample points (National Bureau of Statistics and ICF Macro, 2011). The second phase of sampling involved identifying 16 households in Dar es Salaam and 22 households in each cluster from the rest of the regions (MoHSW et al., 2015).

Fourteen teams participated in data collection: three in Zanzibar and 11 on the mainland. Teams consisted of five interviewers (four women and one man), a field editor, a supervisor, and a driver (National Bureau of Statistics and ICF Macro, 2011). To ensure quality, consistency, and completeness, the supervisor and field editor reviewed questionnaires prior to leaving each area (National Bureau of Statistics and ICF Macro, 2011). Additional quality control was conducted by National Bureau of Statistics staff by visiting teams in the field to monitor their work and data quality and to reinterview particular households (National Bureau of Statistics and ICF Macro, 2011).

The inclusion criteria involved interviewing all women age 15–49 who were visitors or permanent residents in the household at the time of the Woman's survey conduction (National Bureau of Statistics and ICF Macro, 2011). Of the 10,300 households chosen for the survey, 9,741 were inhabited throughout the data collection period. Of these households, 9,623 were interviewed, resulting in a 99% response rate (National Bureau of Statistics and ICF Macro, 2011). In the households interviewed, 10,522 women met the criteria to be interviewed with 10,139 agreeing to be interviewed, producing a response rate of 96% (National Bureau of Statistics and ICF Macro, 2011).

The 2015–2016 TDHS included four questionnaires. In addition to the Woman's Questionnaire, the Household Questionnaire, and the Man's Questionnaire, the 2015–2016 version included the Biomarker Questionnaire, part of the larger Malaria Indicators Survey, resulting in the name TDHS-MIS (MoHCDGEC et al., 2016). These surveys were centered on the DHS program's traditional DHS questionnaires but were adjusted to echo the relevant health issues in more than 90 countries. As with the 2010 data set, only

the woman's questionnaire variables (current age of child, vaccination card available, and date of measles vaccination) were included in the current study.

A two-stage sample process was also used for the 2015–2016 TDHS-MIS in an effort to provide estimates for rural and urban areas of Zanzibar and the Mainland (MoHCDGEC et al., 2016). The 2012 Tanzania Population and Housing Census was used as the basis from which 608 clusters were drawn in the first stage (MoHCDGEC et al., 2016). The second stage involved selecting 22 households out of the 608 identified clusters resulting in a probability sample of 13,376 households (MoHCDGEC et al., 2016). The country was apportioned into nine geographic zones to estimate certain geographic demographic indicator differentials (MoHCDGEC et al., 2016). This grouping of the regions into zones permitted a sizable denominator to reduce sampling error (MoHCDGEC et al., 2016). As with the 2010 TDHS, the 2015–2016 TDMS-MIS used the same inclusion criteria of all women, visitors or residents, age 15–49 who were present in the home at the time of the survey (MoHCDGEC et al., 2016).

Data collection was conducted by 16 field teams for the 2015–2016 survey: 13 on the mainland and three on Zanzibar (MoHCDGEC et al., 2016). Team composition and quality control measures were the same as during the 2010 survey (MoHCDGEC et al., 2016). For the 2015–2016 data collection period, 13,360 households were designated for the study, of which 12,767 were inhabited (MoHCDGEC et al., 2016). The response rate was 98% with 12,563 households successfully being interviewed (MoHCDGEC et al., 2016). Of the 13,634 qualified women, 13,266 agreed to be interviewed (MoHCDGEC et

al., 2016). The response rate for the 2015–2016 DHS was 97% (MoHCDGEC et al., 2016).

SPA Data

The SPA survey offers an overview of the strengths and weaknesses of a country's health care delivery systems through interviewing clients and providers and cataloguing a sample of health care facilities in a country (ICF, 2017a). The SPA is focused on answering four broad questions:

- What is the availability of different health services in a country?
- To what extent are facilities prepared to provide health services?
- To what extent does the service delivery process follow generally accepted standards of care?"
- Are clients and service providers satisfied with the service delivery environment? (ICF, 2017a).

As with the resulting data from the four Model Questionnaires included in DHS, SPA data are promoted as a source for further analysis to examine, compare, and explore trends and indicators (ICF, n.d.).

The 2014–2015 Tanzania SPA consisted of the facility inventory questionnaire, ethe health provider interview questionnaire, the observation protocols, and the exit interview questionnaires for antenatal clinics and family planning clients (MoHSW et al., 2015) and health shifts in developing countries. The study focused on the child health and infrastructure, resources, and systems themes in the facility inventory questionnaire.

A sample of 1,200 of 7,102 formal-sector health facilities was designated to participate in the SPA. The sample was taken from a verified list of active health facilities on Tanzania's mainland and Zanzibar island (MoHSW et al., 2015). Health facilities included health centers, clinics, dispensaries, and hospitals managed by private-for-profit, government, faith-based, and semigovernment organizations (MoHSW et al., 2015). The sample was intended to offer regionally representative results for the 25 regions on the mainland and the five Zanzibar regions (a total of 30 survey regions) and nationally representative outcomes by facility type (MoHSW et al., 2015). Of the 1,200 health facilities designated to take part in the study, 1,188 were surveyed, seven declined to participate, four were not yet functional or were closed, and one was not able to be contacted (MoHSW et al., 2015).

SPA data are typically collected by teams of 10–15 interviewers, often composed of 3–4 health workers (ICF, 2017b). Tanzania implemented 20 teams (18 for the mainland and two for Zanzibar) consisting of five members: three interviewers, a team leader, and a driver (MoHSW et al., 2015). Data collection usually took –2–3 days for hospitals, and approximately 1 day for health centers and dispensary clinics (MoHSW et al., 2015). The data were collected from 400–700 facilities chosen from an inclusive list of health facilities found in a country (sampling frame) characterized by facility type, organization type (nonpublic and public), and area of the country (ICF, 2017b). The sample provides indicators at the national level by facility type and organization type in addition to regional level aggregate indicators (ICF, 2017b). SPA variables included in the study were: child vaccination services at facility; number of days measles vaccination

provided at health facility; number of days measles vaccination provided through outreach; health facility routinely stores vaccines; measles vaccine and diluent stock out information, and health facility cold chain information. This data was intended to be merged with the other data and linked by district of the health facility.

Measles Incidence Data. Disease incidence is the standard measure of an immunization system's impact (WHO, 2013c). Disease incidence data often represents only a portion of actual cases as some patients may not seek medical care or, if diagnosed, are not reported. Nonetheless, the data can be valuable in monitoring trends (WHO, 2013c). As countries implement distinct surveillance systems, ensuing reporting varies in sensitivity and quality (WHO, 2013c). Additional information on the surveillance system is recommended before one compares incidence between countries (WHO, 2013c).

Timely reporting of measles cases is an element of surveillance and is crucial to disease control (WHO, 2013b). Finding and verifying suspected cases through measles surveillance permits: 1) detecting outbreaks early, 2) examination of on-going outbreak transmission to allow for more efficient response efforts, and 3) estimating incidence based on reported data (WHO, 2013b).

The majority of Member States report confirmed and suspected measles cases to WHO (WHO, 2013b). Confirmed measles cases will be used in the study to reflect the measles incidence data for Tanzania. Confirmed measles cases includes clinically-confirmed, epi-link and lab confirmed. As was described earlier, lab confirmed cases are those cases where a specimen has been taken, measles virus is detected, and the patient

presents with the clinical case definition of suspected measles: fever, AND generalized rash, AND cough, runny nose or conjunctivitis (WHO, 2018b). Clinically confirmed cases are those where an individual that meets the clinical case definition of suspected measles who does not have a laboratory-confirmed and epidemiologic linkage to another confirmed measles case (WHO, 2016c). Finally, an epi-linked case is a patient who has direct contact with another laboratory-confirmed measles case and also meets the clinical case definition whose onset of rash was during the preceding 21 days (WHO, 2016c).

Data collection and access procedures for the secondary data were as follows: DHS and SPA data were accessed by registering at the DHS website and providing a summary of the study, the research design, research question and the data analysis plan. The approval letters granting access to both Tanzania's DHS and SPA data are located in the appendix. The data was downloaded into SPSS for analysis.

Reported measles cases data were accessed by going to the WHO website and selecting Tanzania. This data was not merged with the other data but was triangulated to provide an understanding of the country's measles burden.

Measles SIA Data. Supplementary immunization activity data is collected on a global level by the WHO and is readily available to the public (WHO, 2017c). Information is collected on the country, dates of the SIA, extent (national or subnational), age group, target population quantity for the SIA, as well as the percent reached and SIA survey information (WHO, 2017c). Data from the database was triangulated with the above databases as a "yes" or "no" if an SIA was conducted during the time period of secondary data available: 2010 -1016. The above-mentioned qualitative characteristics

will be used to describe those years in question but will not be merged into the larger data set.

Instrumentation and Operationalization of Constructs

The independent variables for the study, MCV coverage pre-SIA (MVPRE), stock-out data, and cold chain information was used to gage any substantial associations on MCV coverage post-SIA, the dependent variable. The variable measles coverage pre-SIA (MVPRE) in the 2010 TDHS described those children that have received at least one MCV at the time of the survey. Routine storage of vaccines at the health facility (HFSV) and presence of measles vaccine and diluent (MVD) provide a description of whether or not vaccines are readily available at that health facility, thus resulting in the parent having to come back at a later date or travel to another health facility to have their child vaccinated. The variable cold chain monitoring chart completed for the past 30 days (CCCP) and current temperature of the vaccine refrigerator (CTVR) provided a glimpse into the supervision and management of the cold chain. Options for the variables include reported as “yes, observed”, reported as “yes, not observed”, and “no.” Standard immunization policy calls for documentation of the vaccine refrigerator temperature twice a day, seven days a week (Wirkas, 2007). Failure to observe fluctuations in vaccine refrigerator temperature outside the appropriate temperature range for vaccines could cause vaccines to be ineffective, thus not providing immunity to the recipient (Wirkas, 2007).

In order to conduct statistical analysis of this association, some of the data will be transformed: numerical values will be given to variables that contain non-numerical

values and be calculated by district, region and national. For example, the ratio level of measurement will be converted from the nominal level of measurement after transforming the measles vaccination variable (Frankfort-Nachmias & Nachmias, 2008). The measles vaccination variable was originally collected as date. If the date is present in the data, it will be converted to a “1”, which represents “yes; a “0” will represent measles vaccination not received. Table 2 summarizes study variables and their levels of measurement.

