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Are children on track with their routine immunisation schedule in a fragile and protracted conflict state of South Sudan?

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ABSTRACT

Objectives The objective of this study was to assess if children aged 0-23 months in a conflict-affected state of South Sudan were on track with their immunisation schedule and to identify predisposing factors that affected this study population from being on track with their routine immunisation schedule.

Design Community-based cross-sectional study using a semi-structured questionnaire. The binary outcome of interest was defined as being on or off track with routine vaccination schedule. Multivariable logistic regression was used to analyse for the association between the predisposing factors surveyed and being off track with one's routine immunisation schedule.

Setting Rural communities in four counties (Rumbek Centre, Rumbek North, Rumbek East and Wulu) of the Western Lakes state in South Sudan during January 10, 2020 to June 10, 2020.

Participants We surveyed 428 children aged 0-23 months and their mothers/caregivers who lived in either of the four counties in the Western Lakes State. Participants were selected using random ballot sampling.

Results More than three-quarters of the children surveyed (75.5%) were off track with their vaccination schedule. Children with an immunisation card had 71% reduced odds of being off track with their immunisation (AOR=0.29; 95% CI 0.10 – 0.83, p-value=0.021) compared to children without immunisation cards. Children who reside near health facilities and do not require transportation to facilities had 87% reduced odds of being off track with their immunisation compared to those who lived far and required transport to facilities. Giving an adequate immunisation notice before conducting immunisation outreach visits to communities was also associated with reduced odds (AOR=0.27; 95% CI 0.09 – 0.78. p-value=0.016) of children being off track with their immunisation.

Conclusion This study revealed that most children were off track with their vaccination schedule in South Sudan, which is not only influenced by maternal characteristics but mainly by community- and state-level immunisation service delivery mechanisms. Interventions to improve child immunisation uptake should put these contextual characteristics into high health agenda consideration.

Keywords: Vaccine-preventable diseases, immunisation defaulters, Immunisation in practice, community healthcare, conflict setting, South Sudan

KEY POINTS

Question: While there is a lot of investment in immunisation in the humanitarian setting, this study is aimed at these research questions - Are children in conflict-prone regions of South Sudan on track with their immunisation schedule? And what are the predisposing factors that affected children between 0-23 months old living in this region from being on track with their routine immunisation schedule?

Finding: This study revealed that most children were off track with their vaccination schedule in South Sudan, which is not only influenced by maternal characteristics but also by community- and state-level immunisation governance.

Meaning: This study imparts a significant deal of knowledge in improvement of immunisation uptake coverage among children living in an armed conflict context

INTRODUCTION

Since 2012, South-Sudan's full immunisation coverage has been around 47.5%, and since then, the country has remained a conflict-prone region (1–3). Data from the WHO vaccine-preventable diseases monitoring system shows that between 2017 and 2020, there has been an alarming rate of Measles and Rubella diseases in the country (3,4). The Measles outbreak in South Sudan and the increasing prevalence of vaccine-preventable diseases could be linked to the challenges with immunisation access and its cold chain logistics (5). This is as a result of the South Sudanese Civil War which lasted between December, 2013 and February 2020 with an estimate of about 50% of the cold-chain infrastructure in the country being vandalized and looted (6). The low coverage of vaccine-preventable diseases in South Sudan is also related to the fragile health system (1), which is bedevilled with the several challenges ranging from health workforce shortages, poor public funding of the health system, limited access to healthcare services, as well as weak vaccine surveillance and monitoring systems (7). The upsurge in some vaccine-preventable diseases clearly indicates the need for more attention to be given to immunisation in South Sudan in a bid to forestall a resultant increase in childhood mortality that could ensue. The re-emergence and increasing prevalence of vaccine-preventable diseases in South Sudan is similar to the situation in conflict-prone regions of countries such as Iraq, Syria and Yemen (8).

Arguably, children in conflict-prone regions rightfully deserve to be fully vaccinated like their peers in other parts of the world. A significant proportion of children would need to be immunized over a prolonged period for herd immunity to be attained in their region or country, and as such, the risk of a child contracting a vaccine-preventable disease is higher if more children have either not been immunized or received incomplete immunisation (9).

