



# Integrating Community Health Worker Roles to Improve Facility Delivery Utilization in Tanzania: Evidence from an Interrupted Time Series Analysis

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Published online: 21 June 2019

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## Abstract

**Objectives** Despite renewed interest in expansion of multi-tasked community health workers (CHWs) there is limited research on HIV and maternal health integration at the community-level. This study assessed the impact of integrating CHW roles for HIV and maternal health promotion on facility delivery utilization in rural Tanzania.

**Methods** A 36-month time series data set (2014–2016) of reported facility deliveries from 68 health facilities in two districts of Tanzania was constructed. Interrupted time series analyses evaluated population-averaged longitudinal trends in facility delivery at intervention and comparison facilities. Analyses were stratified by district, controlling for secular trends, seasonality, and type of facility.

**Results** There was no significant change from baseline in the average number of facility deliveries observed at intervention health centers/dispensaries relative to comparison sites. However, there was a significant 16% increase ( $p < 0.001$ ) in average monthly deliveries in hospitals, from an average of 202–234 in Iringa Rural and from 167 to 194 in Kilolo. While total facility deliveries were relatively stable over time at the district-level, during intervention the relative change in the proportion of hospital deliveries out of total facility deliveries increased by 17.2% in Iringa Rural ( $p < 0.001$ ) and 14.7% in Kilolo ( $p < 0.001$ ).

**Conclusions for Practice** Results suggest community-delivered outreach by dual role CHWs was successful at mobilizing pregnant women to deliver at facilities and may be effective at reaching previously under-served pregnant women. More research is necessary to understand the effect of dual role CHWs on patterns of service utilization, including decisions to use referral level facilities for obstetric care.

**Keywords** Bypassing · Community health worker · Interrupted time series · Facility delivery · Maternal child health services · Segmented regression · Tanzania

## Significance

Given the renewed interest in community health strategies globally, particularly related to the expansion of multi-tasked community-based cadres, further evidence around integration of services at the community-level is

needed. In this paper, we examine the integration of HIV and maternal health promotion roles among a cadre of volunteer community health workers in rural Tanzania, using interrupted time series methods to analyze the effect on facility delivery utilization.

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s10995-019-02783-8>) contains supplementary material, which is available to authorized users.

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## Introduction

In Tanzania, the estimated lifetime risk of maternal death is 1 in 33, with hemorrhage (25%), hypertension (16%), and sepsis (10%) as leading causes of maternal death—conditions that are preventable or treatable by skilled

birth attendants providing timely obstetric care (Tanzania MoHCDGEC, Zanzibar MoH, Tanzania National Bureau of Statistics, Zanzibar Office of Chief Government Statistician, & ICF 2016; Afnan-Holmes et al. 2015). While most Tanzanians live within 5 kilometers (km) of a primary health care facility, service underutilization is common due to a number of reasons including distance to the facility, low quality of care, disrespectful care, and cultural norms (Kante et al. 2016; McMahan et al. 2014). Rural women in Tanzania face additional barriers to access and are half as likely to deliver in a facility as women living in urban areas (Afnan-Holmes et al. 2015). Addressing gaps in coverage and quality of care during birth, particularly in rural areas, is an essential strategy for decreasing Tanzania's maternal morbidity and mortality (Afnan-Holmes et al. 2015).

Tanzania's public health system is multi-tiered and decentralized: pregnant women access basic antenatal care (ANC) and labor and delivery services through dispensaries or health centers located nearest to them, with district hospitals equipped to manage complications and offer emergency obstetrical care through referral (Kwesigabo et al. 2012; Armstrong et al. 2016). Most births still occur in rural primary health care facilities, not hospitals, but hospitals are better equipped to manage childbirth complications (given staffing, supplies, equipment, and service availability). During ANC, health care providers at dispensaries and health centers use national referral guidelines to determine when to refer pregnant women for ANC or delivery care; however, full implementation of the referral guidelines would likely result in over 50% of pregnant women being referred (Pembe et al. 2008; Pembe et al. 2010). While nearly all pregnant women attend at least one ANC visit, compliance with maternal referrals for delivery is sub-optimal in Tanzania due to a variety of factors, including: community and family perceptions of risk and complications during pregnancy and labor; previous experience of referrals; costs of transport to the referral hospital and associated living expenses; and perceived quality of care at hospitals versus health centers (Pembe et al. 2008).

This study is centered in the Iringa Region of Tanzania, where the HIV prevalence (9.1%) is nearly double the national average, and disproportionately affects women (10.9%) compared to men (6.9%) (Tanzania Commission for AIDS, Zanzibar AIDS Commission, Tanzania National Bureau of Statistics, Zanzibar Office of Chief Government Statistician, & ICF International 2013). Although predominantly rural, Iringa is among the leading regions in maternal, newborn, and child health (MNCH) service coverage, with the proportion of women who delivered in health facilities increasing over time from 71.8% (2004/2005), to 80.4% (2010), to 92.8%

(2015/16) (Tanzania MoHCDGEC, Zanzibar MoH, Tanzania National Bureau of Statistics, Zanzibar Office of Chief Government Statistician, & ICF 2016; Tanzania and Macro 2011; Tanzania and Macro 2005). In 2014, Iringa Region had Tanzania's highest facility density (3.1/10,000 population) and second highest skilled health workforce density (8.3/10,000 population)—likely contributors to their elevated facility delivery coverage (Armstrong et al. 2016; Straneo et al. 2016). However, the remaining 10% of women in Iringa who continue to deliver at home are at risk of poor maternal and newborn outcomes which can be prevented. To reach this underserved group, frequent home visitation by community health workers (CHWs) is one strategy to mobilize earlier ANC attendance and motivate maternal referral compliance, with an aim of increasing coverage throughout the continuum of care and improving maternal and newborn survival (Tanzania MoHSW 2012). A systematic review found community-based interventions can significantly improve referral to a health facility for complications during pregnancy, delivery, or postpartum, but noted limited evidence of such interventions also increasing skilled birth attendance or institutional deliveries (Lassi et al. 2010). However, prior research in Tanzania has shown community-driven approaches can be effective in mobilizing women to attend ANC earlier (< 16 weeks) and deliver with a skilled birth attendant (Mushi et al. 2010).

