Increasing facility delivery through maternity waiting homes for women living far from a health facility in rural Zambia: a quasi-experimental study

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Objective To report on the effectiveness of a standardised core Maternity Waiting Home (MWH) model to increase facility deliveries among women living >10 km from a health facility.

Design Quasi-experimental design with partial randomisation at the cluster level.

Setting Seven rural districts in Zambia.

Population Women delivering at 40 health facilities between June 2016 and August 2018.

Methods Twenty intervention and 20 comparison sites were used to test whether MWHs increased facility delivery for women living in rural Zambia. Difference-in-differences (DID) methodology was used to examine the effectiveness of the core MWH model on our identified outcomes.

Main outcome measures Differences in the change from baseline to study period in the percentage of women living >10 km from a health facility who: (1) delivered at the health facility, (2) attended a postnatal care (PNC) visit and (3) were referred to a higher-level health facility between intervention and comparison group.

Results We detected a significant difference in the percentage of deliveries at intervention facilities with the core MWH model for all women living >10 km away (DID 4.2%, 95% CI 0.6–7.6, P = 0.03), adolescent women (<18 years) living >10 km away (DID 18.1%, 95% CI 6.3–29.8, P = 0.002) and primigravida women living >10 km away (DID 9.3%, 95% CI 2.4–16.4, P = 0.01) and for women attending the first PNC visit (DID 17.8%, 95% CI 7.7–28, P < 0.001).

Conclusion The core MWH model was successful in increasing rates of facility delivery for women living >10 km from a healthcare facility, including adolescent women and primigravidas and attendance at the first PNC visit.

Keywords Facility delivery, maternal health, maternity waiting homes, quasi-experimental with partial randomisation, Zambia.

Tweetable abstract A core MWH model increased facility delivery for women living >10 km from a health facility including adolescents and primigravidas in Zambia.

Introduction The long distances women must travel, often in labour, to reach health facilities, present one of the biggest barriers to facility delivery. Maternity waiting homes (MWHs), accommodations located near a health facility where women can stay during pregnancy and/or after birth to enable timely access to maternal and newborn healthcare, have been identified as an intervention to bridge this inequity in access caused by distance.

See Appendix for Partner’s Roles in Study.

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Maternity waiting homes, as a strategy to increase deliveries at health facilities with Basic Emergency Obstetric and Newborn Care (BEmONC) capacity, have been embraced as one approach to reach women who must travel long distances to deliver at a health facility. Rural health facilities are designed to be community-based, equitable and accessible to deliver culturally appropriate and sensitive care in remote areas, where much of the population in sub-Saharan Africa resides. Using census data from over 3800 health facilities, researchers in Ethiopia found the majority of MWHs located in rural regions.

Operational models of MWHs are highly inconsistent in the materials, infrastructure and service availability between and within countries, which impacts drawing generalisable implications. Studies from several countries have found wide variation in the condition of MWHs, including lack of access to basic amenities such as electricity, toilets, cooking facilities and beds with mattresses. These and other studies highlight not only the importance of providing basic amenities but also the importance of community ownership for long-term support.

A recent meta-analysis suggests that in low-income countries, MWH users were 80% less likely to die than non-users. Further analysis of these data on over 68 000 births revealed MWH use had a significant effect in reducing perinatal mortality (stillbirths, early and neonatal deaths). Two chief reasons contribute to the lack of robust evidence regarding the effectiveness of MWHs: the limited number of studies with strong methodological designs and varying operationalised models of MWHs.

The present study addresses an important research gap using a quasi-experimental study design with partial randomisation at the cluster level to test the impact of a standardised core MWH model in rural Zambia. Our primary outcome was to determine the effectiveness of a core MWH model to increase access to facility delivery among women living far from a health facility (>10 km). Secondary outcomes included whether MWHs increased utilisation of postnatal care (PNC) and referral to the next level of care for women living >10 km from a health facility at the study sites.