In accordance with global recommendations for increased vaccination coverage of at least 90% in all countries, it is imperative that vaccination coverage and completion rates in South Sudan are given high attention to ensure that the factors impeding complete vaccination coverage are identified and novel strategies employed to bridge the gap in immunisation coverage (10). This study seeks to assess if children in a conflict-prone state of South Sudan are on track with their immunisation schedule and also to identify the predisposing factors that affected children between 0-23 months old living in South Sudan from being on track with their routine immunisation schedule.

Vaccination Schedule

South Sudan has an elaborate immunisation schedule (see Appendix Table 1) where children are expected to receive a dose of Bacille Calmette-Guérin vaccine (BCG) – given at birth or first encounter with the health system, a three-dose course of the pentavalent vaccine – given at 6, 10 and 14 weeks or at least four weeks apart, four-doses of oral polio vaccine (OPV; given at birth, 6, 10 and 14 weeks), a dose of inactivated polio vaccine (IPV) – given at 14 weeks – and a dose of measles-containing vaccine (MCV1; administered at 9 months) (11).

METHODS

3.1 Study setting

This study was conducted in the rural communities of the four counties - Rumbek Centre, Rumbek North, Rumbek East, and Wulu in the former Western Lakes State (see Figure 2). The former Western Lakes state was a state in South Sudan that was abrogated to function as a state during the peace agreement signed on the 22nd of February 2020, with an aim to reduce the former 28 states to the current 10 states (12,13). Rumbek East, Wulu, Rumbek North and Rumbek Centre counties have a population of 186,412; 61,084; 65,297 and 232,752 in the July 2017 projection population estimate respectively (14).

Since 2005, the former Western Lakes state region, one of the most insecure areas of South Sudan has experienced yearly series of armed conflict and displacement caused by different reasons per county. From land, agricultural and water disputes to armed robberies, these violent occurrences have sustained the insecurity in South Sudan (15). This has been worsened by re-occurrence of natural disasters e.g. heavy (destructive) flooding during the wet season (16).

3.2 Study Design

The study is a comparative community-based cross-sectional study to determine the predisposing factors for on track and off track immunisation among children between 0-23 months in South Sudan. The study was conducted in the communities, also called bomas of the four counties aforementioned using a semi-structured questionnaire. The binary outcome was defined as whether children aged 0-23 months were on track with their immunisation schedule or off track. Being on track was defined as when a child who was eligible for vaccination had received the recommended vaccines' doses they were due for at the time of the study survey. Off track was defined as if a child had not received a vaccine they were eligible for on or before 28 days of delay according to South Sudan's recommended schedule (17).

Information about immunisation was extracted from the child's immunisation card or as reported by the mother and verified on the immunisation register.

3.3 Sampling and Sample size determination

We sampled 428 children and their mothers/caregivers using random balloting sampling.

The number of children under 24 months required for this study was determined using the Leisle Kish formula (18,19), with the assumption margin of 5% margin of error (d), 95% confidence interval level (Z) and the immunisation coverage assumed as 56.5% (20) taken from a study done in Juba on missed immunisation. The sample was calculated as follows:

Where:

P= proportion of vaccine uptake or immunisation defaulters or immunisation refusal.

q= 1-p

d= precision (5%)

Adjusting for a 13.5% rate of non-responses and invalid Response

$n_s = n/\text{expected response rate}$

$n_s = 377/0.865$

$n_s = 435$

3.4 Data collection procedure

Data collection was carried out by three integrated community case management (ICCM) workers per boma who volunteered and collected data between January 10, 2020 and June 10, 2020. The volunteers were given a 2-day orientation on administering the questionnaire. The questionnaire was adopted from the demographic and health survey of Ethiopia (21) and the WHO's questionnaire (22,23), with slight modifications based on the study site context. Inclusion criteria of participants included mothers and caregivers above 16 years-old with children aged 0-23 months. Immunisation history of a child was primarily obtained from their respective immunisation cards; wherein if lost or unavailable, immunisation history was obtained from the mothers'/caregivers' recall which was verified from the immunisation register at the health centre where the immunisation was taken, with the exception for

BCG which the scar proved as evidence. Children with untraceable immunisation records were excluded to minimise recall bias.