This study builds from our prior research showing an existing cadre of volunteer CHWs in Iringa focused on home-based HIV services could successfully be trained and take on additional MNCH health promotion tasks, without detriment to their HIV workload (Shelley et al. 2018, 2019). The objective of this analysis is to assess whether expanding the role of CHWs to include MNCH health promotion resulted in increased facility delivery utilization in two rural districts of Iringa, Tanzania.

## Methods

### Program Context

TUNAJALI (Swahili for “We Care”) was a large-scale HIV/AIDS prevention, care and treatment program in Tanzania with a focus on facility and community-based services. In 2014 TUNAJALI II began supporting MNCH services, with a goal of increasing utilization of antenatal care and facility deliveries. A detailed description of TUNAJALI's community-based component is published elsewhere, along with results showing CHWs could effectively manage their existing HIV support services (linkage to care; adherence support and retention tracking; palliative care; community mobilization; and HIV testing) alongside newly introduced

MNCH health promotion and counseling responsibilities (Shelley et al. 2018, 2019). Approximately half of TUNAJALI volunteer CHWs providing home-based HIV services in Iringa Region received MNCH training on a government-approved 3-week curriculum, thereby establishing a “dual role” CHW tasked with both HIV and MNCH services (compared to “single role” CHWs focused on HIV-only). Training was conducted separately for the two districts: Kilolo (June 2015) and Iringa Rural (November 2015). TUNAJALI volunteer CHWs received a monthly stipend for their service; following MNCH training, the stipend increased from approximately \$15 to \$20 USD for all volunteers irrespective of single or dual role responsibilities. The MNCH curriculum covered a variety of health promotion topics, organized around the timing of pregnancy, postpartum, and early childhood periods. CHWs were trained to offer counseling on developing an individualized birth plan, attending their nearest facility for ANC services, preparing for birth complications and recognizing pregnancy danger signs (plus referral to facilities for management) (Tanzania MoHSW 2012). Discussion with district health officials helped to confirm the absence of other district-wide initiatives aimed at increasing MNCH service utilization.

For additional context on CHWs delivering the intervention, our sample included 187 CHWs: 41% ( $n = 76$ ) dual role and 59% ( $n = 111$ ) single role. On average, CHWs were 43.2 ( $\pm 7.4$ ) years old and reported 5.5 ( $\pm 2.3$ ) dependents and 8.8 ( $\pm 3.6$ ) years of community health experience. The majority of CHWs were married (86%), over half were female (53%), and nearly all reported being primary school (Standard 7) educated (92%) (Shelley et al. 2018). Following the MNCH training, on average each dual role CHW conducted 7 and 9 maternal home visits per month in Kilolo and Iringa Rural, respectively (Shelley et al. 2018).

## Sampling

Among 143 facilities in Iringa Rural and Kilolo districts, 23 facilities (16%) were excluded due to lack of routine MNCH data reported into the government’s electronic district health information system (DHIS2), resulting in sampling from 120 facilities (Supplemental File 1). All dispensaries, health centers, and hospitals supported by single and/or dual role CHWs were eligible for inclusion ( $n = 75$ ; 63%). Facilities with single role CHWs ( $n = 32$ ) were assigned to the comparison group (one facility was excluded due to missing data), while facilities with dual role CHWs ( $n = 21$ ) were assigned to the intervention group. Dispensaries and health centers supported by a mix of single and dual role CHWs were included in the intervention group if  $\geq 50\%$  of CHWs were dual role ( $n = 15$ ), while all others ( $n = 6$ ) were excluded due to a low proportion of dual role CHWs (“low MNCH training dose”). Each district hospital was included

since it served as the referral point for all high-risk deliveries and was supported by a mix of single and dual role CHWs; but there was no comparison site at the hospital level. The final sample consisted of 32 comparison facilities and 36 intervention facilities ( $n = 68$ ) (Supplemental File 2).

## Data Sources

A longitudinal dataset was compiled using several sources: routine data (DHIS2); CHW demographic information; and facility characteristics. The dependent longitudinal outcome variable, number of facility deliveries per month [defined as a facility delivery regardless of the birth outcomes (live and stillborn)], was a facility-level aggregate monthly count (2014–2016) provided from Tanzania’s Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) electronic DHIS2. CHW demographic data was measured through an interviewer-administered survey in 2016 (Shelley et al. 2018). CHW self-reported MNCH training and supervisory facility location was verified using training records. Facility-level time invariant explanatory covariates were extracted from an online health facility registry maintained by Tanzania’s government (Tanzania MoHSW 2015; Darcy et al. 2017). Characteristics included facility type (hospital, health center, or dispensary), facility ownership (government or faith-based organization), availability of HIV care and treatment center (CTC) services, distance to nearest referral point, and number of beds and delivery beds.

Through merging monthly facility delivery counts, facility assignment in intervention or comparison group, and facility characteristics, a time series dataset was created. Each observation in the dataset was uniquely identified using facility and district names plus service month and year. A change point demarcated the “pre-intervention” from the “intervention” when the additional MNCH training, supervision, and reporting was introduced. Since MNCH training was introduced at different times by district, the intervention period contained up to 13 (Iringa Rural) or 18 (Kilolo) monthly data points, while the pre-intervention period contained up to 23 (Iringa Rural) or 18 (Kilolo) monthly data points.

## Statistical Analysis

Exploratory data analysis and statistical checks are described in Supplemental File 3. Frequency of missing data was assessed in the outcome variable: of an expected 2448 monthly observations, 80 values were missing (3.3%) from 35 facilities. To achieve stronger balance, imputation methods were applied to observations determined as “true” missing per verification in DHIS2.