**Methods**

The core MWH model was developed by the Maternity Home Alliance (MHA) and is described in detail elsewhere. Briefly, the core model was co-created with communities based on formative research in response to community standards of acceptability related to: infrastructure, equipment and supplies; policies, management and finances; and linkages and services. Examples of core model components include lighting, lockable doors, concrete flooring, formalised management structure, mechanisms for community/women’s feedback, standard operating procedures, daily check-in by facility staff, availability of emergency transport, and provision of health education. The focus of the core model was to increase access to high-quality obstetric services for the most vulnerable women living far from a health facility.

As part of a quasi-experimental study design with partial randomisation at the cluster level, 20 intervention sites received the core MWH model and 20 comparison sites provided the standard of care for waiting mothers. All intervention sites received newly constructed MWHs during implementation. Standard of care for waiting mothers at facilities without a MWH included informal short stays within the health facility; a simple community-constructed shelter at the site, where women provide their own supplies such as bedding, cooking utensils, etc.; or no dedicated space at all to wait.

Two implementing partners used different methods to assign health facility sites to study arms: one used matched-pair randomisation (10 intervention and 10 comparison) and the other a matched-pair approach without random assignment (10 intervention and 10 comparison) due to political constraints at the district level (Figure S1). Additionally, geographic information system (GIS) techniques were used to geo-locate and map the distance between rural villages and health facility sites in each of the catchment areas. Distances from mothers’ home villages to health facilities were calculated using ArcGIS Online (ESRI, Redlands, CA, USA). Recorded kilometer-distances were determined as the most direct route along roads/paths between each village and their associated health facility.

**Study setting and sample**

Seven districts (Chembe, Choma, Kalomo, Lundazi, Mansa, Nyimba and Pemba) in three provinces (Eastern, Luapula and Southern) were included in the study, with a total estimated population of 369 234 within-catchment communities at all study sites. Baseline characteristics of study sites were primarily rural, with estimates of rural populations between 67% (Chembe) and 95% Lundazi. Choma/Pemba and Mansa/Chembe were administratively combined in the 2010 census. Except for Chembe, each district had at least one district hospital providing Comprehensive Emergency Obstetric and Neonatal Care (CEmONC).

The MWH intervention was examined at rural health facilities that serve women living in remote communities far from a health facility. The government of Zambia supports MWHs as one approach to increase facility delivery. Briefly, facilities were chosen based on meeting the eligibility criteria of conducting at least 150 deliveries annually and situated ≤2 hours driving time from a facility providing CEmONC. Additionally, facilities were required to meet at least one of two sets of conditions: able to...
Data collection

The MHA partners harmonised instruments for data collection prior to the commencement of the study. Working with their local partners, the University of Michigan collected data on the MWH sites from Chembe, Lundazi and Mansa and Boston University collected data on the MWH sites from the remaining districts. Data were extracted from Ministry of Health (MOH) registers at each of the 40 health facility sites in the study for admission, delivery, PNC and referrals for complications to the next level of care (nearest CEmONC). Additionally, data were collected through an MWH register upon admission that captured demographic data, reason for MWH stay, travel time and means of travel to MWH.

Time parameters for baseline data collection were set at 3 months prior to the opening of each individual MWH. The first MWHs opened in June 2016. Because MWHs were built and opened at various time points, time parameters for the study period included the first full month after the opening of the MWH through the end of data collection (August 2018); therefore, the study period reflects MWHs in operation between 12 and 24 months (Figure S2).

Research assistants (RAs) extracted admission, discharge and transfer data from all health facility delivery registers at all 40 sites. They also extracted data on PNC attendance and referrals from facility registers. After obtaining informed consent, admission data were collected from each woman using a MWH survey that was administered verbally by a Zambian RA in the local language.

Data analysis

Process and outcome indicators from the two implementing partners were agreed upon by partners a priori and data were combined at the end of the study. The MHA partners agreed on a small set of primary and secondary outcomes prior to the intervention to answer the overarching research question: ‘does a core MWH model increase access to facility delivery for women living far from the health facility (>10 km)?’. By agreeing on a limited number of indicators easily retrieved from health facility registers to examine the research question, we decreased the burden of data collection on the health system.