3.5 Statistical analysis

Maternal age was regrouped into below 24 years, 25-34 years and above 35 years. Age of the child was grouped into 0-11 months and 12-23 months. Birth order of the child was categorised into 1st child, 2nd-5th order and 6th+ order. Maternal education was defined as none and having some education. Sex of the child was defined as female and male. Distance to the health facility was categorised into ≤ 5 Km, 6-10KM and ≥ 11 Km.

Primary quantitative data was entered into Microsoft Excel and imported into STATA 15 for analysis. Missing data was observed and accounted for in the analysis and reported in the tables. Four approaches were used to analyse the data. First, we performed descriptive analyses to compute the frequencies and percentages of the variables. Second, crude odds ratio (cOR) with 95% confidence intervals (CI) were estimated using univariate logistic regression to quantify the relationship between the outcome with the independent variables. The univariate analysis was used to identify factors that were independently associated with the outcome. Third, factors that were statistically associated with the outcome in the univariate analysis were treated as main exposures and adjusted for potential confounders using the Mantel-Haenszel method. Crude odds ratio from the univariate analysis was compared with the Mantel-Haenszel's OR to identify potential confounders. Homogeneity testing was conducted to compare stratum specific odds ratios in order to identify effect modification. Lastly, the potential confounders were entered into a multi-level multivariable and forward selection stepwise multivariable logistic regression models to control for them. Factors treated as main exposures included in the models included parity, frequent provision of immunisation at health facility on daily basis, immunisation benefits, vaccinator conducting outreach immunisation, vaccinator visiting during family livelihood/business hours, health facility is too far and no transportation means to visit health facility for immunisation, inadequate notice about immunisation outreach visit to community, churches discussed immunisation importance, community leaders discussed immunisation importance. Prior to fitting the multivariable models, we assessed for collinearity using the Pearson's R correlation coefficient ($r > =0.8$), and retained predictors that were within the recommended range as suggested in the literature (24)

Variables with collinearity include religion, marital status, fear of side effects and abusive vaccinators. These variables had all or very few observations in one group, thus, no variations. Estimates with a

p-value less than significance level (5%) were considered statistically significant. Odds ratios (OR), p-values and lower and upper 95% confidence intervals of the variables that were included in the model are presented.

3.6 Ethical consideration

Ethical approval for the study was obtained from the Ministry of Health in South Sudan. Permission to conduct the study was obtained from the state manager of the extended programme on immunisation and the director of primary healthcare, state ministry of health. Prior to completing the questionnaires, participants were given information about the study and written informed consent was obtained. Participants were informed of their right to voluntary participation in the study.

RESULTS

Participant characteristics

Four hundred and twenty eight mothers and caregivers of children aged 0-23 months were included in this study. The median age of the children in the study was 10 months, with 64% (274/428) being 0-11 months and 52.0% (222/427) being boys. Mothers made up 76.5% of the respondents (313/409) compared to caregivers. The median age of the mothers and caregivers was 28 years (age range 15-52) with a majority of the mothers and caregivers (48.6%) between 25-34 years. Majority of the respondents (78.7%) had no formal education. Mothers with 2-5 children formed the largest proportion (63.4%) of participants. Over half (55.2%) of the children reported having immunisation cards.

Immunisation status

Overall, findings from this study showed that 75.5% (320/424) of the children were off track with immunisation (Table 1a). There was no difference in the proportion of children being off track with immunisation (p value=0.152) between female children (78.3%) and male children (72.3%). Compared to the rest of the recommended vaccination doses, BCG had the least proportion of children being off track with immunisation (12.2%, 52/428). For vaccines with more than one dose, such as Penta and OPV, the proportion of children being off track with immunisation increased in subsequent immunisation doses than preceding doses. For instance, while only 19.4% (80/413) of children were off track with the 1st dose of the pentavalent vaccination, more than half (60.6%, 215/355) of the children were off track with the 3rd dose of the pentavalent vaccination.