Longitudinal trends in facility delivery before and after MNCH training were assessed using an interrupted time

series (ITS) analysis, a quasi-experimental approach to establish causal inference when random assignment is not possible (Taljaard et al. 2014). The underlying assumption is that outcome trends for the intervention group would change similarly to the comparison group in the absence of intervention (Lagarde 2012). Segmented regression techniques were applied to estimate a different intercept and slope for pre-intervention and intervention periods and across intervention and comparison groups, controlling for secular trends (the long term variation in the time series) and adjusting for potential autocorrelation in the number of deliveries per facility over time (Lagarde 2012; Wagner et al. 2002; Penfold and Zhang 2013). Our modeling approach assessed how much the mean number of facility deliveries changed both immediately following intervention (level change) and gradually over time (slope change). An immediate level “jump” following MNCH training was expected, along with a gradual ramp up over time as CHWs identified and referred more pregnant women in their communities. In the hospital-level model, the pre-intervention trend in facility deliveries is projected into the intervention period to serve as the estimated counterfactual trend (without use of a comparison group as the same hospitals serve both study areas).

A log-linear Poisson regression using a generalized estimating equation (GEE) approach with a first-order autoregressive working correlation structure was specified to account for correlation in repeated measures from the same facility (Liang and Zeger 1986; Chatterjee and Simonoff 2013). Serial correlation in panel data was confirmed using the Woolridge test (Drukker 2003). Robust estimation of standard errors guarded against misspecification of the working correlation structure and corrected for overdispersion (Liang and Zeger 1986). GEE analyses were stratified to allow for differential effects by district. Separate ITS models were specified for hospitals (no comparison group) and health centers/dispensaries (Supplemental File 3). Regression results are reported as incidence rate ratios (IRR) with 95% confidence intervals. A population offset was not included under the assumption that facility catchment areas were relatively stable over time. Model diagnostics included examination of residual versus fitted plots and quasi-likelihood information criterion to identify the most appropriate working correlation structure (Cui 2007). All statistical analyses were run in Stata Version 13 (StataCorp 2013).

The study was jointly approved by the Institutional Review Boards of Johns Hopkins School of Public Health (IRB No. 00005497) and Muhimbili University of Health and Allied Sciences (ref. no. 2015–12–18/AEC/Vol. X/94) and the research was conducted in accord with prevailing ethical principles. Approval for use of DHIS2 data from Iringa was granted by the MoHCDGEC Permanent Secretary in Tanzania.

## Results

### Sample Characteristics

The final sample consisted of two hospitals, ten health centers, and 56 dispensaries ( $N = 68$ ). Facility characteristics are presented for health centers and dispensaries in Table 1 (excluding hospitals), which included 32 comparison facilities (49%) and 34 intervention facilities (51%). Most facilities were government-run (79%) and supported by a mean 2.2 CHWs ( $SD = 1.7$ ); 30% were designated HIV CTC sites. Facilities had an average 1.6 delivery beds ( $SD = 1.1$ ), serving an expected 14 pregnancies per month ( $SD = 11.3$ ). Facilities were located a median of 35 km from the nearest referral point ( $IQR 20$ – $65$ ). Bivariate analyses revealed sufficient comparability between intervention and comparison groups, with minimal differences in facility ownership, number of CHWs per facility, distance to nearest referral point, beds and delivery beds per facility, and expected pregnancies per month (Table 1). However, there were statistically significant differences in facility type and HIV CTC availability among intervention and comparison groups: Health centers were more common among the intervention than comparison facilities (24% vs. 6%;  $p = 0.05$ ) and CTC services were also more common among intervention than comparison facilities (41% vs. 19%,  $p = 0.05$ )—these differences are relevant in that CHWs that received training on MNCH may have been more likely to be from facilities with greater client volume and more service offerings. See additional bivariate analyses by district and comparing intervention versus comparison facilities in each district (Supplemental File 4).

### Time Series Characteristics

The time series dataset consisted of 2448 observations for facility delivery count from January 2014 to December 2016: 1414 observations (58%) pre-intervention and 1034 observations (42%) during intervention, averaging 20.8 and 15.2 months of data, respectively. In Iringa Rural, there were 23 months of pre-intervention data and 13 months of intervention data, whereas in Kilolo there were 18 months of data in both the pre-intervention and intervention periods.

### Intervention Effect on Facility Deliveries

#### Health Center/Dispensary-Level

On average, health centers and dispensaries performed fewer than ten deliveries per month ( $Mean = 8.2$ ;  $Median = 6$ ;  $SD = 6.3$ ;  $IQR: 4$ – $10$ ). During pre-intervention in Kilolo, intervention facilities on average delivered more babies per month than comparison facilities (9.9 vs. 6.5,  $p < 0.001$ ),

**Table 1** Facility characteristics for all facilities (excluding hospitals), stratified by intervention versus comparison groups

| Facility characteristics          | All sites <sup>a</sup><br><i>N</i> = 66; 100%<br>Mean ± SD;<br>or <i>n</i> (%) | Intervention<br><i>n</i> = 34; 51%<br>Mean ± SD;<br>or <i>n</i> (%) | Comparison<br><i>n</i> = 32; 49% | <i>p</i> |
|-----------------------------------|--|---|----------------------------------|----------|
| Supervisory facility type*        |  |   |                                  |          |
| Dispensary                        | 56 (84.8)  | 26 (76.5)   | 30 (93.7)                        | 0.05     |
| Health center                     | 10 (15.2)  | 8 (23.5)  | 2 (6.3)                          |          |
| Supervisory facility ownership    |  |   |                                  |          |
| Government                        | 52 (78.8)  | 27 (79.4)   | 25 (78.1)                        | 0.90     |
| Faith-based                       | 14 (21.2)  | 7 (20.6)  | 7 (21.9)                         |          |
| Adult and pediatric HIV CTC site* | 20 (30.3)  | 14 (41.2)   | 6 (18.8)                         | 0.05     |
| Total CHWs per facility           | 2.2 ± 1.7  | 2.2 ± 1.7   | 2.2 ± 1.6                        | 0.97     |
| Dual Role CHWs per facility       | –  | 1.8 ± 1.4   | –                                | –        |
| Distance to referral point (km)   | 41.7 ± 27.4  | 41.2 ± 29.0   | 42.3 ± 26.1                      | 0.87     |
| Expected pregnancies per month    | 14.1 ± 11.3  | 15.0 ± 10.0   | 13.0 ± 12.7                      | 0.48     |
| Beds per facility                 | 8.4 ± 11.9   | 8.6 ± 11.4  | 8.1 ± 12.6                       | 0.86     |
| Delivery beds per facility        | 1.6 ± 1.1  | 1.8 ± 1.0   | 1.4 ± 1.2                        | 0.38     |