Table 2

Dependent and Independent Variable Characteristics

Type of variable	Database	Variable	Variable name	Original format	Converted format / categories	Level of measurement
Independent	2010 TDHS	Measles vaccination	MCPRE	0=No, 1=Vacc date on card, 2=Reported by mother, 3=Vacc. marked on card, 8=DK	1=Yes, 0=No, 8=Don't know then, % (district only)	Nominal, then Interval (district only)
Independent	SPA	Facility routinely stores vaccines	HFSV	1= Routinely store vaccines, 2= Stores no vaccines	NA	Nominal
Independent	SPA	Facility maintains cold chain monitoring chart	CCMS	1=Yes, 2=No	NA	Nominal
Independent	SPA	Cold chain monitoring chart completed for past 30 days	CCCP	1= Yes, completed, 2= No, not completed	NA	Nominal
Independent	SPA	Measles vaccine and diluent;	MVDO	1= Observed, at least 1 valid, 2= Observed available, nonvalid, 3= Reported available, not seen, 4= Not available today/Don't know, 5= Never available	NA	Nominal
Independent	SPA	Current temperature in vaccine refrigerator (at the time of the interview)	CTVR	1= Between 2-8˚; 2=>8˚, 3=<2 ˚, 4=Thermometer not functional	N/A	Nominal
Confounding	Measles Incidence	Number of measles cases	MINC	Number	NA	Interval
Dependent	2015-2016 TDHS	Measles vaccination	MCPOS	0=No, 1=Vacc date on card, 2=Reported by mother, 3=Vacc. marked on card, 8=DK	1=Yes, 2=No, 8=Don't Know then % (District only)	Nominal, then converted to Ratio (District only)
	2000 -2016 SIAs	National level SIA conducted in 2011 and 2014		0=No, 1=Yes	NA	Nominal

Data Analysis Plan

Data Cleaning Procedures

The Statistical Package for the Social Science (SPSS) version 23 was used to clean and analyze the data. A frequency analysis was performed to identify missing or inconsistent values for each variable (Frankfort-Nachmias & Nachmias, 2008). Further consistency checking will be performed as many questions may be coded independently and answered, other questions may be interconnected and thus must be internally consistent (Frankfort-Nachmias & Nachmias, 2008). For example, if the response for question *Health facility routinely stores vaccines*=2 or no, there should not be an answer for *Measles vaccine and diluent* observed=1.

Research Questions

The data analysis plan addressed the research questions:

Overall RQ. What was the difference in SIA outcome if subnational-level data was used when planning the timing and implementation strategy of SIAs versus using national level immunization coverage data alone?

RQ1: What was the difference in SIA outcome when subnational-level immunization if coverage data was used, such as MCV, as a basis for SIA timing and implementation compared to using national-level data?

H_o1: There was no difference in SIA outcome, such as MCV coverage post-SIA, if subnational-level immunization coverage data versus national-level coverage data was used for the basis of SIA timing and implementation.

H_a1: There was a difference in SIA outcome, such as MCV coverage post-SIA, if subnational-level immunization coverage data versus national-level coverage data was used for the basis of SIA timing and implementation.

RQ2: What was the difference in SIA outcome if subnational-level vaccine if stock-out data was used as a basis for SIA timing and implementation compared to using national-level data?

H_o2: There was no difference in SIA outcome, such as MCV coverage post-SIA, due to lapse in immunization services, if subnational-level vaccine stock-out data versus national-level stock-out data was used for the basis of SIA timing and implementation.

H_a2: There was a difference in SIA outcome, such as MCV coverage post-SIA, due to lapse in coverage immunization services, if subnational-level vaccine stock-out data versus national-level stock-out data was used for the basis of SIA timing and implementation.

RQ3: What was the difference in SIA outcome if subnational-level cold chain information was used when planning the timing and implementation strategy of SIAs compared to using national-level data?

H_o3: There was no difference in SIA outcome, such as MCV coverage post-SIA, for that area, if subnational-level gaps in the cold chain data versus national-level gaps in the cold chain data was used for the basis of SIA timing and implementation.

H_a3: There was a difference in SIA outcome, such as MCV coverage post-SIA, for that area, if subnational-level data gaps in the cold chain data versus national-level data was used for the basis of SIA timing and implementation.

Descriptive analysis, including the means, range of scores and standard deviations for all independent and dependent variables was conducted (Creswell, 2009). To explore associations between the dependent variable: MCV coverage post-SIA and independent variables: MCV pre-SIA, stock-out data, and inadequacy in cold chain elements, a multiple regression will be performed (Creswell, 2009). Multiple regression pinpoints the soundest assortment of predictors (independent variables) of the dependent variable (Mertler & Vannatta, 2010). It is best utilized when there is one dependent quantitative variable and multiple independent variables (Mertler & Vannatta, 2010). The best combination of predictors of the dependent variable is created when a chronological multiple regression individually chooses independent variables by their capability to explain the greatest difference in the dependent variable (Mertler & Vannatta, 2010).

Rationale for Inclusion of Potential Covariates and/or Confounding Variables

Confounding variables identified for the study are social marketing and timing of the SIA. As described earlier, these factors may influence the outcome, that is, MCV coverage post-SIA, by either encouraging participation in the SIA (social marketing) or facilitating or hindering participation in the SIA (SIA being conducted in schools or taking place during the rainy or harsh weather season or local holidays) (Porta, 2014). Though these elements have been identified as confounding factors, information on their actual effects on MCV coverage have not been found in the literature. Because of this lack of current literature evidence, these confounding factors will be limitations of the study.

In addition to the above confounding factors, measles incidence national level, or aggregate data, may conceal a large variance at the district level, with administrative data often underestimating or overestimating actual coverage or need, for example due to district level vaccine stock-outs (Haddad et al., 2010; WHO, 2013). Haddad et al. (2013) showed that district level coverage estimates vary between and within regions.

The goal of my analysis was to generate a linear grouping of the independent variables that effectively predicts my dependent variable: MCV coverage post-SIA (Mertler & Vannatta, 2010). Interpreting these multiple regression results centered on determining the suitability of the regression model used (Mertler & Vannatta, 2010).

Statistical Tests Used in Testing the Hypothesis

Stepwise multiple regression was planned to determine which independent variables may influence the overall prediction of the outcome (Mertler & Vannatta, 2010). This type of analysis is often used in exploratory studies (Mertler & Vannatta, 2010). For the study at hand, the independent variables measles coverage pre-SIA (MVPRE), routine storage of vaccines at health facility (HFSV), cold chain monitoring chart completed for past 30 days (CCCP), presence of measles vaccine and diluent (MVD), and current temperature of the vaccine refrigerator (CTVR) was analyzed with regard to outcome difference, that is, measles coverage, post-SIA (MCPOS). Analyses involved determining if there was indeed a difference in outcome and a description of the relationship or correlation between the independent and dependent variables (Porta, 2014).

The following statistical steps were used in the analysis: 1) Descriptive statistics were conducted on all records or observations (frequency, standard deviations, means and ranges); and 2) Inferential statistics, including correlations, model summary, ANOVA and coefficients calculations on the independent and dependent variables.

The model summary was presented in a table that provides the *R* and R^2 values and examins how well each independent variable or a combination of the independent variables, MCV pre-SIA, vaccine stock data, and inadequacy in cold chain elements, predicts MCV coverage post-SIA, the dependent variable (Mertler & Vannatta, 2010).

The analysis of variance (ANOVA) table provides information on the *F*-test (used to exam variance among populations) and its respective significance (Mertler & Vannatta, 2010). This test assesses the association between the independent and dependent variables: if the *F*-test is linear, the relationship will be also and the model appropriately predicts the dependent variable (Mertler & Vannatta, 2010).

The coefficient output table includes the partial or unstandardized regression coefficient, the standard error, and *t* and *p* values (Mertler & Vannatta, 2010). The regression coefficient provides the anticipated change in the dependent variable for a one-unit increase in the independent variable which signifies the slope weight for each independent variable (Mertler & Vannatta, 2010). A positive coefficient indicates a positive or affirmative relationship: when the independent variable increases, so does the dependent variable. A negative coefficient is the opposite. The *p*-value, or significance, is the likelihood of reaching a result no less extreme as the result observed (Silva-Aycaguer, et al., 2010). Similar to the t-value, it is used to “measure the strength of evidence against

the null hypothesis in a single experiment assuming that the null hypothesis is true (Silva-Aycaguer, et al., 2010).” A low *p*-value (<0.05) is indicative of rejecting the null hypothesis (Silva-Aycaguer, et al., 2010), which is the objective. Table 3 summarizes the statistical tests planned for each hypothesis and combination of variables.

Table 3

Hypotheses and Statistical Analysis Plan

No	Hypothesis	Variables	Type of variable	Statistical analysis
H_1	There is a difference in SIA outcome, such as MCV coverage post-SIA, when **subnational -level immunization coverage** data versus national-level coverage data is used for the basis of SIA timing and implementation.	MVPRE	Independent	Multiple Regression
		MCPOS	Dependent	
		MINC	Confounding	
H_2	There is a difference in SIA outcome, such as MCV coverage post-SIA, due to lapse in coverage immunization services, when **subnational -level vaccine stock-out data** versus national-level stock-out data is used for the basis of SIA timing and implementation.	HFSV	Independent	Multiple Regression
		MVDO	Independent	
		MCPOS	Dependent	
H_3	There is a difference in SIA outcome, such as MCV coverage post-SIA, for that area, when **subnational -level gaps in the cold chain** data versus national-level data is used for the basis of SIA timing and implementation.	CCMS	Independent	Multiple Regression
		CCCP	Independent	
		CTVR	Independent	
		MCPOS	Dependent	

Threats to Validity

In general, validity is “the extent to which a statistical measure reflects the real meaning of what is being measured” (Wolverton, 2009) whereas design validity, or reliability, is the consistency of scores on an instrument (Creswell, 2009) or the extent to

which an instrument contains variable error (Frankfort-Nachmias & Nachmias, 2008). These errors may appear sporadically between observations either during one measurement application or each time a variable is measured by the same instrument (Frankfort-Nachmias & Nachmias, 2008). Absence of research validity may come from a number of sources and determining the validity of research involves many considerations such as external validity, internal validity, construct validity, and statistical conclusion validity (Wolverton, 2009).

External validity exists when a study is generalizable as its results are valid in other settings, populations, and programs (Fink, 2013). Internal validity suggests an experimental program results in a difference with satisfactory proof to back it up. A study can claim internal validity when one can identify causation between a factor and an outcome (Fink, 2013). Ruling out threats to internal validity is a laborious task because it requires explicit identification of each alternative explanation for causation along with the rationale for rejecting it. If all reasonable alternative causes cannot be ruled out, the research may be inconclusive and invalid (Wolverton, 2009).

Construct validity is attained by connecting a study instrument to the general theoretical framework on which the study is based (Frankfort-Nachmias & Nachmias, 2008). This helps to determine whether the instrument is empirically and reasonably linked to the theoretical assumptions and theories on which the study is based (Frankfort-Nachmias & Nachmias, 2008). Statistical conclusion validity measures how practical an experimental or research conclusion is (Frankfort-Nachmias & Nachmias, 2008). Since 1984, DHS has evaluated representative data on childhood illness, vaccinations, and

newborn care through more than 300 surveys in more than 90 countries (ICF, n.d.). This has allowed the surveys to adjust to evolving and ongoing health issues, but also to strengthen its reliability in measuring the intended concepts (Frankfort-Nachmias & Nachmias, 2008).

Ethical Procedures

Agreement to gain access to the Tanzania DHS and SPA data sets was requested and approved (See Appendix B). Access to subnational measles incidence data was requested, however, the WHO Africa Regional office does not allow publication of the sub-national data analysis. This prevents usage of the subnational incidence data in the doctoral study and analysis will have to rely solely on the national level measles incidence data. This data is in the public domain and is readily accessible online (WHO, 2018b). The qualitative data surrounding measles SIAs is also readily available in the public domain and an agreement to access is also not necessary (WHO, 2017c).

As the 2010 TDHS contained sensitive questions regarding domestic violence, interviewers ensured privacy of the participant prior to the conduction of the interview by ensuring the presence of others was avoided and the conversation could not be overheard by others (National Bureau of Statistics and ICF Macro, 2011). Informed consent was attained prior to collecting the confidential information (National Bureau of Statistics and ICF Macro, 2011). Personal information of the participant was protected by assigning a study identification number to the participant versus using the person's name (National Bureau of Statistics and ICF Macro, 2011). To ensure the 2010 TDHS complied with federal regulations for the protection of human subjects as identified in 45 CFR 46 (U.S.