Factors associated with being off track with immunisation

In the univariate analysis (see Table 1b), there was a strong statistical association between being off track with immunisation and being in Wulu County (crude odds ratio (cOR) 0.13, 95% CI: 0.07-0.23); mothers with 6 and above children (cOR 0.42, 95% CI: 0.19-0.93); being a guardian (cOR 6.32, 95% CI: 2.67-14.96); maternal age 25-34 years (cOR 1.98, 95% CI: 1.17-3.36); immunisation card unavailable (cOR 3.49, 95% CI 2.09- 5.81); functional facility being a Primary Health Care Center (cOR 4.63, 95% CI: 2.59- 8.25); health facility does not conduct routine immunisation outreach (cOR 2.61, 95% CI: 1.50-4.51); no frequent provision of (EPI) immunisation at health facility (cOR 1.80; 95% CI: 1.11-2.90); Immunisation benefits being child growth (cOR 3.96, CI 95% (1.35, 11.53); no vaccinator conducting outreach immunisation (cOR 2.32, CI 95% 1.45-3.71); vaccinator comes during family livelihood business time (cOR

0.39, 95% CI 0.21- 0.68); for health facility in close proximity with transportation (cOR 0.20, 95% CI 0.10-0.37); vaccinator are happy to regularly come to the community (cOR 0.13, 95% CI 0.04-0.43); completed all immunization for child and informed to come back (cOR 0.37, 95% CI 0.19, 0.71); Adequate notice about immunization outreach visit to community (cOR 0.23, 95% CI 0.12-0.42); boma health workers visiting household 4-14 times (cOR 0.16 95% CI 0.07- 0.36); churches not discussing immunisation importance (cOR 7.42, 95% CI 4.28-12.82); and community leaders not discussing immunization importance (cOR 7.76 95% CI 4.50-13.36). In addition, there were potential confounding effects on the above associations. For example, and as seen in Table 2, after adjusting for maternal age, children whose mothers and caregivers had adequate notice about immunization outreach were about 90% less likely to be off track with immunisation compared to those who did not receive adequate notice (cOR 0.11, 95% CI 0.04-0.29).

Multivariable analysis

The stepwise multivariable logistic regression models results (see Table 3) showed that the predisposing factors that mainly were associated with the study population's immunization status was not children's characteristics such as sex and age, but rather, by community- and state-level contexts. In fact, children were up to more than 2 times more likely to be off track with immunization when there was no vaccinator conducting outreach immunization compared to when there was (OR 2.27, 95% CI 1.29-3.96). The probability of a child being off track for immunization was reduced by 85% for those who lived close to health facilities and had transportation compared to those who did not (OR 0.15, 95% CI 0.07-0.28). Children whose mothers and caregivers had adequate notice about immunization outreach were up to 85% less likely to be off track with immunisation compared to those who did not receive adequate notice (OR 0.15, 95% CI 0.07- 0.28). Lastly, it was observed that the absence of community engagement discussing immunization importance in both the church (OR 2.42, 95% CI 1.16-5.01) and from the greater community (OR 3.62, 95% CI 1.42-9.18) increased the odds of children being off track with immunization compared to communities that did engage.

The findings were further supported by the results in the multilevel multivariable logistic regression models that adjusted for potential confounders in a 3-multilevel model - maternal and child (model 1a), community (model 2b) and state health systems (model 3c), see Table 3. The study found that children cared by mothers or guardians with 6 and more children were 60% less likely to be off track with immunization than those with 1 child. The odds of children being off track with immunization increased for children whose mothers reported that immunization was essential for child growth compared to

protection against diseases (AoR 7.45, 95% CI 2.06-26.87). Children whose mothers reported that vaccinators did not visit during family business and livelihoods and had no means of getting to the health facility were 57% and 83% less likely to be off track within immunization. The chances of being off track with immunization increased among children whose mother reported that vaccinators did not conduct outreach services (AoR 7.21, 95%CI 3.82, 13.5), and lack of discussion by the community (AoR 8.01, 95% CI 4.02, 15.92) and churches (AoR 7.62, 95% CI 3.90, 14.87) on the importance of immunization.