Significant at: \**p* < 0.05; \*\**p* < 0.01; \*\*\**p* < 0.001<sup>a</sup>Hospitals excluded from facility characteristics comparison

SD standard deviation

with a relatively flat trend over time; similarly, during pre-intervention in Iringa Rural the mean number of deliveries was greater at intervention than comparison facilities (9.5 vs. 7.3, *p* < 0.001), with a gradual increase in facility deliveries over time in both groups (Fig. 1; Table 2). However, intervention and comparison facilities were considered sufficiently similar at baseline, given parallel pre-intervention trends and relatively low facility delivery volume. In comparison facilities, there was a small, but significant decrease in average facility deliveries during the intervention period in both Kilolo and Iringa Rural, whereas there was no change in average deliveries observed at intervention facilities over time (Table 2). Given the already low volume of facility deliveries, this finding translated to one fewer delivery per month at comparison facilities during the intervention.

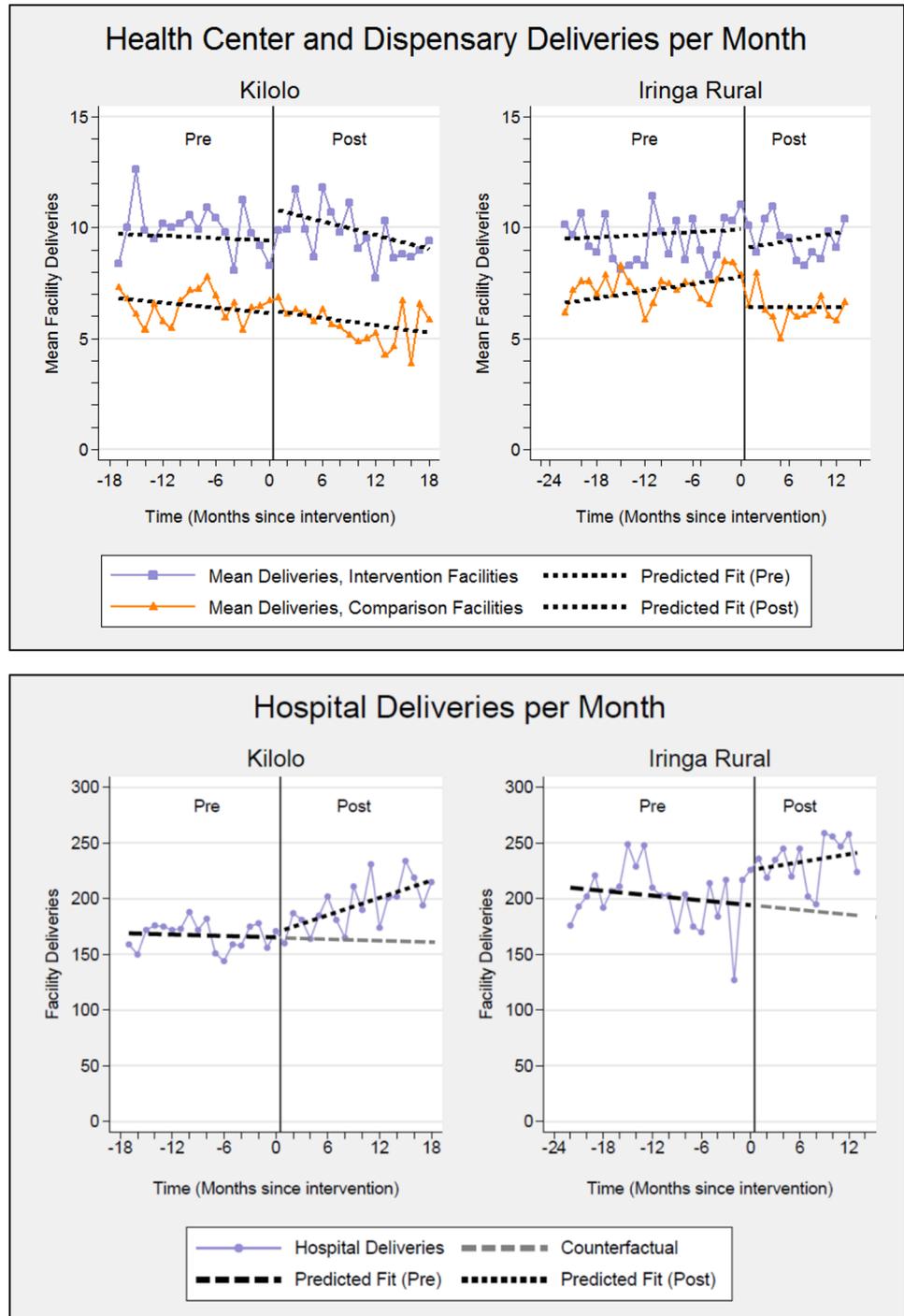
After adjusting for secular trends, seasonality, and facility covariates in the ITS analysis, we found no evidence of a change in level ( $\beta_6$ ) or change in slope ( $\beta_7$ ) in either district in the mean facility delivery count after the intervention began. In Kilolo, the time series plot depicts a gradually decreasing slope in facility deliveries for both intervention and comparison groups during the intervention, whereas in Iringa Rural the comparison group slope was relatively flat and the intervention group slope slightly increasing during the intervention (Fig. 1). However, the monthly volume of facility deliveries remained stable over time, and the changes in slope following intervention were not significant in either district (Supplemental File 3; Table S3.2).