Department of Health & Human Services, 2010), the primary study received internal review board (IRB) approval prior to the conduction of the study. A copy of the IRB Review Findings Form can be found in Appendix C. The 2015 TDHS maintained the same study procedures and went through the same approval procedures (MoHCDGEC, et al., 2016). The 2015 IRB approval form is also available in Appendix B.

Surveillance data, for the purposes of this study, measles surveillance data, allows public health entities to detect measles epidemics and outbreaks, to assess measles prevention and control measures, to examine isolation activities, as well as a number of other measures to better the public's health (Lee, et al., 2012). Though the data starts off as name-based, it does not go through the ethical approval process as this type of public health surveillance, due to its necessity, transpires without explicit consent from the patient (Lee, et al., 2012). However, in the process of submitting surveillance data to the WHO, confidentiality is maintained as personal identifiers are removed (WHO, 2013c).

I completed the National Institutes of Health (NIH) Office of Extramural Research training course "Protecting Human Research Participants" in December 2014. Walden University IRB approval was received June 7, 2019, under approval #06-07-19-050712 found in appendix B. Secondary data analysis started shortly thereafter.

Summary

A retrospective, cross-sectional study was used to determine to what degree using district-level data results in differences in SIA outcome versus using national level immunization coverage data alone. Multiple secondary data sets were planned to be combined to explore potential sub-national data as a source for determining timing,

implementation and impact on SIAs. A power analysis with a 0.5 effect size and alpha level of .005 will be employed to ensure the finite secondary data will have adequate power to respond to the research questions. A multiple regression analysis approach was planned to interpret the results. A model summary, ANOVA and coefficients analysis was used with a traditional CI level of 95% a significance level of <0.05 will guide the determination of rejecting or accepting the null hypothesis. Threats to validity were minimal as DHS data has been employed and modified over decades to safeguard reliability. The next section will provide details on analysis of the secondary data and interpretation of study findings.

Section 3: Presentation of the Results and Findings

The study was aimed at filling the gap on whether subnational data can be used to guide the timing, implementation, or impact of measles SIAs in a way that will result in increased MCV coverage. The quantitative study addressed different subnational data for the country of Tanzania to see how they affected MCV pre- and post-SIA. This involved examining national- and district-level independent variables (MCV coverage pre-SIA, vaccine stock out data, and cold chain information pre-SIA) with how they compare to the dependent variable, MCV post-SIA.

The overarching research question was the following: What is the difference in SIA outcome when district-level data are used for planning the timing and implementation strategy of SIAs, versus using national-level immunization coverage data alone? District-level data assessed included immunization coverage, vaccine stock, and cold chain information. The data were analyzed to determine whether the results showed

any statistically significant effects. The null hypotheses would confirm there was no effect, and the alternate hypotheses would indicate there was an effect. Section 3 includes the analysis of the data sets and addresses any discrepancies between the planned analysis and what was carried out. Descriptive and inferential analysis findings are presented in detail to answer each research question.

Data Collection of Secondary Data Set

2010 TDHS

Data collection for the 2010 Tanzania DHS took place between December 19, 2009, and May 23, 2010, by 14 teams: 11 on the Mainland and three in Zanzibar (National Bureau of Statistics and ICF Macro, 2011). Teams consisted of four female interviewers, a supervisor, one male interviewer, a field editor, and a driver (National Bureau of Statistics and ICF Macro, 2011). The supervisor and field editor ensured all questionnaires were complete and of high quality, and maintained consistency prior to the team leaving the area or cluster (National Bureau of Statistics and ICF Macro, 2011).

A sample of 10,300 households was selected, and 9,741 were found to be inhabited throughout the data collection period (National Bureau of Statistics and ICF Macro, 2011). Of those households, 9,623 were interviewed, producing a response rate of 99% (National Bureau of Statistics and ICF Macro, 2011). In those households interviewed, 10,139 women completed interviews with a response rate of 96%; 2,520 interviewed men resulted in a 91% response rate (Nowak et al., 2015). Failure to find eligible women or men at home after repeated visits was found to be the main reason for nonresponse (National Bureau of Statistics and ICF Macro, 2011).

2014–2015 Tanzania SPA

Data collection for the 2014 TSPA took place from October 20, 2014, to February 21, 2015, though some facilities were revisited in Dares es Salaam from March 2 to 13 (MoHSW et al., 2015). Data collection, on average, took 2 or 3 days for hospitals or large facilities and 1 day for small facilities such as health centers and dispensary clinics. Because assessments included observations of family planning, sick child, and antenatal clinic services, every effort was made to ensure that teams were present during days these services were offered, or the teams returned when the service was offered (MoHSW et al., 2015). If no clients came on the designated service day, the team did not revisit the facility (MoHSW et al., 2015). Of the 1,200 health facilities sampled, four facilities had closed, seven refused to be surveyed, and one was unable to be reached resulting in a response rate of 99% (MoHSW et al., 2015). Among the facilities that were surveyed, 379 were health centers, 493 were dispensaries, 256 were hospitals, and 60 were clinics (MoHSW et al., 2015).

2015–2016 TDHS

Data collection for the 2015 TDHS was completed by 16 field teams: 13 on Tanzania Mainland and three in Zanzibar (MoHCDGEC et al., 2016). Each team was provided with a four-wheel drive vehicle and a driver. The teams consisted of one male interviewer, four female interviewers, a field editor who also entered data into a tablet, a team supervisor, and a driver (MoHCDGEC et al., 2016).

A total of 12,767 houses were occupied of the 13,360 households selected for the 2015 TDH survey (MoHCDGEC et al., 2016). A response rate of 98% was attained as a

result of 12,563 of the occupied households being successfully interviewed (MoHCDGEC et al., 2016). Within the interviewed households, 13,266 women completed the survey of the 13,634 eligible women identified, producing a response rate of 97% (MoHCDGEC et al., 2016). There was little variation between the response rates of urban and rural households (MoHCDGEC et al., 2016).

Tanzania Measles Incidence and Case Data

Confirmed measles cases were used to reflect the measles incidence data for Tanzania. Confirmed measles cases included clinically confirmed, epi-link, and lab confirmed. The time frame for measles case data in the study was 2010 to 2016 (see WHO, 2018b).

WHO Summary Measles SIAs 2000–2016

The time frame from which the SIA data were drawn came from WHO's summary of member states' SIAs for the years 2000–2016. However, Tanzania's last SIA during this time frame was in 2014 (WHO, 2017c).

Discrepancies in the Use of the Secondary Data Set From the Plan Presented in Section 2

Once the data sets were accessed and reviewed, discrepancies in the planned use of the secondary data set from the plan presented in Section 2 was found. The plan was to merge the DHS and SPA data based on the district variable. Once the data were opened and select variables were recoded as described in section 2, it became apparent that it would be difficult to merge the data: the number of districts in each region was not consistent or possibly the same, and the regions were not consistent. In the DHS 2010

data set, there were 26 regions identified by name and eight districts identified by the numbers 1–8. Reformed in 2012, Tanzania's mainland administrative units went from 21 to 25 compared to the previous population census conducted in 2002 (MoHCDGEC et al., 2016). The 2015 DHS data had 10 districts, identified by the numbers 1–10, and 30 regions. The 2014 SPA data contained 30 regions identified by name, including the same quantity and names as the 2015 DHS data. Four regions were renamed between 2010 and 2014: (Zanzibar) Unguja North to Kaskazini Unguja, (Zanzibar) Unguja South to Kusini Unguja, Pemba North to Kaskazini Pemba, and Pemba South to Kusini Pemba. The Town West region name was removed, and the regions of Njombe, Katavi, Simiyu, Geita, and Mjini Magharibi were created. A clear description of how the new regions were defined or how or why the old regions were removed was not found in the documentation of the any of the data sets other than the following: "zones differed slightly from previous DHS surveys and therefore comparisons from survey to survey should be made with caution" (MoHCDGEC et al., 2016, p. 51). Finally, the 2014 SPA data contained nine districts identified by the numbers 1–9. The codebook and documentation provided by DHS did not provide names for the districts, and upon request the authors did not provide names of the districts to ensure that the numeric labels were consistent with the names of the districts. As a result, the data could not be merged. Given the complexities around selecting consistent subnational groupings across data sets, residence (urban and rural, same categories across data sets) and region were selected as the most appropriate level for subnational analysis.

During development of the study, the intent was to use the DHS women's questionnaire and its women's data file because it contained the requisite vaccination-related variables: current age of child, vaccination card available, date of measles vaccination, and vaccinations received through immunization campaign in the last 2 years (see ICF, 2007a). Once the data were accessed and further review of DHS documentation was conducted, I decided that the women's questionnaire would still be used, but the children's data file would be analyzed (see ICF, n.d.). The unit of analysis for this data set was children between the ages of 0 and 59 months, which was the age range of the target population versus the woman as the unit of analysis in the woman's data file. The Child data file contained data on the children born in the last 5 years of the woman interviewed (see ICF, n.d.). As a result of changing the data file, the data defaulted to children between the ages of 12 and 59 months. Because the data could not be merged, the appropriateness of the analysis plan and research questions was reconsidered. Modified research questions and hypotheses were defined as well as the statistical analyses for them. Table 4 identifies the research question changes, and Table 5 describes the new statistical analyses.

Table 4

Updated Research Questions

No	Previous research question	New research question
Overall RQ	What was the difference in SIA outcome when subnational-level data was used for planning the timing and implementation strategy of SIAs, versus using national level immunization coverage data alone?	What were the patterns of association between using subnational data in children 12-59 months compared to using national-level data as a basis for SIA timing and implementation?
RQ1	What was the difference in SIA outcome when **subnational-level immunization coverage data**, such as MCV, was used as a basis for SIA timing and implementation compared to using national-level data?	What was the association between using **subnational-level MCV coverage** in children under five compared to using national-level MCV coverage data as a basis for SIA timing and implementation?
RQ2	What was the difference in SIA outcome when **subnational-level vaccine stock-out data** was used as a basis for SIA timing and implementation compared to using national-level data?	What was the association between using **subnational-level vaccine stock data** compared to using national-level vaccine stock-data as a basis for SIA timing and implementation?
RQ3	What was the difference in SIA outcome when **subnational-level cold chain information** was used when planning the timing and implementation strategy of SIAs compared to using national-level data?	What was the association between using **subnational-level cold chain data** compared to using national-level cold chain data as a basis for SIA timing and implementation?

Because the data could not be merged, the decision to conduct subnational data analysis by data source and then triangulate all data was recognized as the best option in this situation. Data triangulation in this instance would allow for critical synthesis of data from more than two sources to address relevant questions for program planning and decision making. The possible convergence of results from different sources would enhance the validity of conclusions produced (see CDC, UNICEF, WHO, 2019). Table 5 lists the updated hypotheses and analyses.