Descriptive analyses were performed comparing demographics across baseline and study period using Chi-square tests for categorical variables and t-tests for continuous variables. We used the difference-in-differences (DID) methodology to examine the effectiveness of the core MWH model on our primary and secondary outcomes. This approach adjusted for potential biases from underlying time trends and other unmeasured confounders between BEmONC facilities with MWHs (the intervention group) and BEmONC facilities without MWHs or unimproved MWHs (the comparison group). Based on data from the Saving Mothers Giving Life (SMGL) initiative Phase I and district level MOH, intervention facilities experienced a common trend in attendance for maternal and newborn services to comparison facilities until the opening of MWHs. For both groups, we calculated the proportions of women living >10 km from a health facility who came for deliveries at a BEmONC facility, attended a PNC visit at the recommended intervals (within 72 hours; 7–14 days; 6 weeks postpartum), and were referred to a higher-level health facility in baseline and the study period. We compared the differences in the change of percentages in the intervention group versus comparison group during the study period relative to baseline (3 months prior to MWH opening) to identify associations between MWHs and outcomes.

Logistical regression was used to test the association between MWHs and the proportions of women who lived >10 km away from the facility for deliveries, PNC visits and referrals. In each model, we included two dummy variables: (1) equal to 1 for the intervention group and 0 for the comparison group and (2) equal to 1 for observations from the study period and 0 for those from baseline. We used an interaction term between these two dummy variables to perform a statistical test of the DID estimator. We then performed a risk-adjusted model controlling for age, gravida and an indicator of whether randomisation was used in the facility assignment. We also conducted a sub-analysis by facility assignment (randomised versus non-randomised). All hypothesis tests were two-sided with the level of statistical significance set to 0.05. Statistical analyses were conducted in STATA version 15.0 (StataCorp, College Station, TX, USA).

Results

Overall, the intervention and comparison groups were similar. Delivery records from MOH registers indicated women were on average 24 years of age, having their third child, with 24–27% primigravidas. However, there was a greater number of women under age 18 years in the intervention sample than in the comparison sample at baseline (P = 0.01). During the course of the study period (June 2016 to 1 August 2018), 63.3% (n = 6622) of all women delivering at an intervention health facility used an MWH. Complete demographics are listed in Table 1.

A total of 18 544 women delivered at an intervention or comparison health facility during the study period timeframe. Table 2 presents the absolute DID for women living >10 km away and delivering at the health facility, adolescent women (<18 years old), primigravida women and grand multipara women. The absolute DID compares...
We detected a significant difference for the percentage of adolescent women living >10 km away and delivering at the health facility (\(P = 0.001\)) living >10 km away and delivering at a health facility, with a higher percentage delivering at health facilities in the intervention group after introduction of the core MWH model. The risk-adjusted model, controlling for age, gravida and an indicator of whether randomisation was used in the facility assignment, found no significant differences in our outcome variables for women living >10 km away.

Next, the absolute DID for women living >10 km from a health facility and attending a PNC visit within 72 hours, 7–14 days and 6 weeks postpartum and those women referred for complications to a CEmONC facility, was calculated (Table 3). There was a significant difference in women attending the first PNC visit (within 72 hours) postpartum \((P < 0.001)\), with a higher percentage of change in the number of women at the intervention sites after the core MWH model was introduced. There was not a significant difference in attendance at the 7- to 14-day visit \((P = 0.414)\) or at the 6-week visit \((P = 0.612)\). Distance data on referrals were collected at half our study sites \((n = 10\) intervention, \(n = 10\) comparison). A significant difference was noted in the proportion of women referred to the next level of care from baseline to endline in this sub-sample \((P = 0.023)\).