DISCUSSION

This study analysed the factors that influence children aged 0-23 living in South Sudan to be off track with their routine immunization schedule. We found that 75.5% of the participants were off track and that the percentage of off track status increased in subsequent vaccine doses. These similar findings have also been reported in a study in Ethiopia that showed decreasing immunization coverage in subsequent vaccine doses (25). The high prevalence of off track children was found to be driven mainly by community and state-level variables. A child who did not attend a church that discussed immunization importance was more than 2 times more likely to be off track with immunisation than children who went to a church that discussed immunization importance. A child whose community leaders did not discuss immunization importance was more than 3 times more likely to be off track than a child whose community leader did. Additionally, the probability of a child being off track was reduced by 85% when mothers and caregivers were given adequate notice about immunization outreach. In relation to this, vaccinators conducting outreach immunization were shown to be influential in that children without this service were 2 times more likely to be off track than children with access to outreach immunization. Furthermore, children who did not have vaccinators during family livelihood business were about 70% less likely to be off track. When it came to mothers and caregivers and their thoughts towards immunization, children were more than 4 times more likely to be off track if they had mothers who believed the benefits of immunization is for child growth compared to protection against diseases. Additionally, children who had 6 siblings or more were up to 60% less likely to be off track compared to being an only child. Not only was the outcome dependent on community factors, but also geographical factors in that living close to health facilities and having transportation reduced a child's chances of being off track by 85%.

Churches that did not discuss immunization importance were found to be a strong predictor of being off track with immunization. This finding is supportive of the role religious platforms play as influential sources for educating and communicating the essence of immunization to their worshippers. However, a study in Nigeria reported that religious leaders have proved reluctant to recommend vaccination to their followers on behalf of health authorities (26), this could be as a result of their belief that vaccination is against the will of God as seen in the case of Benin (27). It is to be noted that our study did not investigate whether and to what extent churches and worship centres are involved in immunization activities, there is the need to review the policy guiding the roles and involvement of churches, and other religious centers in planning and implementing immunization programmes at the community level,

as well as monitoring vaccine utilization. Similarly, a child whose community leader did not discuss immunization importance was more than 3 times more likely to be off track than a child whose community leader did. This finding justifies the need for the active involvement of community leaders in driving immunisation programme success. The finding corroborated a study in Nigeria (28) which reported that efforts of community leaders to create immunization awareness influenced the knowledge of mothers on immunization benefits. This finding also corroborated a study which focused on community engagement, routine immunization, and polio legacy in Northern Nigeria, a similar conflict context area with a long history of poor immunization and health performance (29). Another study showed that the quality and volume of immunization and health information available in mothers' social environment influenced the uptake of immunization services (30). In the case of this study, the quality and volume of immunization information would be promoted by means of community leaders. There is a need to review the role of community leadership in promoting immunization education taking into account the limited higher learning health institutions and resources, especially for girls and women, to strengthen community health education flow. We observed that the probability of a child being off track was reduced by 85% when mothers and caregivers were given adequate notice prior to immunization outreach. This finding is a reflection of the benefit around optimization of immunization outreaches conducted with adequate notice to mothers and caregivers, and encourages the enhanced application of it to our study population. The finding was supported by WHO's *Immunization in practice: a practical guide for health staff* that identified inadequate prior notice to immunisation as one of the barriers to vaccine utilisation (31). In order to achieve an effective immunization outreach program, a micro-plan that involves rigorous communications with community stakeholders during the pre- or post-planning process should be implemented. Existing EPI micro-plans should be reviewed for areas where services are not optimized to reflect what works best, commonly, for all stakeholders. The micro-plan developed in consultation with the benefiting communities, should have social mobilization well integrated in it as outreach activity is partially determined by the robustness of social mobilizers' commitment (see Figure 1). Furthermore, the commitment and quality of social mobilizers should be reestablished to ensure communities, government and the donors are not being short-changed with inadequacy or non provision of services. Since social mobilizers are engaged as a matter of policy in implementing immunization outreaches, immunization programme managers should ensure that mobilizers have good knowledge of the area they are to cover, comfortable to work in these insecure areas and are accepted by their assigned community. Otherwise, the use of multiple mobilizers may be adopted by communities with wide land mass or with security challenges. Social mobilizers and EPI Vaccinators providing outreach

services should be regularly supported, mentored and monitored (SMM) to improve integration and deliver quality immunization services. In this regard, we recommend not more than two to three immunisation sessions per week with more days available for adequate social mobilisation. Furthermore, as seen in the study's results, children who did not have vaccinators during family livelihood business were about 70% less likely to be off track. In a study conducted in Burkina Faso, mothers who gave more concern to their business were found not to have their children with full vaccination (32). The finding gave a pointer to the existence of children with incomplete vaccination, perhaps as a mark of clash of interest between mothers/caregivers' livelihood business and timing for immunization. This reiterates the usefulness of a well planned and coordinated vaccination plan with input from various interests including the working mother population.