Table 5

Updated Hypotheses and Statistical Analysis Plan

No	Hypothesis	Variables	Type of variable	Subnational analysis
H_1	What was the association between using subnational-level **MCV coverage** in children under five compared to using national-level MCV coverage data as a basis for SIA timing and implementation?	MVPRE	Independent	*t*-test (IV=2 categories), ANOVA (IV=2+categories) and Chi-Square
		MCPOS	Dependent	
		MINC	Confounding	
		NMCPRE	Covariate	
		SIA	Covariate	
H_2	What was the association between using subnational-level **vaccine stock data** compared to using national-level vaccine stock data as a basis for SIA timing and implementation?	VAXAF	Covariate	*t*-test (IV=2 categories), ANOVA (IV=2+categories) and Chi-Square
		HFSV	Independent	
		RI_M_Vax_days	Independent	
		RI_M_Vax_pst_days	Independent	
		MVDO	Independent	
		MCPOS	Dependent	
		NHEPI	Covariate	
		NHFSV	Covariate	
		NMVDO	Covariate	
H_3	What was the association between using subnational-level **cold chain data** compared to using national-level cold chain data as a basis for SIA timing and implementation?	HFEPI	Covariate	*t*-test (IV=2 categories), ANOVA (IV=2+categories) and Chi-Square
		HFSV	Independent	
		CCMS	Independent	
		CCCP	Independent	
		CTVR	Independent	
		MCPOS	Dependent	
		NCCMS	Covariate	
		NCCCP	Covariate	
		NCTR	Covariate	

Given the updated hypotheses and statistical analyses, the current data analysis plan was the following:

1. Create a working data set with subnational-level data and variables used in the proposed models, recode and relabel variables from 1,2 to 0,1 (2 = no, none recoded to 0), and collapse categories of dependent variables so there are two categories rather than three.
2. Recode independent variables as dichotomous variables to allow more flexibility in analysis (see Mertler & Vannatta, 2010).
3. Analyze frequency distributions of categorical variables.
4. Set up relational models for analysis of differences and relationships.
    - To assess the possibility of differences between key variables, use an independent sample *t* test for the subnational categorical variable residence (two categories: urban and rural). To analyze by region (25 or 30 categories), use a one-way analysis of variance (ANOVA).
    - Use a chi-square test to evaluate the relationship between key variables.
5. Analyze the output of models to determine model fit, model significance, and statistically significant independent variables.

Dependent and independent variables with updated characteristics are listed in Table 6.

Table 6

Definitions and Variable Codes of Interest

Data set	Variable name	Definition	Variable codes
2010 TDHS	**1. MCPRE**	1. Received measles vaccination	1. 0=No, 1=Yes
	2. EVERVAX	2. Ever had vaccination	2. 0=No, 1=Yes
	3. MOMESCHL	3. (Mom) Ever attended school	3. 0=No, 1=Yes
	4. MOMHELVL	4. (Mom) Highest educational level	4. 1=Primary school only, 2=Above primary school
	5. PARTEDLVL	5. Partner's level of education	5. 1=Primary school only, 2=Above primary school
	6. PART_WRK	6. Partner worked in last 12 months	6. 0=No, 1=Yes
2015-2016 TDHS	1. EVERVAX	1. Ever had vaccination	1. 0=No, 1=Yes
	2. MCVPOS	2. Received one measles vaccination	2. 0=No, 1=Yes
	3. MOMESCHL	3. (Mom) Ever attended school	3. 0=No, 1=Yes
	4. MOMHELVL	4. (Mom) Highest educational level	4. 1=Primary school only, 2=Above primary school
	5. PARTEDLVL	5. Partner's level of education	5. 1=Primary school only, 2=Above primary school
	6. PART_WRK	6. Partner worked in last 12 months	6. 0=No, 1=Yes
TSPA	1. VAXAF	1. Child vaccination services at facility	1. 0=No, 1=Yes
	2. RI_M_Vax_days	2. # of days MCV provided at facility	2. Range
	3. RI_M_Vax_pst_days	3. # of days MCV provided through outreach	3. Range
	4. HFSV	4. Facility routinely stores vaccines	4. 0=No, 1=Yes
	5. CCMONTYP	5. Type of temperature monitoring device used in vaccine refrigerator	5. 1=Thermometer OR Freeze Tag; 2=Thermometer AND Fridge Tag
	6. CCMS	6. Facility maintains cold chain monitoring chart	6. 0=No, 1=Yes
	7. CCCP	7. Cold chain monitoring chart completed for past 30 days	7. 0=No, 1=Yes
	8. MVDO	8. Measles vaccine and diluent observed	8. 0=No, 1=Yes
	9. CTVR	9. Current temperature in vaccine refrigerator	9. 0=Outside of range or thermometer nonfunctional, 1=Appropriate range: +2 and +8 degrees
	10. ASSESSIMM	10. Child vax status assessed before consult	10. 0=No, 1=Yes
WHO Measles Incidence Data	**MINC**	# of measles cases	N/A
WHO Summary Measles SIAs	SIA00; SIA01; SIA05; SIA06; SIA08; SIA11; SIA14	National SIA conducted (yes/no)	N/A
WHO Administrative coverage	NMCPRE	National level MCV1 coverage	N/A
TSPA	NHFSV; NMVDO	National-level stock data	N/A
TSPA	NCCMS; NCCCP; NCTR	National-level cold chain data	N/A

Note. Bolded items are dependent or independent variables.

Descriptive Statistics

Statistical analysis was conducted on three sets of data: the 2010 DHS, 2015 DHS and the 2014 SPA SPSS data sets. To describe the population of the DHS data sets, five categorical variables (all measured at the nominal level) were selected and frequency distributions provided: mother's age (in 5-year increments); if mother ever attended school; mother's highest education level; partner's highest educational level; and if partner worked in the last 12 months. Two continuous variables, age of child and number of births, were selected and described with mean, minimum, maximum and range.

Table 7 shows the DHS samples included 5934 children aged 12 – 59 months in 2010 and 7655 in 2015. Eighty one percent of the 2010 DHS population were rural, and the remainder identified as being in an urban setting. The urban/rural breakdown was similar in the 2015 DHS respondents. The samples were intended to deliver estimates for the entire country resulting in a comparatively large number cases to reduce sampling error (MoHCDGEC et al., 2016; National Bureau of Statistics and ICF Macro, 2011). Percent representation by region ranged from 1.9% – 6.4%, with an over sampling of rural regions, in the 2010 DHS respondents and between 1.9% and 6.4% for the 2015 respondents. The region of Shinyanga had the highest representation in 2010 and Simiyu in 2015. Over two-thirds of the mothers were between ages of 20-34 in both sets of data, with a mean of 1.76 children in 2010 and 1.68 in 2015. The table shows that the mean births by residence type was a maximum of six children in the rural setting and a maximum of four children in the urban setting. There was a slight decrease in these number during the 2015 DHS collection period. Mom's educational status was similar

from 2010 to 2015: approximately 90% ever attended school, with the urban setting having more respondents going beyond primary school. Interestingly, the mother's partner tended to work in the past year more frequently in the rural setting than in the urban setting for both time periods: 88.5% and 86.5% rural vs. 74.7% and 75.7% urban, while at the same time, only completing primary school – 85.7% in 2010 and 67.8% in 2015. Regional breakdown of the data for both years followed similar patterns. Given that there were 26 regions in the 2010 data set and 30 in 2015, the decision was made to limit tabular and graphical representation of descriptive data to type of residence and describe regional data in the text.

Table 7

DHS Demographic Characteristics: Urban vs. Rural

Characteristic	2010 TDHS					2015 TDHS				
	Urban		Rural		Total	Urban		Rural		Total
	n	%	*n*	%	N	*N*	%	*n*	%	N
	Mom age (5-year groups)									
15-19	34	3.1	135	2.8	169	64	3.6	243	4.1	307
20-24	243	22.1	1066	22.0	1309	400	22.5	1321	22.5	1721
25-29	321	29.2	1273	26.3	1594	496	27.9	1446	24.6	1942
30-34	258	23.5	945	19.5	1203	400	2 2.5	1128	19.2	1528
35-39	151	13.7	809	16.7	960	278	15.6	969	16.5	1247
40-44	66	6.0	462	9.6	528	117	6.6	581	9.9	698
45-49	26	2.4	145	3.0	171	25	1.4	187	3.2	212
Total	1099	100.0	4835	100.0	5934	1780	100.0	5875	100.0	7655
	Mom ever attended school									
No	113	10.3	1408	29.1	1521	166	9.3	1526	26.0	1692
Yes	986	89.7	3427	70.9	4413	1614	90.7	4349	74.0	5963
Total	1099	100.0	4835	100.0	5934	1780	100.0	5875	100.0	7655
	Mom's highest education level									
Primary school only	668	67.7	3051	89.0	3719	984	61.0	3585	82.4	4569
> Primary school	318	32.3	376	11.0	694	630	39.0	764	17.6	1394
Total	986	100.0	3427	100.0	4413	1614	100.0	4349	100.0	5963
Current age of child (years)	Mean		Mean			Mean		Mean		
	2.47 yrs		2.48 yrs			2.38 yrs		2.45 yrs		
Number of births in the last 5 years	Mean	Range	Mean	Range		Mean	Range	Mean	Range	
	1.53	1-4	1.76	1-6		1.46	1-4	1.75	1-6	
	Partner's highest education level									
Primary school only	592	63.1	3245	87.5	3837	784	56.4	3433	67.8	4217
> Primary school	346	36.9	464	12.5	810	532	38.3	706	13.9	1238
Total	938	100.0	3709	100.0	4647	1390	100.0	5067	100.0	6457
	Partner worked in the last 12 months									
No	278	25.3	556	11.5	834	432	24.3	794	13.5	1226
Yes	821	74.7	4279	88.5	5100	1348	75.7	5081	86.5	6429

Characteristic	2010 TDHS					2015 TDHS				
	Urban		Rural		Total	Urban		Rural		Total
	n	%	*n*	%	N	*N*	%	*n*	%	N
Total	1099	100.0	4835	100.0	5934	1780	100.0	5875	100.0	7655

Mean measles vaccine coverage for the study population of 12-59 months was 0.88 with a standard deviation of 0.325 in 2010 and 0.87 in 2015 with a standard deviation of 0.335. This means that 88% and 87% of the study population, reflecting the national level, received one MCV with a dispersion of approximately 33% indicating a somewhat significant difference between the mean and the max coverage. MCV by residence type and region, however, shows a greater dispersion of MCV coverage. Table 8 shows a somewhat higher coverage in urban settings versus rural with a similar standard deviation rate as the national level.

Table 8

Means, Standard Deviations, and ANOVA of MCV by Residence and Year

Variable	Urban		Rural		F	η^2
	M	*SD*	M	*SD*		
Received MCV 2010	0.93	0.259	0.87	0.337	29.428***	0.005
Received MCV 2015	0.93	0.256	0.85	0.354	38.475***	0.009

****p*<.001

MCV coverage by region reflected a significant difference. The three lowest regions in 2010 were Tabora (55%), Shinyanga (79%) and Rukwa (82%). In 2015, the lowest regions were: Katavi (67%), Tabora (68%) and Shinyanga (80%). The regions with highest coverage in 2010 were Zanzibar South (96%), Iringa & Kagera (97%) and Dar Es Salaam (99%). In 2015, regions with the highest coverage were Dar Es Salaam

(96%), Dodoma (97%) and Kagera (99%). Table 9 shows that across the regions the standard deviations (0.115 – 0.498 in 2010 and 0.117 – 0.472 in 2015) were greater, reflecting a greater difference in the vaccinated population. This difference is lost if looking at the national level numbers.

Table 9

Range of Means, Standard Deviations, and ANOVA of MCV by Region and Year

Variable	Regions		F	η^2
	M (range)	*SD* (range)		
Received MCV 2010	0.55 – 0.99	0.115 – 0.498	22.425***	0.087
Received MCV 2015	0.67 – 0.99	0.117 – 0.472	8.813***	0.060

****p*<.001

To describe the population of the SPA data sets, four categorical variables (all measured at the nominal level) were selected and frequency distributions provided: type of medical facility; managing authority of the facility; if the facility provided child vaccinations; and child vaccination status assessed.