### Hospital-Level

At the hospital in Kilolo there was a statistically significant increase of 27 deliveries per month (95% CI 14.8–39.1; *p* < 0.001), from a mean of 167 deliveries per month pre-intervention to 194 hospital deliveries per month during intervention (Table 2). After adjusting for secular trends and seasonality in the ITS analysis, the number of hospital deliveries remained flat during pre-intervention (aIRR: 1.0, 95% CI 0.99–1.00, *p* = 0.36) with no immediate jump at the change point when the intervention began (aIRR: 1.03, 95% CI 0.97–1.10, *p* = 0.32) (Fig. 1; (Supplemental File 3, Table S3.1)). During the intervention, there was a statistically significant increase in the slope of hospital deliveries compared to the expected counterfactual in the absence of the intervention (aIRR: 1.02, 95% CI 1.01–1.02, *p* < 0.001).

The hospital in Iringa Rural demonstrated a statistically significant increase of 32 deliveries per month (95% CI 14.2–49.5; *p* < 0.001), from a mean of 202 deliveries per month pre-intervention to 234 during intervention (Table 2). In the adjusted ITS analysis, a gradual, but significant decline in the slope of monthly hospital deliveries was evident pre-intervention (aIRR: 0.99, 95% CI 0.98–0.99, *p* = 0.003) (Table 3). This was followed by a statistically significant 36% jump at the change point (aIRR: 1.36, 95% CI 1.19–1.55, *p* < 0.001) and a flat trend thereafter throughout the intervention (aIRR: 1.01, 95% CI 0.99–1.01, *p* = 0.95). Time series plots visually confirm data patterns reflected by the ITS models (Fig. 1).

**Fig. 1** Time series plots of mean monthly facility deliveries at intervention and comparison facilities (panel 1) and hospitals (panel 2), by district



**District-Level: Proportion of Hospital Deliveries out of Total Facility Deliveries**

Within each district, the total volume of facility deliveries summed across all sites (including non-program facilities without single or dual role CHWs) was examined alongside the proportion of hospital deliveries out of total facility deliveries (noting that hospitals were intervention facilities

with dual role CHWs, but also served as the delivery referral point for all facilities—intervention and comparison—in the districts). The average number of facility deliveries in Kilolo increased by 1.3%, an average of 6.3 additional deliveries per month (95% CI 3.7–8.9;  $p < 0.001$ ), from 496.6 to 502.9 deliveries in pre-intervention and intervention periods, respectively (Table 4). The percent of deliveries at the hospital out of total facility deliveries in Kilolo increased by 4.9%

**Table 2** Mean number of facility deliveries per month in the pre-intervention and intervention periods stratified by district, for hospitals and health centers/dispensaries in the intervention versus comparison groups

| Facility deliveries                | Pre-intervention<br>Mean (95% CI) | Intervention<br>Mean (95% CI) | Difference<br>Mean (95% CI) | Relative<br>Change |
|------------------------------------|-----------------------------------|-------------------------------|-----------------------------|--------------------|
| <b>Health centers/dispensaries</b> |                                   |                               |                             |                    |
| District 1: Iringa Rural           |                                   |                               |                             |                    |
| All facilities                     | 8.4 (7.9, 8.8)                    | 7.8 (7.3, 8.4)                | - 0.54 (- 1.26, 0.17)       | - 7.1%             |
| Comparison group                   | 7.3 (6.7, 7.9)                    | 6.3 (5.6, 7.0)                | - 1.06 (- 0.11, - 2.00)*    | - 13.7%            |
| Intervention group                 | 9.5 (8.8, 10.1)                   | 9.5 (8.6, 10.3)               | 0.00 (- 1.05, 1.04)         | 0.0%               |
| District 2: Kilolo                 |                                   |                               |                             |                    |
| All facilities                     | 8.4 (7.8, 8.9)                    | 7.9 (7.4, 8.3)                | - 0.53 (- 1.26, 0.21)       | - 6.0%             |
| Comparison group                   | 6.5 (6.0, 7.0)                    | 5.6 (5.2, 5.9)                | - 0.88 (- 1.48, - 0.28)**   | - 13.8%            |
| Intervention group                 | 9.9 (9.0, 10.8)                   | 9.7 (9.0, 10.5)               | - 0.23 (- 1.40, 0.94)       | - 2.0%             |
| <b>Hospitals</b>                   |                                   |                               |                             |                    |
| District 1: Iringa Rural           | 202.1 (190.4, 213.9)              | 233.9 (221.4, 246.5)          | 31.8 (14.1, 49.5)***        | 15.7%              |
| District 2: Kilolo                 | 167.3 (161.2, 173.3)              | 194.2 (183.2, 205.2)          | 26.9 (14.8, 39.1)***        | 16.1%              |