A sub-analysis, by facility assignment, of women living >10 km from a health facility found a significant DID in the absolute and adjusted models for grand multipara women in the randomised group \((P = 0.04)\). Alternatively, the matched-pair without randomisation noted a significant DID in the absolute and adjusted models for women living >10 km away and delivering at the health facility \((P = 0.002)\), for adolescent women \((P = 0.001)\) and for primigravida women \(P \leq 0.001\) (Table S2). Similarly, differences were noted between the randomised and non-randomised facilities for PNC within 72 hours postpartum \((P = 0.63\) versus \(P < 0.001)\) (Table S3).

Using the GIS data, we calculated the travel distance for 98% of the women utilising a MWH during the study period using medians and interquartile ranges (IQR). The median distance travelled by all women utilising a MWH was 7.3 km (IQR 6.5 km), with a median length of stay of 9.0 days (IQR 19.0 days). The median length of stay based on type of care was 5.0 days (IQR 12.0 days) for antenatal care, 12.0 days (IQR 19.0 days) for those awaiting delivery, and 1.0 day (IQR 1.0 day) for those using the MWH to receive PNC. As noted in Table 4, overall 38.6% of women travelled from >10 km away, representing the largest group of women using an MWH for any reason. The median distances for each type of care received included 6.9 km (IQR 9.9 km) for antenatal care, 7.5 km (IQR 6.7 km) for those awaiting delivery, and 6.1 km (IQR 6.7 km) for those receiving postnatal care.

Additionally, transportation data were calculated for 97% of the women using an MWH (Figure S3). The majority of participants (82.5%) used non-motorised means to get to the health facility, including walking, bicycle, or carried in hammock/wheelbarrow or an ox cart.

### Table 1. Characteristics of women delivering at health facilities at baseline and following opening of maternity waiting home (MWH) core model

|                         | Intervention before MWHs opened | Comparison before MWHs opened | \(P\)-value** | Intervention following opening of MWH | Comparison following opening of MWH | \(P\)-value** |
|-------------------------|---------------------------------|-----------------------------|--------------|--------------------------------------|-----------------------------------|--------------|
| **Age, mean (SD)**      | Intervention 20 sites \(n = 1570\) 24.6 (6.8) | Comparison 20 sites \(n = 1162\) 24.7 (6.6) | 0.57         | Intervention 20 sites \(n = 10\ 463\) 24.6 (6.6) | Comparison 20 sites \(n = 8081\) 24.7 (6.5) | 0.1         |
| **Age <18 years, n (%)  | intervention 20 sites \(n = 1570\) 183 (11.9) | Comparison 20 sites \(n = 1162\) 103 (8.9) | 0.01*        | Intervention 20 sites \(n = 10\ 463\) 1081 (10.5) | Comparison 20 sites \(n = 8081\) 785 (9.8) | 0.13        |
| **Gravida, mean (SD)**  | intervention 20 sites \(n = 1570\) 3.2 (2.1) | Comparison 20 sites \(n = 1162\) 3.2 (2.1) | 0.64         | Intervention 20 sites \(n = 10\ 463\) 3.2 (2.0) | Comparison 20 sites \(n = 8081\) 3.2 (2.0) | 0.95        |
| **Parity, mean (SD)**   | intervention 20 sites \(n = 1570\) 2.2 (2.0) | Comparison 20 sites \(n = 1162\) 2.3 (2.0) | 0.62         | Intervention 20 sites \(n = 10\ 463\) 2.2 (2.0) | Comparison 20 sites \(n = 8081\) 2.3 (2.0) | 0.16        |
| **Primigravida, n (%)   | intervention 20 sites \(n = 1570\) 421 (27.1) | Comparison 20 sites \(n = 1162\) 276 (24.1) | 0.08         | Intervention 20 sites \(n = 10\ 463\) 2479 (24.1) | Comparison 20 sites \(n = 8081\) 1902 (23.8) | 0.7         |
| **Grand multipara >6 pregnancies, N (%)** | intervention 20 sites \(n = 1570\) 139 (8.9) | Comparison 20 sites \(n = 1162\) 88 (7.7) | 0.24         | Intervention 20 sites \(n = 10\ 463\) 810 (7.8) | Comparison 20 sites \(n = 8081\) 574 (7.2) | 0.09        |
| **Distance from healthcare facility >10 km, n (%)** | intervention 20 sites \(n = 1570\) 440 (28.3) | Comparison 20 sites \(n = 1162\) 291 (25.1) | 0.06         | Intervention 20 sites \(n = 10\ 463\) 3185 (31) | Comparison 20 sites \(n = 8081\) 1900 (23.6) | <0.001      |

*Missing data: Of total deliveries, 224 (1.05%) have missing age; 250 (1.18%) have missing gravida; 242 (1.14%) have missing parity.