Table 10 shows a total of 1200 facilities were in the sample with 1001 providing child vaccinations. Government owned/managed facilities were the main type of facilities in the urban context (62.7%) as well as in the rural setting (79.4%). The type of medical facility available in general and that provided vaccination varied by setting: 50.5% were dispensaries and 37.5% were health centers in the rural areas. Whereas 29.5% were predominately health centers and 21% were district hospitals and approximately the same percent for private hospitals (17.5%) and dispensaries (17.8%) in the urban settings. The

remainder of the analysis will focus solely on those facilities that provided child vaccinations.

Table 10

SPA Characteristics

Facility Characteristics	All facilities *n=1200*				Facilities that provide child vaccinations *n=1001*			
	Urban		Rural		Urban		Rural	
	n	%	*n*	%	*n*	%	*n*	%
Type of medical facility								
National Referral Hospital	11	0.9	1	0.1	6	2.1	1	0.1
Regional Hospital	20	1.7	3	0.3	14	4.8	3	0.4
District Hospital	64	5.3	12	1.0	62	21.2	11	1.6
District-Designated Hospital	11	0.9	12	1.0	11	3.8	9	1.3
Private Hospital	70	5.8	62	5.2	51	17.5	60	8.5
Health Centre	108	9.0	272	22.7	86	29.5	266	37.5
Clinic	55	4.6	6	0.5	10	3.4	1	0.1
Dispensary	105	8.8	391	32.6	52	17.8	358	50.5
Total	444	37.0	756	63.0	292	100.0	709	100.0
Managing authority of facility								
Government/public	206	17.2	577	48.1	183	62.7	563	79.4
Private-for-profit	157	13.1	31	2.6	47	16.1	14	2.0
Mission/faith-based	66	5.5	138	11.5	57	19.5	126	17.8
Parastatal	15	1.3	10	0.8	5	1.7	6	0.8
Total	444	37.0	756	63.0	292	100.0	709	100.0

Facilities that provide child vaccinations						
Variable	Urban		Rural		Total/National level	
	n	%	*n*	%	*n*	%
Child vax status assessed before consult	124	69.3	223	69.3	501	69.3

Table 11 shows the means and standard deviations related to how often MCV vaccinations were provided either at the health facility or through outreach. 2014 SPA

data showed that on average, MCV was available 9.57 days a month, with a standard deviation of 7.9 days. This means that MCV was available on average, less than 10 days a month, or 50% of the time that the health facility was open. MCV availability through outreach was less frequent: averaging 1.96 days with a standard deviation of 3.1 days.

Table 11

Means and Standard Deviations for MCV Availability

Descriptive Statistics	*n*	Range	*Mean*	*SD*
Days MCV available at facility	1001	0-30	9.57	7.865
Days MCV available through outreach	1001	0-24	1.96	3.051

Inferential Statistics

Analysis of Hypotheses

The next part of this section will explore each hypothesis by determining the patterns of association between using subnational data versus national level data to inform SIA timing and implementation. Statistical analysis techniques were employed to measure the differences versus relationships between key variables: *t*-test (for two field categorical variables) and ANOVA analyses (categorical variables with three or more fields) were used to evaluate differences and chi-square analysis for relationships.

Research Question 1

RQ1: What was the association between using subnational-level MCV coverage in children under five compared to using national-level MCV coverage data as a basis for SIA timing and implementation?

H_o1: There was no association between using subnational-level MCV coverage in children under five compared to using national-level MCV coverage data as a basis for SIA timing and implementation.

H_a1: There was an association between using subnational-level MCV coverage in children under five compared to using national-level MCV coverage data as abasis of SIA timing and implementation.

An independent-sample t-test was conducted using SPSS software version 25 to evaluate the hypothesis that there was an association between district-level MCV coverage, in this instance, residency type (urban or rural), as a basis for informing SIAs versus using national-level MCV coverage. The test was significant for both years ($p<.001$) and Cohen's *d* for both years showed a small effect size. Table 12 shows that in the 2010 sample, urban children averaged about 6% higher in MCV coverage than rural children and about 5% higher than the national average ($t[5918]=5.425$, $p<.001$, 95% CI[(.038, .080]. The 95% confidence interval with this difference (.038, .080) is narrow suggesting there is some certainty in the difference in MCV coverage between residence type. The 2015 sample showed slightly higher differences: urban children averaged about 8% higher in MCV coverage than rural children and about 6% higher than the national average ($t[4032]=6.203$, $p<.001$, 95% CI[(.052, .101], also showing a narrow confidence interval.

Table 12

Analysis of Difference in MCV by Residence and Year: t-Test

Variable	Urban		Rural		Total/National level		*t*	*p*	Cohen's *d*
	M	*SD*	M	*SD*	M	*SD*			
Received MCV 2010	0.93	0.259	0.87	0.337	0.88	0.325	5.425	<.001	0.18
Received MCV 2015	0.93	0.256	0.85	.0354	0.87	0.335	6.203	<.001	0.23

To test the null hypothesis that the was no association between MCV coverage by region, a one-way analysis of variance was conducted using SPSS. The independent variable, region, included 26 separate regions in 2010 and 30 in 2015. The dependent variable was the receipt of MCV for the study population of 12 – 59 months. MCV for the study population was 88% with a standard deviation of 0.325 in 2010 and 87% in 2015 with a standard deviation of 0.335. Levene's Test for Homogeneity of Variances showed that the variances between the 26 regions in 2010 varied: F (25, 5894) = 58.15, p < .001. Between the 30 regions in 2015 it also varied slightly: F (29, 4004) = 32.3, p < .001. Therefore, differences between regions were statistically significant. The results from the ANOVA analysis revealed difference in receipt of the MCV: F (25, 5894) = 22.43, p = .001 in 2010 and F (23, 4004) = 8.82, p = .001in 2015. The Eta Squared for 2010 and 2015, $\eta 2$ = .087, .06 respectively, confirmed that the region of residence had an effect, though small, or contributed to 8.7% or 6% of the variability in the receipt of the measles vaccine. The Tukey post hoc test showed that MCV coverage in 2010 differed significantly in the Tabora region (mean difference range of -.240 - -.436 with other regions, p < .001) and Shinyanga (mean difference range of -.107 - -.318 with other

regions, p < .001 -.014). Rukwa, Mara, Pemba North, and Pemba South regions had significant mean differences at the 0.05 level compared to multiple regions. All other pair-wise comparisons between regions revealed non-significant results (data not shown). The Tukey post hoc test showed that MCV coverage in 2015 differed consistently and significantly in the Tabora region (mean difference range of -.129 - -.306 with other regions, p < .001 - .01) and Katavi (mean difference range of -.141 - -.318 with other regions, p < .001 -.005). Shinyanga, Kagera and Simyu regions had significant mean differences at the 0.05 level compared to other regions. All other pair-wise comparisons between regions revealed non-significant results.

In Table 13, chi-square analysis for the 2010 data exposed a statistically significant relationship between measles vaccine and residency type (urban or rural): $\chi 2(1, N = 5920) = 29.3$, $p < .001$. In 2015, similar results were noted: $\chi 2(1, N = 4034) = 38.1$, $p < 0.001$. A difference would indicate that type of residency has an association with measles vaccine coverage and is notably different than the national MCV coverage. In this case it does so, there was a statistically significant association between using subnational-level MCV coverage in children under five compared to using national-level MCV coverage data as a basis for SIA timing and implementation.

Table 13

Frequencies and Chi-Square for MCV by Residence and Year

Variable		Urban		Rural		Total/national level		χ^2	*P*
		n	%	n	%	n	%		
2010 Measles vaccine (N=5920)	No	79	7.2	631	13.1	710	12.0	29.3[a]	<0.001
	Yes	1018	92.8	4192	86.9	5210	88.0		
2015 Measles vaccine (N=4034)	No	68	7.1	452	14.7	520	12.9	38.1[b]	<0.001
	Yes	894	92.9	2620	85.3	3514	87.1		

[a.] 0 cells (.0%) have expected count less than 5. The minimum expected count is 131.57.
[b.] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 124.01.

Chi-square analysis by region also revealed a significant relationship between receipt of the measles vaccine and region. In 2010, data exposed a statistically significant relationship between measles vaccine and region: $\chi 2(25, N = 5920) = 514.2$, $p < .001$. In 2015, similar results were noted: $\chi 2(29, N = 4034) = 242.1$, $p < 0.001$. Overall, these results suggest there was an association between regional MCV coverage as a basis for SIA timing an implementation versus using national-level MCV coverage. Therefore, the null hypothesis can be rejected.

Research Question 2

RQ2: What was the association between using subnational-level vaccine stock data compared to using national-level vaccine stock-data as a basis for SIA timing and implementation?

H_o2: There was no association between using subnational-level vaccine stock data compared to using national-level vaccine stock-data as a basis for SIA timing and implementation.

H_a2: There was an association between using subnational-level vaccine stock data compared to using national-level vaccine stock-data as a basis for SIA timing and implementation.

Tanzania's 2014 SPA data was used to assess the association between subnational levels and vaccine stock and cold chain status. Vaccine stock variables analyzed were facility routinely stores vaccines; number of days MCV provided at facility; number of days MCV provided through outreach; measles vaccine and diluent observed; and current temperature in vaccine refrigerator. In addition, the variable child vaccination status assessed before consult was available in the SPA data and was analyzed to gain insight on staff capacity, program management and implementation variability.

An independent-sample t-test was conducted using SPSS software version 25 to evaluate the hypothesis that there was an association between district-level vaccine stock data (by residence type) as a basis for SIA timing and implementation versus using national-level vaccine stock. The test was statistically significant for both variables facility stores vaccines and MCV and diluent available. Table 13 shows urban facilities averaged about 6% higher in storing vaccines than rural facilities and about 2% higher than the national average ($t[999]=2.25$, $p<.001$, 95% CI[(.005, .072]. Presence of MCV and diluent was slightly higher in rural facilities than in urban and at the national average ($t[876]=3.71$, $p<.001$. 95% CI[(.034, .010]. Cohen's d for both variables reflects there was a significant difference by the type of residence, though having a small effect.

Table 14

Analysis of Difference in Vaccine Stock by Residence: t-Test

Variable	Urban		Rural		Total/national level		*T*	*p*	Cohen's *d*
	M	*SD*	M	*SD*	M	*SD*			
Facility stores vaccines	0.96	0.191	0.92	0.265	0.94	0.247	2.25	.025	0.16
MCV and diluent available	0.98	0.148	1.00	0.000	0.99	0.082	3.71	<.001	0.27
Child vaccination status assessed	0.69	0.463	0.69	0.462	0.69	0.462	.004	.996	<0.001

A one-way analysis of variance was conducted using SPSS to evaluate the difference between vaccine stock and regions in the 2014 SPA data set. The independent variable, region, included 30 regions, consistent with the 30 regions in the 2015 DHS data set. Levene's Test for Homogeneity of Variances showed that for the variable facility stores vaccines, the variances between the 30 regions varied slightly: F (29, 971) = 7.36, p < .001. The results from the ANOVA analysis also revealed that there were statistically significant differences in facility stores vaccines, F (29, 971) = 2.16, p <.001. The Eta Squared, η2 = .006, showed that the region of residence had a small effect on the facility storing vaccines. The Tukey post-hoc test showed that for the variable facility stores vaccine, the Kusini Unguja region (mean difference range of -.267 - -.333 with other regions, p = 001 -.038) showed the most statistically significant difference. All other pair-wise comparisons across regions revealed non-significant results (data not shown).