This study observed that health facilities frequently conducting routine (static) immunization services on a daily basis were influential in reducing the amount of children off track with immunization. Policy on immunization in South Sudan advises the implementation of routine immunization outreach across communities outside the 5km radius of a health facility (1,33,34). Considering the need for improvement of immunization success in countries like South Sudan, continuous vaccine availability and punctuality of EPI vaccinators at health facilities, creation and sustainability of more outreach posts with regular supplementary immunisation activities in hard-to-reach areas could translate into higher vaccine uptake. The above mixed intervention should be evaluated regularly to ensure communities, government and the donors get appropriate service and value for immunisation programmes. While promoting staff retention is important to achieving sustained progress, vaccinators who are found deficient with low-commitment should be given refreshers' training while those with repeated underperformance should be let go in order to engage committed ones. We also recommend the continual usage of performance incentives to pay vaccinators for services rendered; and for every falsehood identified in the immunization accountability conducts and reports, sanctions should be designed. To promote the effectiveness of performance based incentives, an improved system of accountability has to be put in place. There is an urgent need for South Sudan to put forward a clear policy and implementable strategies on training of vaccinators, and/or who should be responsible for vaccination delivery at health facilities and within communities. State immunization performance monitoring and evaluation strategy must be reviewed at least twice in a year, and interventions should be fashioned to model collaborative, iterative and inclusive and targeted problem solving approaches. According to a unicef report, a 'one-size-fits-all' approach in this changing world is no longer appropriate (35). Nevertheless, analysis of

data available from DHIS2 have shown more vaccination still takes place during outreaches activities for most counties in south Sudan (1,36).

When it came to mothers/ caregivers and their thoughts towards immunization, children had a higher odds of being off track if they had mothers who believed the benefits of immunization is for child growth compared to protection against diseases. Extensive evidence has also consistently listed child protection from diseases as a primary benefit from complete vaccination of children (37,38). Interestingly, our sampled mothers place higher value on good child growth as the benefit of immunisation rather than protection against diseases to their children. In this regard, we recommend educating caregivers on the benefits of immunization as it has a great influence on immunization uptake (see Figure 1).

In this study, it was noted that mothers who had 6 or more children had a lower odds of being off track compared to those whose mothers had one child. Studies conducted in Liberia and another in Kenya showed a reduced chance of completion of vaccination for children with 2- 3 siblings but the chance of completion increased for children with 4 siblings and above, when compared to one child only (39). Studies conducted in Liberia and another in Kenya showed a reduced chance of completion of vaccination for children with 2- 3 siblings but the chance of completion increased for children with 4 siblings and above, when compared to one child only. This finding is contrary to the reports from Eastern Ethiopia (OR 3.55, CI: 1.32 - 9.58) (40) and West Africa that showed higher odds of defaulting from immunization with mothers of higher parity (41).

Not only was the outcome dependent on community factors, but also geographical factors in that living close to health facilities and having transportation reduced a child's chances of being off track by 85%. This finding demonstrates the importance of health equity and increasing immunization access to hard-to-reach and far communities. This study finding is in line with a study conducted in Kenya that showed mothers residing about >5 km from a health facility (OR 1.6, CI: 1.1–3.1) were more likely to default from completing vaccination (39). Contrarily, studies conducted in Mali (OR:0.6, CI: 0.4 – 0.8) and Niger (OR :0.8, 0.6 – 1.0), showed that living closer to health facilities was not associated with complete vaccination of children (41). Activities that positively influence health seeking behaviour and immunization information sharing should be promoted to optimise immunization service utilization. While it may be a good recommendation based on the study finding for government and partners to establish more health facilities considering its potential benefits to immunization and population health generally, location and localization of health facilities are governed by other factors including population and resources which may not immediately support that. Hence, a proper assessment of the health

(facility) needs is highly recommended. Political influence in the positioning of health facilities should be minimized if it cannot be completely stopped. Robust implementation and coordination between the health facility, outreach and mobile immunisation services should be urgently considered as they could be ideal in reducing the amount the caregivers use in transportation costs.