**\(P\)-value compares intervention and comparison; two sample t-test used to compare means; Chi-square test used to compare proportions.

facilities with the core MWH model with comparison sites.

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Main findings

In the present study, we examined how the core MWH model can increase facility delivery, attendance at PNC visits and referral for complications to a CEmONC facility for women living >10 km away from a health facility. Overall, this study found the core MWH model was successful in increasing facility delivery and attendance at the first PNC visit for women living >10 km from a healthcare facility. The core MWH model also increased the percentage of women <18 years old and primigravida women living >10 km away accessing health facilities for deliveries. There was no significant difference for the percentage of women attending a PNC visit at 7–14 days or 6 weeks postpartum living >10 km away. A significant difference was found among women referred to a CEmONC facility, but there are limitations to this finding due to the small sample size at baseline.

Strength and limitations

This study has several strengths, including a large sample of women living in rural, remote areas of Zambia and the use of selection criteria to match comparison and intervention sites. Additionally, the harmonisation of indicators prior to the start of data collection ensured that partners used the same definitions and measured similar outcomes.

There are several limitations that constrain interpretation of the findings. First, implementing partners used different methods to select and assign health facility sites to study arms. In four districts, one partner randomly assigned health facilities to receive the MWH intervention, whereas in three districts, the second partner used input from district health teams and purposively sampled from eligible rural health facilities. Due to lack of randomisation, selection bias may have been introduced into the study. In our sensitivity analysis, we conducted a risk-adjusted model and did not find a significant difference between facilities randomised and those not randomised. This may be a reflection of the strict criteria established for inclusion in the study. We acknowledge that it is possible there are inherent differences between the comparison and intervention sites that cannot be fully adjusted. Secondly, the study was conducted in districts where the SMGL initiative had implemented evidence-based interventions to reduce maternal and newborn mortality, including improving the quality of BEmONC services while improving access and demand. However, these SMGL districts were purposively chosen to ensure adequate quality of care if the intervention increased access and demand. Additionally, distance data for women referred to a CEmONC facility was only collected at half our study sites, leading to small numbers at baseline and threatening the validity of these results. Finally, MOH facility registers were used for collection of various data. Data were
entered into these registers by the nurse or midwife on duty. Although each health facility was issued standard data collection registers with definitions for each cell, there was the chance of varying interpretation by the recorder. To address this, we conducted training at each site with nurses and midwives to ensure accuracy of the data.

**Interpretation**

Overall, this study found the core MWH model was successful in reaching women with historically low rates of facility delivery and attendance at the first PNC visit—those living >10 km from a healthcare facility. Data on utilisation of maternal and newborn care from five East African countries suggests that greater geographical inaccessibility (often defined as >10 km from a health facility) contributes to lower rates of receiving recommended antenatal care, delivering at a facility with a skilled birth attendant, and obtaining PNC. The core MWH model provided access to this population regardless of how they initially reached the MWH, via motorised or non-motorised transportation.