Levene's Test for Homogeneity of Variances showed that for the variable availability of MCV and diluent the 30 regions varied: F (29, 848) = 3.63, p < .001. The

results from the ANOVA analysis revealed, however, that there were not statistically significant differences in availability of MCV and diluent across regions, F (29, 848) = 0.85, p = .069. The Eta Squared, η2 = .028, showed that the region of residence had small effect on availability of MCV and diluent across regions. The Tukey post hoc test revealed non-significant results (data not shown).

Levene's Test for Homogeneity of Variances showed that for the variable child vaccination status assessed F (29, 471) = 5.189, p <.001. The results from the ANOVA analysis revealed however, that there were not statistically significant differences in child vaccination status assessed across regions, F (29, 471) = 2.69, p <.001. The Eta Squared, η2 = .142 showed that the region of residence had a large effect on vaccination status being assessed. The Tukey post hoc test showed that for the variable child vaccination status assessed, the Lindi region (mean difference range of -.527 - -.800) showed the most statistically significant difference (regions, p < .001 -.040). All other pair-wise comparisons across regions revealed non-significant results (data not shown).

These results indicated that the region of residence showed some difference in the variability of the variables availability of MCV and diluent and facility stores vaccine, but less of a difference on child vaccination status being assessed.

A chi-square analysis was completed to see if there was a difference between vaccine stock by region or residence type. In Table 14, chi-square analysis exposed a statistically significant difference between facilities that store vaccines and residency type: $\chi 2(1, N = 1001) = 5.01$, $p = .025$. For the variable availability of MCV and diluent, similar results were noted: $\chi 2(1, N = 1001) = 13.6$, $p < 0.001$. A difference would

indicate that urban or rural residency has an association with facilities that store vaccines and availability of MCV and diluent is different than the national variables. In this case it does so there was a statistically significant association between using subnational-level vaccine stock data compared to using national-level vaccine stock data as a basis for SIA timing and implementation. Therefore, I can conclude that the null hypothesis can be rejected.

Additional analysis on the variable child vaccination status assessed showed consistency across residence type and at the national level - no statistically significant difference, as shown in Table 15. However, at the regional level, there were some differences: $\chi 2(29, N = 501) = 71.2$, $p < 0.001$.

Table 15

Frequencies and Chi-Square Results for Vaccine Stock by Residence

Variable	Urban		Rural		Total/National level		χ^2	*p*
	n	%	n	%	N	%		
Facility stores vaccines	281	96.2	663	92.4	936	93.5	5.04[a]	0.025
MCV and diluent available	264	97.8	608	100	872	99.3	13.6[b]	<.001
Child vaccination status assessed	124	69.3	223	69.3	501	69.3	.000[c]	0.996

[a.] *0 cells (.0%) have expected count less than 5. The minimum expected count is 18.96.*
[b.] *2 cells (50.0%) have expected count less than 5. The minimum expected count is 1.85.*
[c.] *0 cells (0.0%) have expected count less than 5. The minimum expected count is 55.02.*

Chi-square analysis by region also revealed a statistically significant relationship across facilities that store vaccines and availability of vaccine by region*:* $\chi 2(29, N = 1001) = 60.67$, $p < .001$. Chi-square analysis by region, however, did not find a relationship between availability of vaccine and region: $\chi 2(29, N = 878) = 24.89$ $p = .684$. Overall, the results are mixed when it comes to an association between regional

immunization services data as a basis for SIA timing an implementation versus using national-level vaccine stock levels. Therefore, the null hypothesis cannot be rejected. Section 4 will delve into interpreting this dichotomy.

Table 16 shows a recap of the continuous variables days MCV available at facility and days MCV available through outreach and the Chi-square analysis results. MCV availability in urban facilities ranged from 0-30 days with an average of 10.5 days when families could take their children in to be vaccinated. Rural facilities averaged 9.2 days with the range of availability the same as urban facilities, and slightly lower than the national average. The availability of MCV through outreach was much different: urban outreach averaged 2 days, with a maximum of 24 days, while in the rural setting, the maximum availability was 22 days, averaging the same 2 days. Regional availability in health facilities and through outreach reflected similar differences: $\chi 2(493, N = 1001) = 1028.7$, $p < 0.001$ for in-facility availability and $\chi 2(522, N = 1001) = 781.7$, $p < 0.001$. for outreach. These findings show that there was a statistically significant association between MCV availability in health facilities and through outreach-based residence type and region. This means there was a statistically significant association between using subnational-level service availability data compared to using national-level service availability data as a basis for SIA timing and implementation. Therefore, I can conclude that the null hypothesis can be rejected.

Table 16

Frequencies and Chi-Square Results for Immunization Services by Residence

Variable	Urban			Rural			Total/national level			χ^2	*p*
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode		
Days MCV available at facility	10.5	8.0	4	9.2	4.0	4	9.6	8.0	4	50.5[a]	<.001
Days MCV available through outreach	2.0	.00	0	2.0	1.00	0	2.0	1.0	0	75.8[b]	<.001

[a] *19 cells (52.8%) have expected count less than 5. The minimum expected count is .29.*
[b] *21 cells (55.3%) have expected count less than 5. The minimum expected count is .29.*

Research Question 3

RQ3 – What was the association between using subnational-level cold chain data compared to using national-level cold chain data as a basis for SIA timing and implementation?

Ho3= There was no association between using subnational-level cold chain data compared to using national-level cold chain data as a basis for SIA timing and implementation.

H3= There was an association between using subnational-level cold chain data compared to using national-level cold chain data as a basis for SIA timing and implementation.

An independent-sample t-test was conducted using SPSS software version 25 to evaluate the hypothesis that there was an association between district-level cold chain data (by residence type) as a basis for SIA timing and implementation versus using national-level cold chain data. The test was statistically significant for all cold chain variables. As shown in Table 17, urban facilities averaged about 5% higher in

maintaining their cold chain monitoring system than rural facilities and about 4% higher than the national average (t[931]=2.29, *p*<.001, 95% CI[(.007, .090]. Completion of the temperature record during the past 30 days had similar differences between urban, rural facilities and the national average (t[931]=1.669, *p*=.002. 95% CI[(.010, .128]. Urban facilities averaged about 7% higher than rural facilities in maintaining the temperature in the vaccine refrigerator within the appropriate range of 2º -8º C and 5% higher than the national average: (t[759]=2.877, *p*<.001. 95% CI[(.023, .122] Urban facilities tended to use two types of monitoring devices in the vaccine refrigerator more than rural facilities and the nation as a whole: : (t[931]=1.669, *p*<.001. 95% CI[(.010, .128]. Cohen's d for all cold chain variables reflects there was a significance difference by the type of residence, though having a small effect.

Table 17

Analysis of Difference in Cold Chain by Residence: t-Test

Variable	Urban		Rural		Total/National level		*T*	*p*	Cohen's *d*
	M	*SD*	M	*SD*	M	*SD*			
Cold chain monitoring system maintained	0.94	0.246	0.89	0.317	0.90	0.298	2.29	<.001	0.16
Temp record completed past 30 days	0.83	0.377	0.78	0.412	0.80	0.402	1.21	0.002	0.11
Current temperature in vaccine refrigerator	0.93	0.252	0.86	0.348	0.88	0.323	2.89	<.001	0.22
Type of temp monitoring device in vaccine refrigerator	1.62	0.486	1.56	0.497	1.58	0.494	1.67	<.001	0.12

A one-way analysis of variance was conducted using SPSS software version 25 to evaluate the relationship between cold chain and regions in the 2014 SPA data set. The

independent variable, region, included 30 regions. The following results were revealed for the four cold chain variables:

Levene's Test for Homogeneity of Variances showed that for the cold chain monitoring system maintained, the variances between the 30 regions varied slightly: $F(1,931) = 22.376$, $p < .001$. The results from the ANOVA analysis also revealed, that there were statistically significant differences in cold chain monitoring system maintained, $F(29, 903) = 3.23$, $p < .001$. The Eta Squared, $\eta 2 = .094$, showed that the region of residence had a medium effect on the variability of these two variables. The Tukey post-hoc test showed that for the variable cold chain monitoring system maintained, the Tabora region (mean difference range of -.265 - -.297 with other regions, p = .002 -.048) showed the most statistically significant difference. The Geita region also showed some difference (mean difference range of -.282- -.310 with other regions, p = .003 -.032) All other pair-wise comparisons across regions revealed non-significant results (data not shown).

Levene's Test for Homogeneity of Variances showed that for the temp record completed past 30 days, the variances between the 30 regions varied slightly: $F(1,931) = 22.376$, $p < .001$. The results from the ANOVA analysis also revealed, that there were statistically significant differences in the temperature record being completed in the past 30 days, $F(29, 793) = 4.24$, $p < .001$. The Eta Squared, $\eta 2 = .134$, showed that the region of residence had a large effect on the variability of this variable. The Tukey post-hoc test showed that for the variable Temp record completed past 30 days, the Tabora and Lindi regions (mean difference range of -.380 - -.615 and -.372 - -.607 with other regions, p <

.001 -.039 and < .001 -.040 respectively) showed the most statistically significant difference. All other pair-wise comparisons across regions revealed non-significant results between regions (data not shown).

Levene's Test for Homogeneity of Variances showed that for the current temperature of the vaccine refrigerator, the variances between the 30 regions varied slightly: F (29,731) = 13.837, p < .001. The results from the ANOVA analysis also revealed, that there were statistically significant differences in current temperature of the vaccine refrigerator, F (29, 731) = 2.48, p <.001. The Eta Squared, η2 = .090, showed that the region of residence had a medium effect on the variability of this variable. The Tukey post-hoc test showed that for the variable current temperature of the vaccine refrigerator, however, pair-wise comparisons across regions revealed non-significant results (data not shown).

Analysis of current temperature in Vaccine refrigerator did show statistically significant differences between regions. Levene's Test for Homogeneity of Variances showed that for this variable, the variances between the 30 regions were slight: F (29,731) = 13.84, $p < .001$. The results from the ANOVA analysis also revealed, that there were statistically significant differences in current temperature in vaccine refrigerator, F (29,731) = 2.48, $p <.001$. The Eta Squared, η2 = .090, showed that the region of residence had little effect on the variability of these two variables. The Tukey post-hoc test showed marginal differences between regions without any one region showing statistically significant differences. All other pair-wise comparisons across regions revealed non-significant results (data not shown).

Levene's Test for Homogeneity of Variances showed that for the type of temp monitoring device in vaccine refrigerator, for this data set using a thermometer and Freeze Tag was the preferred method versus just a thermometer OR just a Fridge Tag, the variances between the 30 regions varied slightly: $F(29,903) = 9.863$, $p < .001$. The results from the ANOVA analysis also revealed, that there were statistically significant differences in the type of temperature monitoring device, $F(29, 903) = 3.24$, $p < .001$. The Eta Squared, $\eta 2 = .094$, showed that the region of residence had little effect on the variability of these two variables. The Tukey post hoc test showed marginal differences between regions without any one region showing statistically significant differences. All other pair-wise comparisons across regions revealed non-significant results (data not shown).

A chi-square analysis was completed to see if there is a relationship between cold chain by region or residence type. In Table 18, chi-square analysis exposed a statistically significant association between facilities that maintain their cold chain monitoring system and residency type: $\chi 2(1, N = 933) = 5.02$, $p = .023$ and between facilities whose current temperature in vaccine refrigerator was in the appropriate range, $\chi 2(1, N = 761) = 8.2$, $p < 0.004$. There were no significant differences noted for temp record completed past 30 days and thermometer and Freeze Tag in vaccine refrigerator by type of residence.