CI confidence interval

Significant at: \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$

**Table 3** Interrupted time series estimates, by district, unadjusted and adjusted models

| Interrupted time series parameters                                     | District 1: Iringa Rural |                            | District 2: Kilolo     |                            |
|--|--------------------------|----------------------------|------------------------|----------------------------|
|  | IRR (95% CI)             | aIRR (95% CI) <sup>a</sup> | IRR (95% CI)           | aIRR (95% CI) <sup>a</sup> |
| Dispensary and health center deliveries                                |                          |                            |                        |                            |
| Intercept, comparison group ( $\beta_0$ )                              | 7.81 (5.43–11.25)***     | 6.57 (4.05–10.66)***       | 6.17 (4.56–8.34)***    | 5.12 (3.93–6.67)***        |
| Pre: comparison group slope ( $\beta_1$ )                              | 1.01 (0.99–1.02)         | 1.01 (1.00–1.02)*          | 0.99 (0.98–1.00)       | 1.00 (0.99–1.01)           |
| Immediate post: difference in comparison group level ( $\beta_2$ )     | 0.82 (0.65–1.04)         | 0.72 (0.59–0.89)**         | 1.02 (0.75–1.40)       | 0.98 (0.76–1.26)           |
| Post vs pre: difference in comparison group slope ( $\beta_3$ )        | 0.99 (0.97–1.01)         | 0.99 (0.98–1.01)           | 1.00 (0.98–1.01)       | 0.99 (0.98–1.01)           |
| Pre: difference intervention vs. comparison intercept ( $\beta_4$ )    | 1.27 (0.76–2.11)         | 1.02 (0.70–1.50)           | 1.53 (1.00–2.33)*      | 1.15 (0.83–1.60)           |
| Pre: difference intervention vs. comparison slopes ( $\beta_5$ )       | 0.99 (0.98–1.01)         | 1.00 (0.98–1.01)           | 1.00 (0.99–1.02)       | 1.00 (0.99–1.02)           |
| Immediate post: diff. intervention vs. comparison levels ( $\beta_6$ ) | 1.11 (0.78–1.59)         | 1.13 (0.83–1.54)           | 1.14 (0.80–1.61)       | 1.14 (0.85–1.53)           |
| D-in-D intervention and comparison slopes, post vs. pre ( $\beta_7$ )  | 1.01 (0.98–1.04)         | 1.01 (0.98–1.04)           | 1.00 (0.97–1.02)       | 1.00 (0.98–1.02)           |
| Within facility autocorrelation <sup>^</sup>                           | 0.81                     | 0.64                       | 0.75                   | 0.59                       |
| <b>Hospital deliveries</b>   |                          |                            |                        |                            |
| Intercept ( $\beta_0$ )  | 195.2 (177.0–215.2) ***  | 200.5 (178.9–224.7)***     | 165.7 (155.2–176.8)*** | 156.9 (144.4–170.5)***     |
| Pre-intervention trend ( $\beta_1$ )                                   | 1.00 (0.99–1.00)         | 0.99 (0.986–0.997)**       | 1.00 (0.99–1.01)       | 1.00 (0.99–1.00)           |
| Difference in level, immediate post ( $\beta_2$ )                      | 1.15 (0.98–1.36)         | 1.36 (1.19–1.55)***        | 1.03 (0.93–1.13)       | 1.03 (0.97–1.10)           |
| Difference in slope, post–pre ( $\beta_3$ )                            | 1.01 (0.99–1.03)         | 1.00 (0.99–1.01)           | 1.01 (1.01–1.02)**     | 1.02 (1.01–1.02)***        |
| Within facility autocorrelation <sup>^</sup>                           | 0.03                     | - 0.09                     | - 0.12                 | - 0.30                     |

aIRR adjusted incidence rate ratio; CI confidence interval; D-in-D difference in difference; IRR incidence rate ratio; <sup>^</sup>ARI correlation structure

Significant at: \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$

<sup>a</sup>Adjusted for calendar month, clinic type, facility ownership, availability of HIV CTC services, and total number of CHWs

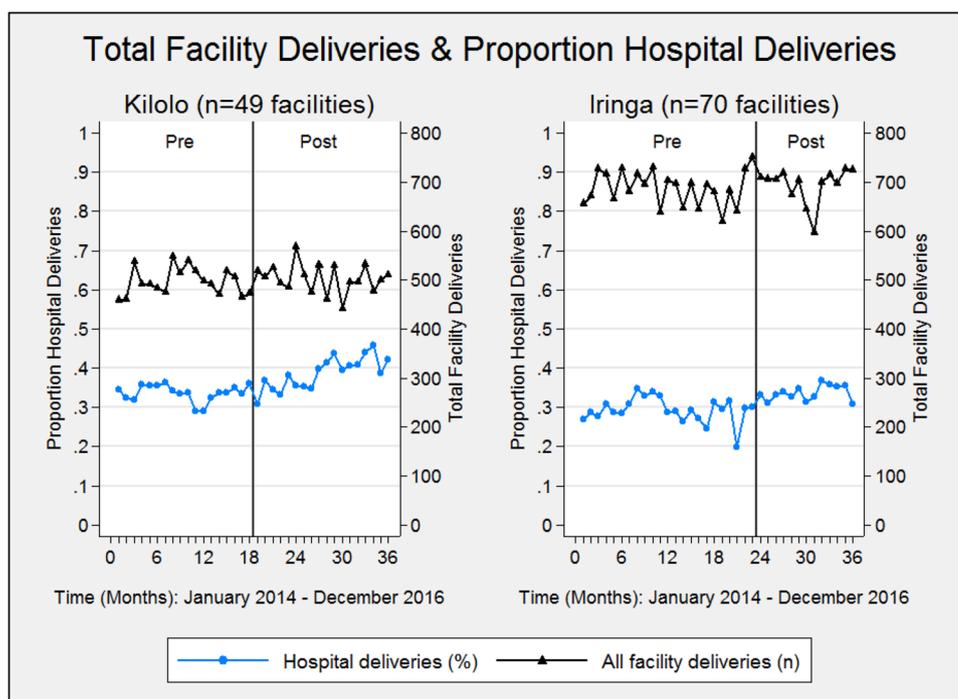
<sup>b</sup>Adjusted for calendar month only

**Table 4** Mean total facility deliveries per month (all facilities, district-wide) and proportion of hospital deliveries out of total facility deliveries per month, during the pre-intervention and intervention periods, stratified by district

| District (all facilities)               | Pre-intervention<br>Mean (95% CI) | Intervention<br>Mean (95% CI) | Difference<br>Mean (95% CI) | Relative<br>Change |
|---|-----------------------------------|-------------------------------|-----------------------------|--------------------|
| <b>Facility deliveries (n)</b>          |                                   |                               |                             |                    |
| District 1: Iringa Rural                | 687.6 (685.9, 689.3)              | 694.2 (691.9, 696.5)          | 6.6 (3.8, 9.5)***           | 0.95%              |
| District 2: Kilolo                      | 496.6 (494.8, 498.4)              | 502.9 (500.9, 504.8)          | 6.3 (3.7, 8.9)***           | 1.27%              |
| <b>Hospital deliveries (proportion)</b> |                                   |                               |                             |                    |
| District 1: Iringa Rural                | 0.29 (0.28, 0.31)                 | 0.34 (0.32, 0.35)             | 0.043 (0.023, 0.063)***     | 17.2%              |
| District 2: Kilolo                      | 0.34 (0.32, 0.35)                 | 0.39 (0.37, 0.41)             | 0.049 (0.027, 0.072)***     | 14.7%              |