**Table 3. Absolute difference-in-differences for women living >10 km away and attending a postnatal care (PNC) visit within 72 hours, 7–14 days and 6 weeks postpartum or referred to comprehensive emergency obstetric and neonatal care (CEmONC) facility**

|                        | Intervention sites (n = 20) | Comparison sites (n = 20) | Absolute difference-in-differences** |
|------------------------|-----------------------------|---------------------------|-------------------------------------|
|                        | Baseline | Study period | Study period—baseline | Baseline | Study period | Study period—baseline | DID (95% CI) | P-value |
| PNC visit within 72 hours postpartum | n = 183 43 (23.5%) | n = 291 796 (27.3%) | | n = 142 47 (33.1%) | n = 2203 421 (19.1%) | | 17.8% (7.7, 28.0) | <0.001 |
| PNC visit at 7–14 days postpartum | n = 785 230 (29.3%) | n = 5336 1448 (27.1%) | | n = 700 155 (22.1%) | n = 5160 965 (18.7%) | | 1.3% (−3.4, 6) | 0.414 |
| PNC visit at 6 weeks postpartum | n = 185 43 (23.2%) | n = 1131 295 (26.1%) | | n = 154 27 (17.5%) | n = 848 149 (17.6%) | | 2.8% (−6.5, 12.1) | 0.612 |

**Table 4. Length of maternity waiting home (MWH) stay in days by type and distance at intervention sites**

| MWH length of stay in days | Distance (km) |
|----------------------------|---------------|
| Median (IQR) | <5 km | 5–10 km | >10 km |
| Overall (n = 6622) | 9.0 (19.0) | 7.3 (6.5) | 1630 (28.8%) | 1852 (32.7%) | 2186 (38.6%) |
| By reason | | | | | |
| Antenatal care (n = 27) | 5.0 (12.0) | 6.9 (9.9) | 10 (43.5%) | 4 (17.4%) | 9 (39.1%) |
| Antenatal delivery (n = 5627) | 12.0 (19.0) | 7.5 (6.7) | 1333 (27.7%) | 1613 (33.5%) | 1867 (38.8%) |
| Postnatal care (n = 949) | 1.0 (1.0) | 6.1 (6.7) | 281 (34.4%) | 229 (28.1%) | 306 (37.5%) |

*P* < 0.05.

**The absolute difference-in-differences compares facilities that have the MWH core model with comparison sites.

***Women attending postnatal care between 4 and 14 days were included so as not to exclude women who attended their second PNC visit.

****Women attending postnatal care between 15 and 42 days were included so as not to exclude women who attended their third PNC visit.
The postnatal period, the days and weeks following delivery, represent a critical phase in women and newborn’s lives. The World Health Organization recommends at least three postnatal contacts following delivery for all mothers and newborns. Pool analysis of nine studies from low- and middle-income countries found that 75% of newborn deaths occur in the first week of life (74.3%), with the highest number of deaths in the first week during the first 3 days of life (37.6%). The core MWH model increased the proportion of women attending this essential PNG visit within the first 72 hours post-delivery.

While a statistically significant difference was found in the average referral rate between the intervention and comparison sites, the small number of referrals at baseline contributes to the lack of robustness of these data. Our study was intentionally conducted in districts where SMGL had previously been implemented to provide quality services for women choosing facility delivery. Prior to the beginning of this study, all sites received upgrading of services through the SMGL initiative, including improving communication and transportation systems. Further research is needed to assess the impact of MWHs on referral patterns for women living >10 km from a health facility.

There may be several explanations for the differences for women living >10 km from a health facility noted at a sub-analysis level. Temporal variations may have occurred in collection of baseline data. Baseline data were collected in the non-randomised communities 3 months prior to baseline data in the randomised communities and therefore a longer timeframe for study period data collection occurred in the non-randomised communities. Additionally, in the non-randomised communities, site selection was driven by the district ministry, who expressed concern that community fatigue due to large numbers of projects and research activities in the area would affect implementation.

In addition to increasing access for all women at geographical risk, the core MWH model also increased the percentage of adolescent women (<18 years old) and primigravida women living >10 km away accessing health facilities for deliveries. Adolescents are known to be at greater risk for maternal morbidity and mortality due to biological and socio-cultural factors. The government of Zambia specifically recommends that all adolescent pregnancies, primigravidas and grand multiparas should deliver at a health facility due to increased risk for maternal morbidity and mortality related to age and pregnancy status.

A persistent decline was seen in almost all our outcome variables from the baseline-study period in the comparison communities. It is possible that women chose to deliver at facilities with MWHs. Several studies have shown women regularly bypass clinics in search of quality services.