Table 18

Frequencies and Chi-Square Results for Cold Chain by Residence

Variable	Urban		Rural		Total/National level		χ^2	*p*
	n	%	N	%	N	%		
Cold chain monitoring system maintained	261	93.5	580	88.7	841	90.1	5.204[a]	0.023
Temp record completed past 30 days	214	82.9	443	78.4	657	79.8	2.266[b]	0.132
Current temperature in vaccine refrigerator in appropriate range	219	93.2	452	85.9	671	88.2	8.210[c]	0.004
Thermometer and Freeze Tag in vaccine refrigerator	173	62.0	367	56.1	540	57.9	2.784[d]	0.095

[a] *0 cells (.0%) have expected count less than 5. The minimum expected count is 27.51.*
[b] *0 cells (.0%) have expected count less than 5. The minimum expected count is 52.04.*
[c] *0 cells (.0%) have expected count less than 5. The minimum expected count is 27.79.*
[d] *0 cells (.0%) have expected count less than 5. The minimum expected count is 117.52.*

Chi-square analysis by region found a statistically significant relationship between cold chain monitoring system maintained, temp record completed past 30 days, current temperature in vaccine refrigerator in appropriate range, and thermometer and Freeze Tag in vaccine refrigerator by region: all had $p<.001$. This shows that there was a statistically significant association between using subnational-level cold chain data compared to using national-level cold chain data as a basis for SIA timing and implementation. Therefore, I can conclude that the null hypothesis can be rejected.

Summary

Prior to final analysis, the three data sets were reviewed, working data sets were created, and variables were recoded to dichotomous options, where appropriate. Additionally, frequency distributions of categorical variables were completed and relational models to assess differences and relationships were employed.

Because of the array of research questions and analysis steps, a summary of the results can be found in Table 19. There appeared to be a statistically significant

difference and relationship between subnational measles vaccine coverage versus the national level coverage, though small effects sizes were noted. As such, the alternative hypothesis for RQ1 was accepted. For RQ2, overall, there appeared to be a statistically significant difference and relationship between subnational vaccine stock data, including vaccine services, versus the national level vaccine stock, though the small effects sizes were noted. As such, the overall alternative hypothesis for RQ2 was accepted. The data revealed, however, that for the variable child vaccination status assessed, the national level and subnational levels consistently measured low. Discussion as to what these outcomes may suggest, and recommendations can be found in Section 4. RQ3, overall, there appeared to be a statistically significant difference and relationship between subnational cold chain data versus the national level cold chain, again, small effects sizes were noted. As such, the overall alternative hypothesis for RQ3 was accepted.

Table 19

Summary of Hypotheses Outcomes

No	Research question	Key variable	Analysis of a difference		Analysis of a relationship		Hypothesis outcome
			t-test *p*	ANOVA *p*	Chi-square *p*		
					U/R	Reg	
RQ**1**	What was the association between using subnational-level MCV coverage in children under five compared to using national-level MCV coverage data as a basis for SIA timing and implementation?	Received MCV 2010	<.001	<.001	<.001	<.001	Null hypothesis can be rejected at the subnational level
		Received MCV 2015	<.001	<.001	<.001	<.001	Null hypothesis can be rejected at the subnational level
RQ**2**	What was the association between using subnational-level vaccine stock data compared to using national-level vaccine stock data as a basis for SIA timing and implementation?	Facility stores vaccines	<.001	<.001	.025	<.001	Null hypothesis can be rejected at the subnational level
		Days MCV available at facility	N/A	N/A	<.001	<.001	Null hypothesis can be rejected at the subnational level
		Days MCV available through outreach	N/A	N/A	<.001	<.001	Null hypothesis can be rejected at the subnational level
		MCV and diluent available	<.001	*.069*	<.001	*.684*	Null hypothesis cannot be rejected at the regional level
		Child vaccination status assessed	*.996*	<.001	*.996*	<.001	Null hypothesis cannot be rejected at the residency level
RQ**3**	What was the association between using subnational-level cold chain data compared to using national-level cold chain data as a basis for SIA timing and implementation?	Type of temp monitoring device in vaccine refrigerator	<.001	<.001	*.095*	<.001	Null hypothesis cannot be rejected at the residency level
		Cold chain monitoring system maintained	<.001	<.001	.023	<.001	Null hypothesis can be rejected at the subnational level
		Temp record completed past 30 days	.002	<.001	*.132*	<.001	Null hypothesis cannot be rejected at the residency level
		Current temperature in vaccine refrigerator	<.001	<.001	.004	<.001	Null hypothesis can be rejected the subnational level

Italics indicate a difference or relationship were not found

Section 4 will provide details on interpretation of the study findings, recommendations and implications for professional practice and social change.

Section 4: Application to Professional Practice and Implications for Social Change

SIAs provide vaccinations to targeted people regardless of their vaccination status because the goal is to quickly raise population level immunity and decrease the number of susceptibles to reach elimination goals or disease control (WHO, n.d.). SIAs are an effective strategy for reaching children who may have been missed by routine immunization services or who are outside of the targeted age groups set by the routine immunization program (WHO, 2016a). Reasons for being missed could challenges around coverage and equity (DTP1, DTP3, and MCV1, zero dose and underimmunized children), surveillance of vaccine-preventable diseases (suspected and confirmed cases and outbreaks), supply and immunization services (health facilities providing routine vaccinations, cold chain equipment, vaccination sessions, stock supply), demand for immunization, data quality, financing, or other program issues (Gavi, 2020).

The current study was aimed at filling the gap on the patterns of association between using subnational data in children 12–59 months compared to using national-level data as a basis for SIA timing and implementation. The quantitative study addressed different subnational DHS data for the country of Tanzania to determine how they might inform SIA timing and implementation. This involved examining national- and district-level EPI elements: coverage and equity (MCV coverage) and supply and immunization services (vaccine stock, cold chain equipment monitoring, and MCV service availability) at particular points in time.

The results showed an association between using subnational data versus national-level data as a basis for SIA timing and implementation. Subnational data analysis

revealed that SIAs should be implemented sooner, in a specific geographical location, or suggest strategic changes to RI that could improve MCV and other antigen coverage. This finding is not apparent when only national-level data are used.

Interpretation of the Findings

The study showed that there was an association between urban/rural residence and region when looking at MCV coverage. Though the differences were slight, urban children had 6%–8% higher MCV coverage in 2010 and 2015 (93% for both years) than their rural counterparts for the same years. The regions with the lowest MCV coverage showed statistically significant differences. MCV coverage for the Tabora region for both years was 33% lower than the national rate of 88% in 2010 and 19% lower than the national coverage of 87% in 2015. Shinyanga ranked somewhat higher than Tabora with MCV coverage of 79% in 2010 and 80% in 2015. On the high end of the spectrum, Dar Es Salaam and Kagera regions had MCV coverage of 98.7% and 97.4% respectively in 2010. In 2015, regions with the highest MCV coverage were Kagera (98.6%) and Dodoma (96.6%). Most of the other regions, notably rural, ranked lower in the MCV coverage than the national level. A number of researchers noted that these differences may be attributable to a number of factors such as high mobility across health districts and migration through the country, which can affect target population estimates and coverage rates (Haddad et al., 2010), or program effectiveness, including accountability and implementation strategies (Erchick et al., 2017; Hardt et al., 2016; Perry et al., 2015). Fields et al. (2013) suggested that low coverage could be reflective of deficiencies in procurement, management, and transportation of vaccines; limited cold chain capacity; or

challenges related to the planning and policies of the routine immunization program. All of these potential scenarios are valid and merit further review to understand the exact case for Tanzania. Current guidance suggests that SIAs should be implemented every 2–4 years if a country has not reached and maintained at least 95% or more for MCV2 coverage, and that optimal SIA intervals increase with increasing MCV1 coverage (WHO, 2016a). Though the current study did not address MCV2 coverage, the lower than optimal MCV1 coverage at the national and subnational levels suggests that Tanzania should continue to implement their measles SIAs every 2–3 years until both MCV doses reach and maintain more than 95%.

The current study showed that there was an association between urban/rural residence and region when looking at immunization services such as vaccine stock and MCV service availability. Service availability depends not only on whether a facility provides the service but also on the frequency with which it is offered (MoHSW et al., 2015). The 2014 SPA data showed that 83% of the 1,200 facilities sampled, or 1,001 facilities, provided child vaccinations. Within these 1,001 facilities, MCV was available on average 9.57 days at the facility and on average 1.96 days through outreach at the national and regional levels. Urban settings averaged slightly higher at 10.5 days a month. Rural facilities averaged 9.2 days. These numbers indicated limited service availability for MCV (i.e., not available on a walk-in basis). Further review of the SPA data indicated that other antigens in the routine immunization schedule, except Bacillus Calmette–Guérin (BCG), were usually available at least 5 days per week (MoHSW et al., 2015). Frequency in vaccination sessions and permanent access to vaccines have been

identified as significant factors affecting the number of unvaccinated children in an area (Mensah et al., 2019). The reason for the variability in MCV and BCG availability in Tanzania was not clear. At the start of the 2014–2015 SPA, Tanzania followed a one-dose MCV plan in the RI schedule with the second dose being administered through SIAs. The country introduced the two-dose MCV into the RI schedule in October 2014 (Magodi et al., 2019). A one-dose requirement for both measles and BCG at the time could have been why the vaccines were offered so infrequently. Another reason could have been an absence of appropriate plans for the routine immunization program, which could have affected demand or turnout for outreach sessions or could have reflected insufficient resources for the program, such as human resources or inadequate cold chain and logistics resources (Fields et al., 2013). Answers to these questions could identify why certain communities have lower vaccination coverage, and could have immense ramifications in closing the immunity gap and reducing measles cases (Patel et al., 2020). However, providing those answers was beyond the scope of the current study. Taking advantage of each interaction with children and assessing their vaccination status, as well as other prevention regimes such as nutritional status and diarrhea and dehydration, addresses the well-being and overall health of the child (Benguigui, 2006). Each consult, including sick care, is an opportunity to assess and update the child's vaccination status and should be seen as an opportunity to avert severe childhood infections (Freeman et al., 2017). Contraindications to providing vaccinations do not always include illness because sick children may often be more in need of the protection provided by vaccinations than well children (Benguigui, 2006). Tanzania's 2014 SPA data consistently revealed that at

all levels the child's vaccination status was assessed 69.3% of the time in facilities that provided vaccinations. This indicated that approximately 30% of the time providers missed the opportunity to reinforce immunization services, explain the benefits of vaccination, or advise when to return for the next vaccination according to the country's immunization schedule (Benguigui, 2006). There could also be an opportunity to update incorrect documentation that could lead to opportune dosing going forward (Casillas & Bednarczyk, 2017). For the low MCV-coverage regions of Tabora and Shinyanga, reinforcing this simple strategy of the routine immunization program could increase coverage closer to appropriate levels (Fields et al., 2013).