CI confidence interval

Significant at: \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$

**Fig. 2** Total facility deliveries per month and proportion of deliveries occurring at hospitals out of all facilities, by district

(95% CI 2.7–7.2;  $p < 0.001$ ), from 34% pre-intervention to 39% during intervention, a 14.7% relative increase. Similarly, in Iringa Rural average facility deliveries increased by 1.0% (average of 6.6 additional deliveries per month) (95% CI 3.8–9.5;  $p < 0.001$ ), from 687.6 during pre-intervention months to 694.2 during intervention months, while the percent of deliveries at the hospital (out of total facility deliveries in Iringa Rural) increased by 4.3% (95% CI 2.3–6.3;  $p < 0.001$ ), from 29% pre-intervention to 34% during intervention, a 17.2% relative increase. Time series plots of total facility deliveries (black line) confirm the relatively stable trend in monthly facility delivery volume, compared to the increasing proportion of hospital deliveries during the intervention (blue line) (Fig. 2).

## Discussion

While there was no measurable change in the average number of facility deliveries at health centers and dispensaries, the share of hospital deliveries increased following intervention, suggesting that dual role CHWs were successful at mobilizing pregnant women to deliver at facilities. Iringa Region is unique among rural Tanzania for attaining high facility delivery coverage: only an estimated 10% of pregnant women deliver at home in Iringa, compared to the estimated national average of about 40% (Tanzania MoHCDGEC, Zanzibar MoH, Tanzania National Bureau of Statistics, Zanzibar Office of Chief Government Statistician, & ICF 2016). A recent study in Iringa Rural district

found women who delivered at home were less educated, lived further from the clinic, and started antenatal care after their first trimester (Straneo et al. 2016), while other studies in Tanzania found that women of lower socioeconomic status and multiparous women were much less likely to deliver in facilities (Ndao-Brumblay et al. 2013; Exavery et al. 2014). These studies suggest the need for further strategies to reach underserved women to improve health equity.

Through household visits and community mobilization, dual role CHWs provided MNCH counseling on the importance of antenatal care, facility delivery and postnatal care. CHWs were trained to identify danger signs and refer pregnant women with potential complications for facility delivery. Since dual role CHWs were already well known and respected in the community for their HIV role, they were well positioned to identify pregnant clients earlier in the gestational period (Shelley et al. 2019). Furthermore, they could provide counseling to increase social expectations around facility delivery, as well as the importance of developing individualized birth plans, and compliance with maternal referrals. Taken together with implementation research demonstrating dual role CHWs could manage both HIV and MNCH responsibilities (Shelley et al. 2018, 2019), these findings suggest further integration of HIV and MNCH services at the community-level is warranted.

### Public Health Implications: Improved Referral Compliance or Bypassing for Childbirth Services?

Total facility deliveries remained stable overall, increasing by about six additional facility deliveries per month in each district, translating to a small relative increase of 1.0% in Iringa Rural and 1.3% in Kilolo—effectively closing roughly 10% of the estimated facility delivery coverage gap in Iringa. However, the relative increase in the proportion of facility deliveries at hospitals was much greater: 14.7% in Kilolo and 17.2% in Iringa Rural. Delivery services are available at dispensaries, health centers, and hospitals, but the increase in facility deliveries was only observed at the hospital-level. In health centers and dispensaries, there were slight downward trends in the average number of deliveries per month during the intervention, although not significant in either district.

There are several potential underlying explanations for the observed findings. First, dual role CHWs may have been effective at motivating pregnant women to comply with referrals for hospital delivery. Given that an estimated 50% of pregnant women would be identified as high risk and given a referral if guidelines are properly executed (Pembe et al. 2008), frequent counseling through home visitation

by dual role CHWs is a likely mechanism through which referral compliance could increase, thereby increasing hospital-level deliveries. CHWs are particularly well positioned to increase awareness of the utility of hospital-based delivery, and to address community and family perceptions of risks during childbirth, which has been found to be a major factor in referral non-compliance in rural Tanzania (Pembe et al. 2008). Our findings align with previous studies in Tanzania that suggest a role for community-based client engagement to keep women retained along the continuum of care, including: Improving antenatal and delivery care through community involvement in safe motherhood promotion in Mtwara (Mushi et al. 2010); increasing postnatal care through CHW counseling in Morogoro (although no association found between CHW counseling and facility delivery) (Mohan et al. 2017); and increasing facility delivery through CHW home visits in Dar es Salaam (although no association found between home visits and increasing ANC4 attendance) (Geldsetzer et al. 2019). In Uganda, community mobilization, male partner engagement, and music and drama groups were found to have stronger effects on place of delivery than on pre-birth preparation, including completing 4 ANC visits (Ediau et al. 2013). These studies suggest there may be different care seeking patterns along the continuum of care, which may be more or less responsive to CHW counseling.

A second explanation is that women may have chosen to bypass their nearest dispensary or health center to seek delivery services at the district hospital (without referral) (Akin and Hutchinson 1999). Per national guidelines on referral indications in Tanzania, women who have not experienced prior obstetric complications are expected to attend their nearest dispensary or health center for delivery services, while those considered “high risk” or with prior complications are referred to hospitals by health care providers at the dispensary or health center (Kante et al. 2016; Pembe et al. 2010; Mkoka et al. 2014). There is growing evidence to document bypassing for childbirth services in Tanzania, with rates ranging from 42 to 64%, and increased bypassing significantly associated with primigravid status, previous birth complications, perception of low quality of care at the local clinic, wealth, and staying at maternity waiting homes (Kante et al. 2016; Kruk et al. 2009; Kruk et al. 2014). Poor quality of care, including mistreatment and abuse during childbirth, is widely documented across Tanzania and has been found to influence facility delivery (McMahon et al. 2014; Rockers et al. 2009; Tancred et al. 2016; Hanson et al. 2013; McMahon et al. 2018), including a positive association between rural women giving birth in a facility and quality of care (Armstrong et al. 2016).