In all, this study has revealed that improving immunization coverage requires strengthening community health systems, and this should remain a key priority for government and major health partners.

Study Limitation

This cross-sectional study is reported in accordance with the 22- item checklist that are considered highly essential by the STROBE- strengthening the Reporting of Observational Studies in Epidemiology statement; however, this study would have had more improved quality if a well-structured survey with a variety of variables. In addition, we acknowledge bias in the study questionnaire like social desirability bias as a result of mothers who may have given inaccurate answers in an effort to be viewed more favorably as well as interviewers' bias or influence would have occurred from the integrated community case management {(ICCM) or Boma health} workers with the tendency of the interviewer to obtain answers that support preconceived notions, while writing on behalf of mothers who were unable to read and write. Infact, bias as a result of a non- standardized measurement of conflict or risk intensity among these counties which could have had an association with the immunisation uptake coverage in these respective counties at the time of the study. This study could not assess the timeliness of vaccine uptake by children, and also recommend further studies with a larger sample size with more equal sampling across the counties for more comparable conclusions. We also admit differential misclassification of caregivers or mothers may have occurred with adopted children in the class of mothers with a higher parity; in addition to that, excluding children of mothers who reported the child is being immunised but with untraceable immunisation data records from the study could also have resulted in selection bias and non-differential misclassification and could have underestimated the proportion of the groups of children being on and off track with their immunisation schedule. Lastly, we also acknowledge that residual confounding may have occurred in the grouping of mother and child's ages, parity, distance to health facility.

CONCLUSION

This study showed that there is a high prevalence of children being off track with their immunisation schedule that is mainly driven by community- and state-level immunisation service delivery mechanism factors. Most suitable interventions to improve child immunisation uptake was also recommended. This study is advisable not to be generalized into a non-conflict context, nevertheless, we strongly recommend regular evaluation of the performance of the health system in the delivery of vaccines to the community.

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Competing interests

The authors declare no conflict of interest that might have influenced the work in this paper

Ethics approval

The study protocol and conduct adhered to the principles laid down in the Declaration of Helsinki. Ethics approval for this study was granted by the Health Research Ethics Committee of the State Ministry of Health (SMoH) of Lakes State (formerly Western Lakes State), South Sudan. Written informed consent was obtained from all study participants before data collection.

Authors' contribution

IOI conceptualized this study, organised data collection and management, planned the methodology, analyzed the data and led the report writing. JT planned the methodology, participated in data management, analyzed the data and participated in report writing. GK participated in data analysis and report writing. GOA was involved in study conceptualization, participated in data collection, and report writing. FIA participated in report writing. JGO was involved in the study conceptualization, supervised data collection and reviewed the final manuscript draft. All authors reviewed the final manuscript draft, and approved the submitted manuscript.

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This study was conducted with no fund support from an organization.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Patient and public involvement statement

The immunisation uptake data used in this study is based on mothers of children eligible for all the vaccine doses in the South Sudan' immunisation schedule. Children and parents/adult carers were not involved in setting the research question or the outcome measures; however, the study results were solely based on their response to the survey questions.

TABLES

Table 1a shows the distribution of the proportion of vaccine coverage by vaccine and gender

Distribution of the proportion of vaccine coverage by vaccine and gender			
Variable	Overall on track with immunization	On track with immunization by Gender	
	Frequency N (%)	Male N (%)	Female N (%)
BCG vaccine			
Off track	52 (12.15)	26(11.71)	26 (12.68)
On track	376 (87.85)	196(88.29)	179 (87.32)
1st dose of OPV and Pentavalent vaccine			
Off track	80 (19.37)	40(18.02)	41 (20.00)
On track	333 (80.63)	182 (81.98)	164 (80.00)
2nd dose of OPV and Pentavalent vaccine			
Off track	135 (35.62)	74 (37.56)	61 (33.70)
On track	244 (64.38)	123 (62.44)	120 (66.30)
3rd dose of OPV and Pentavalent vaccine			
Off track	215 (60.56)	114 (61.29)	100 (59.52)
On track	140 (39.44)	72 (38.71)	68 (40.48)
IPV			
Off track	126 (35.59)	68 (36.56)	58 (34.73)
On Track	228 (64.41)	118 (63.44)	109 (65.27)
Measles vaccine (9-23 months)			
Off track	180 (70.87)	96 (71.64)	84 (70.00)
On track	74 (29.13)	38 (28.36)	36 (30.00)
Child on/off track with immunization status			
Children on track with immunization	104 (24.53)	48 (21.72)	56 (27.72)