The current study found that though urban facilities were slightly more likely to store vaccines, rural facilities consistently maintained their stock of MCV and diluent. Regional associations differed: Differences were not found when it came to MCV and diluent being maintained, but an association did exist. Overall, the study found there were differences and a relationship between facilities that store vaccines by residence and regional level. Routine storage of vaccines at a health facility and the presence of the measles vaccine and diluent could make a difference as to whether and how often parents are likely to have their child vaccinated when they go to the health facility or return later due to stock outs (Erchick et al., 2017). Favin et al. (2012) highlighted how undervaccination is a reflection of these deficits in vaccine stock levels and cold chain capacity. National-level data may not reveal district-specific challenges such as lack of storage capacity or funding or inadequate delivery, requisition systems, staff capacity (Favin et al., 2012). If vaccine stock levels have been compromised for a certain period, a

planned response to this deficit should include additional EPI service availability, including outreach and SIAs, and the timing and implementation of these strategies should be local-context dependent (Favin et al., 2012). This means that addressing stock out on a regional basis could be merited. Lack of vaccine on a regional level could mean a larger portion of the population is missing out on routine vaccinations for a given period of time. Awaiting SIA implementation every 2–3 years could accentuate the gap in susceptibles. A more immediate approach to addressing undervaccinated children would be to employ an occasional campaign to dispense vaccinations to those in the affected regions when the vaccine stock is replenished. Implementing a periodic intensification of routine immunization activity (PIRI) instead of an SIA at these times could be warranted (WHO, n.d.). This type of event could provide vaccinations only or combine them with other child health interventions; it would depend on the objective of the PIRI (WHO, 2009).

The current study showed that there was an association between urban/rural residence and region when looking at cold chain data. The study found that were differences by residence in cold chain attributes: Urban facilities were slightly more likely than rural facilities to maintain their cold chain monitoring system, to complete the temperature record for the last 30 days, to maintain the vaccine refrigerator within the appropriate temperature range, and to rely on both types of temperature-monitoring devices. Regional differences were noted for the same variables. A relationship at the residence level was only noted for maintaining the cold chain monitoring system variable but for all cold chain variables at the regional level. For this research question, the

notable associations were not only in significance values but also in the fact that any one time any of these variables were not 100% completed and affirmative in answer, which could be a threat to immunity levels of children in that area (see Colson et al., 2015). Faulty or inconsistent cold chain management of MCV could contribute to children who received the vaccine not seroconverting (acquiring assumed protective measles antibodies) and possibly succumbing to the disease upon exposure (Campbell et al., 2021). Insufficient cold chain capacity as well as differences in adherence to cold chain procedures, inadequate refrigerator maintenance, and lack of understanding of the risks of vaccine freezing occurs at subnational levels. These deficiencies add to the weakness of the existing cold chains (Wirkas et al., 2007; WHO, 2016a). These breaks in the cold chain during vaccine shipment, storage, or delivery may lead to the vaccines being ineffective (Colson et al., 2015). For these reasons, close monitoring and supervision of the vaccine cold chain at all levels is warranted based on the current study findings.

The patterns of association reflected in the multiple sources of subnational data used in the study (DHS, SPA, SIAs, measles cases, and coverage data) showed how two or more sources of data can enhance the picture of the problem at hand (see CDC et al., 2020) and may identify strategic decision-making paths along the route to the best-informed action. This triangulation of data may identify limitations within any one data set, such as data not being available for a certain year or questions regarding quality or completeness, and the subnational perspective allows for important distinctions that are not possible when looking at combined national-level data. For example, when national coverage rates are high and subnational disease incidence is high, comparisons of

surveillance with coverage data may help to highlight where coverage data may be inaccurate (Gavi, 2020). In situations like this, the RI program and surveillance program would meet to discuss the data discrepancy. This process of data triangulation supports collaboration between programs and the possibility for greater data access and sharing through the shared data triangulation task (CDC et al., 2020).

Interpreting the results in the context of the community mobilization theory, I surmised that subnational staff have insight into their local context and play an active role in the collection of the subnational data, analysis of the data (specifically supply and immunization services), and how to act on the data. Major causes of child morbidity and mortality in resource-limited settings can be undertaken at the community level by involving communities and supporting subnational staff (Freeman et al., 2017). The idea of the community helping to recognize common problems and developing and implementing strategies and goals they set collectively are hallmarks of the community mobilization theory (Wallerstein et al., 2015). Because the community mobilization theory is often used to improve the preparation for and use of health care services (Undie et al., 2014), the theory begs to be implemented in practice and clearly reflects the results of the current study.

Interpreting the results through the lens of the diffusion of innovation theory would mean adopting a microlevel or small-scale tactic to change behavior, such as encouraging staff to check the immunization status of children when they present in the clinic for curative or preventive care, or when in the clinic with their family. The behavior change would be at the level of the medical staff as well as the family member:

At each interaction in the health facility, getting in the habit of asking and being asked the immunization status of the child present could lead to proactive or reactive action of children being immunized due to the prompt. Each opportunity to avert a childhood infection or disease should be taken (Freeman et al., 2017).

Limitations of the Study

Though the current study revealed compelling findings, it had several limitations. The first limitation was that the study included secondary data sources and was limited to the questions posed and data collected by the initial investigator (see Frankfort-Nachmias & Nachmias, 2008), variables present, and time period of the data sets. Additionally, this retrospective cross-sectional study was limited by assessing patterns of association between the variables available rather than being able to identify cause-and-effect relationships that may have been present between the dependent and independent variables. The plan was for the data to be merged, but that was not possible due to DHS and SPA reorganization of the regions and lack of names for the districts. Though confounding variables were identified in Section 2, including social marketing and timing of SIAs, their effects on MCV coverage were not found in the literature.

Other limitations included compatibility and quality of the different data collected. Using data collected at different points in time by the same primary researchers (i.e., the same data collection procedures and variable naming conventions) could have reduced certain limitations of the data. I was not able to combine the data in the normal sense based on district or some other geographical variable. However, I was able to triangulate the information from the best available data and highlight patterns of

association that warrant further research to reveal cause-and-effect relationships. Future research could focus on this cause-and-effect relationship in which the confounding factors of social marketing (community education and sensitization) and timing and location of the SIA (e.g., SIA being conducted in schools or taking place during the rainy season [Mensah et al., 2019] or holidays) are considered and data are collected for this purpose.

One final limitation is the fact that the data were collected and the analysis was started prior to the COVID-19 pandemic. Vaccination programs were suspended, and MCV coverage was affected globally during the pandemic (Wang et al., 2022). Action will be needed to reverse the negative trend caused by the pandemic. This will require focused methods to increase immunizations that will be affected by numerous factors, notably geographic and community-specific frameworks (Nuhoza et al., 2021).

Recommendations

Results from the study shows that triangulating subnational data could offer more clarity on the districts, regions, etc. that are significantly and consistently lower in rates of MCV coverage and quantity and quality of supply and immunization services. Based on these results, I recommend that when documenting and observing suboptimal cold chain attributes, vaccine stock outs and lack of or low availability of immunization services for an extended period, awaiting SIA implementation every 2-3 years could accentuate the gap in susceptibles. A more immediate approach to addressing these under vaccinated children would be to employ a selective or subnational campaign to dispense vaccinations to those in the effected regions when the vaccine stock is replenished. If the

geographical spread of the deficiency in services is large, a nationwide or selected district/region SIA could be employed to address these high-risk districts (WHO, 2017d). For smaller areas, implementing a PIRI instead could be warranted (WHO, n.d.). The goal of the PIRI would be to vaccinate non- and undervaccinated children - the hard-to-reach population - as well as to bring attention or visibility to the RI program (WHO, n.d.). The selective SIA and PIRI strengthen RI: a) doses would be included in RI coverage data reflecting a more up-to-date target population (PIRI, specifically); b) bolster supplies; and c) bring an opportunity for supervision and additional training activities (WHO, 2009).

The following study findings are outside the scope of the study but have a significant effect on the vaccination coverage of the study population. I recommend further research on them:

1. The consistently low MCV coverage in one or more regions. What factors contributed to this deficiency and how can they be ameliorated? What are the potential causes in other regions?
2. Why were MCV and BCG antigens available on a very limited basis versus other antigens in the routine immunization program and how can this be rectified?
3. Why is it that child vaccination status often was not questioned during routine and sick care visits and how can it be better integrated into those services?
4. Why does it appear that the vaccine cold chain was not monitored consistently and how can staff and supervisors actively improve these important steps?

Implications for Professional Practice and Social Change

The study found that there were the patterns of association between using subnational data compared to using national-level data as a basis for SIA timing and implementation: differences and relationships that should be acted upon. Recommendations for professional practice center on acting more immediately and locally on triangulated, subnational data. When documenting and observing suboptimal cold chain attributes, vaccine stock outs and lack of or low availability of immunization services for an extended period, awaiting SIA implementation every 2-3 years could accentuate the gap in susceptibles. A more immediate approach to addressing these non- or under-vaccinated children would be to employ a selective or subnational campaign to vaccinate those in the effected regions when the vaccine stock is replenished. If the geographical spread of the deficiency in services is large, a regional SIA could be employed to address these high-risk districts (Zhuo et al., 2011). A PIRI could be warranted for smaller areas (WHO, n.d.). The routine immunization program could be strengthened by the PIRI as doses would be included in RI coverage data and SIAs bring more supplies and additional opportunities for supervision and training (WHO, 2009).

Because the community mobilization theory is often used to improve the preparation for and use of health care services (Undie et al., 2014), reminding subnational staff of their roles may empower them to play a more distinct role in SIA or PIRI planning and implementation. With respect to the diffusion of innovation theory, results of the triangulation of subnational data in the study show there are clear subnational differences that should be addressed sooner and more geographically than waiting and

using national level data to inform SIA or PIRI implementation. This new concept would be based on the previously mentioned community mobilization theory empowerment actions and spread through lessons learned as coverage rates could increase as measles cases decrease. Both of the theories regard communities and organizations as multi-layered, crucial elements and mechanisms for developing, accepting and implementing interventions. Acting more immediately and locally on triangulated, subnational data could positively impact local staff by helping them recognize the importance they play in the collection of their data as well as the impetus for action if they are also included in the planning of the selective SIA or PIRI. This positive social change could have ramifications on the quality of their work (individual), the availability and quality of services (family, organizational, and societal) as well as increased MCV coverage and decreased measles cases (societal).

Conclusion

Current guidelines recommend that countries with weaker health infrastructures use SIAs to deliver MCV to reach children outside of the health system - those that are unreached or unvaccinated through the RI program in the community (WHO, 2009). Intervals for the national SIAs should range from 2-4 years, depending on the national vaccination coverage. Results from the study showed that triangulating subnational data could offer more clarity on the districts, regions, etc. that are significantly and consistently lower in rates of MCV coverage and quantity and quality of vaccine supply and immunization services. Based on these results, I recommend that when deficiencies in MCV coverage and immunization services (health facilities providing routine

vaccinations, cold chain equipment, vaccination sessions, stock supply), are documented, a more immediate approach should be taken versus waiting the recommended 2-4 years for the next SIA. If the geographical spread of the deficiency in services is large, a regional or national level, nonselective SIA should be employed; for smaller areas, implementing a PIRI instead could be warranted. Acting more immediately and locally on triangulated, subnational data could positively impact local staff by helping them recognize the importance they play in the collection of their data as well as the impetus for action if they are also included in the planning of the selective SIA or PIRI. This improvement of the RI system helps to improve the well-being of children under five by helping to maintain or elevate population immunity (WHO, 2016a) and the well-being of the community by increasing equity of service delivery by reaching the under-vaccinated (Biellik & Orenstein, 2018). When the strategy emanates from the local level, benefits will first be noted in the subnational data and the improved population immunity will radiate outward to the national level's increased MCV coverage and decreased measles cases – reflecting the importance of examining subnational data to effect change.

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