Past research has noted there are numerous barriers to the use of MWHs once they are constructed, and some studies have seen minimal use and sustainability. Maternity waiting homes in Guatemala and Ethiopia were not used due to lack of knowledge and community awareness about the homes and limited provision of culturally appropriate care. A qualitative thematic synthesis of 29 studies from 17 countries additionally noted poor utilisation due to inadequate structures, absence of community involvement in the design and upkeep, as well as culturally inappropriate care and lack of knowledge and acceptance by women and community members. Alternatively, the core MWH model implemented in this study incorporated many of the facilitators identified in past research, including no cost to stay, community involvement, awareness raising and integration of culturally appropriate practices to ensure uptake and sustainability. Early harmonisation of indicators ensured that MHA partners used the same definitions and measured similar outcomes. This allowed for comparisons using all partner data and is essential to ensure that large-scale data obtained using a quasi-experimental design are comparable across sites. This methodology addresses many of the problems noted in the literature that have led to mixed and inconclusive results regarding the outcomes and effectiveness of MWHs.

**Conclusion**

This study is one of the first to examine the impact of an MWH intervention to increase access to reproductive health services for women living >10 km from a rural health facility. Results of this study indicate that a community-driven, entrepreneurial core MWH model is effective at increasing facility delivery for women living far from the health facility (>10 km), especially primigravidas and women <18 years old. The core MWH model also significantly increased attendance at the first PNC visit for women living >10 km from the health facility, a critical time in the lives of women and newborns. Maternity waiting homes are one strategy to improve access to facility delivery for women living a great distance from a healthcare facility.

**Disclosure of interests**

None declared. Completed disclosure of interests forms are available to view online as supporting information.

**Contribution to authorship**

JRL, CJB, DHH, NAS designed the study and data collection instruments. TN, JLK, MB, GM, JEP collected data. JRL, MLMK, HL, KLM, XZ, PK, PCR, NL, NAS managed and conducted data analysis. JRL, MLMK, HL, KLM, XZ, HL, TN, JLK, MB, GM, IS, JEP, RMF, CJB, PC, PCR, DHH, GB, TV, RB, NL, NAS contributed to the development of the manuscript. All authors reviewed and approved the final version of the manuscript.
Details of ethics approval
Ethical approvals were obtained from the University of Michigan (Ref No. HUM00110404, Date of Approval 18 January 2016) and Boston University Institutional Review Boards (Ref No. H-34526, Date of Approval 12 January 2016) as well as ERES Converge (Where Research, Ethics, and Science Converge) IRB (Ref No. 00005948, Date of Approval 14 December 2015), a private research ethics board in Zambia governed by the National Health Research Ethics Committee. We also obtained approval to proceed with the study from the Zambia National Health Research Authority, which is responsible for oversight of all research conducted in that country.

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Data availability statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Supporting Information
Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Study sites and participants by randomisation and non-randomisation.

Figure S2. Study timeline.

Figure S3. Comparison of non-motorised versus motorised transportation by time in hours.

Table S1. Health facilities meeting eligibility criteria.

Table S2. Absolute difference-in-differences for women living >10 km away group by sites; n (%).

Table S3. Absolute difference-in-differences for women attending a postnatal care (PNC) visit within 72 hours, 7–14 days and 6 weeks postpartum, by site.

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Appendix

Authors’ roles in the reported study

Jody R. Lori1, PI
Michelle L. Munro-Kramer1, co-I
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Jeanette L. Kaiser2, co-I
Misheck Bwalya3, co-I
Gertrude Musonda4, co-I
Isaac Sakala4, co-PI
Joseph E. Perosky1, data management
Rachel M. Fong1
Carol J. Boyd1, co-I
Parker Chastain1, co-I
Peter C. Rockers2, co-I
Davidson H. Hamer2, co-I
Godfrey Biemba3, co-I
Taryn Vian4, co-I
Rachael Bonawitz2, co-I
Nancy Lockhart1, data management
Nancy A. Scott7 PI

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