Due to data limitations of this aggregate-level analysis we were unable to investigate the referral status and origin for hospital-level deliveries. In any case, the increase in the

proportion of facility deliveries at Kilolo and Iringa Rural district hospitals is a positive finding, provided the increased demand is manageable. More research is necessary, including examining the risk status of women delivering at hospitals and whether referrals are being generated from CHWs or from health providers at dispensaries and health centers. To more precisely understand the effect of dual role CHWs on patterns of service utilization, further investigation is needed into whether CHWs make appropriate referrals, as well as how and why they may have contributed to improved patient compliance to referral criteria and/or to bypassing decision making. In addition, further research to test the dual role model in areas of Tanzania with lower facility delivery uptake would enhance generalizability of the findings.

### Strengths and Limitations

A major strength of this study was the use of a longitudinal quasi-experimental study design, which improves confidence in the internal validity of the findings. Use of comparison facilities helped limit the extent to which co-occurring events or initiatives could explain the observed trends in deliveries at health centers and dispensaries (Biglan et al. 2000). While there was no comparison facility at the hospital-level, interventions were introduced five months apart in Kilolo and Iringa Rural, which produced a multiple baseline design in adjacent districts and strengthened confidence that the intervention was responsible for the observed change in hospital deliveries (Biglan et al. 2000). Nonetheless, alternative pathways should be considered; however, our analytic design was strengthened through discussions with district officials that did not reveal other district-wide programs targeting increasing MNCH service utilization.

Results should be interpreted considering several limitations. ITS analyses are subject to several additional threats to internal validity (Biglan et al. 2000). Instrumentation threats are unlikely since the outcome measure relied on a routinely collected metric. Data instability (noise) can be problematic for detecting an intervention effect, but the extended baseline helped establish confidence in the pre-intervention trends. Selection refers to any preexisting differences between the intervention and comparison facilities that could account for the experimental effect—the average number of deliveries was slightly higher at intervention facilities, but the overall delivery volume across health centers and dispensaries was generally very low and pre-intervention trends were similar.

The reliance on routine HMIS data, which was done to reinforce the use of routine data in the health systems, may also be subject to data quality concerns. However, this study relied on commonly reported HMIS indicators from the labor and delivery reports. Missing data was extremely infrequent. Further data quality validation efforts were not

logistically feasible but would have helped improve confidence in the accuracy of outcome measurements. Despite data quality concerns, the benefits of routine data were considerable, including: numerous repeat observations over an extended period of time; coverage across nearly all facilities; real-time data availability; and multiple indicators of service utilization (Wagenaar et al. 2016). A further limitation is the lack of data on facility referrals for delivery nor measures of CHW fidelity to the MNCH health promotion messages—both of which would have strengthened the study design and our overall confidence in the casual pathways.

### Conclusion

Even in areas of high facility delivery coverage, such as Iringa Region, additional approaches are needed to reach the remaining underserved women. The results of this study suggest community-level outreach by CHWs to encourage facility delivery may be effective: there was a slight, although insignificant, downward trend in facility deliveries at health centers and dispensaries, while a significant increase in deliveries was notable at the hospital-level. The findings support previous evidence that community-level strategies show promise in improving MNCH access and could be critical in reaching the hardest-to-reach pregnant women that would otherwise deliver at home.

**Acknowledgments** This work was funded by the United States Agency for International Development (USAID) through the Health Research Challenge for Impact (HRCI) Cooperative Agreement [#GHS-A-00-09-00004-00] with the Johns Hopkins Bloomberg School of Public Health (JHSPH). The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government. The Community Health Worker Learning Agenda Project (CHW-LAP) was a multiyear implementation research partnership between JHSPH in the USA and Muhimbili University of Health and Allied Sciences (MUHAS) in Tanzania, within which we embedded the present research. Our thanks and remembrance to the late Helen Semu, Assistant Director of Health Promotion in the Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) for her guidance and support throughout CHW-LAP. Thanks to the Iringa Regional Medical Office and the Iringa Rural and Kilolo District Health Management Teams for facilitation of our data collection plans and overall interest in the research. Collaboration with Deloitte Limited Consulting and Christian Social Services Commission, implementers of TUNAJALI II, was instrumental to this research—they provided numerous insights on their program design and approach, in addition to access to their local civil society organization partners who were essential to facilitating the data collection. Our special thanks for the work of our data collection team: Ismail Amiri, Bernadetha Hubert, Emmanuel Maawe, Christina Maluli, Debora Mlambo, Hereswida Monyiechi, Maurus Mpunga, Annobeatrice Mville, and Zaina Sheweji. We also thank several CHW-LAP staff, including Juliana Joachim who helped coordinate the initial round of data collection, Patrick Kazonda who oversaw survey data entry, and Aisha Omary and Mary Glory

Emmanuel who provided administrative support. Special thanks also to Priscia Wanjiro of MoHCDGEC for serving as our government liaison during data collection in Iringa. Thank you also to Dr. Asha George for mentorship and guidance throughout the project; Dr. Kadia Petricca for early input on the study design; and Dr. Ashley Sheffel for design of an electronic interface for tablet data entry.

**Authors' Contribution** AB and JK are the Principal Investigators of the overarching evaluation within which we designed and collected data for this study. As part of her PhD dissertation, KS designed the protocol and developed data collection instruments with inputs from all authors. KS, GF and RM coordinated and oversaw data collection and management. KS conducted quantitative analyses, with guidance from DP, ES, and AB on interpretation and presentation of results. KS wrote the first draft of the paper, with revision and inputs from all authors. All authors read and approved the final manuscript.

## Compliance with Ethical Standards

**Ethical Approval** The study was jointly approved for ethical clearance by the Institutional Review Boards of Johns Hopkins School of Public Health in Baltimore, Maryland (IRB No. 00005497) and Muhimbili University of Health and Allied Sciences in Dar es Salaam, Tanzania (Ref. No. 2015-12-18/AEC/Vol. X/94).

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**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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