Children off track with immunization	320 (75.47)	173 (78.28)	146 (72.28)
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Table 1b shows the descriptive and univariate analysis

Table 1b– Descriptive and univariate analysis for predisposing factors that affected children between 0-23 months old living in South Sudan from being on track with their routine immunisation schedule					
Variable	Category	On track N(%)	Off track N(%)	Crude Odds Ratio	
				OR and (95% CI)	P-value
Geographical Characteristics					
County (N=427)	Rumbek centre	20 (19.23)	155 (88.57)	1	
	Rumbek north and Rumbek east	3 (9.23)	78 (96.30)	3.35 (0.96, 11.63)	0.056
	Wulu	81 (48.50)	86 (51.50)	0.13(0.07, 0.23)	<0.001
Maternal Characteristics/Role					
Parity (N=418)	1 child	11 (19.30)	46 (80.70)	1	
	2-5 children	59 (22.52)	203 (77.48)	0.82 (0.40, 1.68)	0.595
	6 and above	34 (35.79)	61 (64.21)	0.42 (0.19, 0.93)	0.034
Education of Mothers (N=422)	None	77 (23.33)	253 (76.67)	1	0.444
	Having some education	24 (27.27)	64 (72.73)	0.81 (0.47,1.38)	
Are you Parent/guardian of the child (N=409)	Parent	94 (30.13)	218 (69.87)	1	<0.001
	Guardian	6 (6.38)	88 (93.62)	6.32(2.67, 14.96)	
Maternal age (N=385)	<24 years	39 (33.33)	78 (66.67)	1	
	25-34 years	37 (20.11)	147 (79.89)	1.98 (1.17, 3.36)	0.011
	>35 years	17 (21.25)	63 (78.75)	1.85 (0.95, 3.58)	0.067
Availability of child immunisation card (N=411)	Yes	78 (34.67)	147 (65.33)	1	<0.001
	No	24 (13.19)	158 (86.81)	3.49 (2.09, 5.81)	
Child Characteristics					
Sex (N=427)	Male	48 (21.72)	173 (78.28)	1	0.153
	Female	56 (27.72)	146 (72.28)	0.72 (0.46, 1.12)	
Child age (N=428)	0-11 Months	71 (26.10)	201 (73.90)	1	0.314
	12-23 Months	33(21.71)	119 (78.29)	1.27 (0.79, 2.04)	
Communal/Health System Role					
Functional health facility in the area (N=420)	Yes	99 (78.29)	285 (74.22)	1	0.80
	No	3 (10.34)	26 (89.66)	1.86 (0.40, 8.54)	
Functional facility type in the area (N=413)	PHCU	86 (34.26)	165 (65.74)	1	<0.001
	PHCC	16 (10.13)	142 (89.87)	4.63 (2.59, 8.25)	

Distance to facility N=(406)	<=5km	39 (25.49)	114 (74.51)	1	0.082
	6-10Km	22 (18.80)	95 (81.20)	1.47 (0.81, 2.66)	
	>=11Km	41 (31.06)	91(68.94)	0.75 (0.45, 1.27)	
Facility provides immunization (N=417)	Yes	99 (25.78)	285 (74.22)	1	0.076
	No	3 (10.34)	26 (89.66)	3.01 (0.89, 10.16)	
Health facility conduct routine immunization outreach services (N=417)	Yes	84 (30.11)	195 (69.89)	1	0.001
	No	19 (14.18)	115 (85.82)	2.61 (1.50, 4.51)	
Frequent provision of (EPI) immunization at health facility on daily bases (N=420)	Yes	73 (28.85)	180 (71.15)	1	0.017
	No	30 (18.40)	133 (81.60)	1.80(1.11, 2.90)	
Health facility Conduct mobile immunization (N=418)	Yes	56 (27.72)	146 (72.28)	1	0.192
	No	47 (22.17)	165 (77.83)	1.34 (0.861, 2.10)	
Is immunization good for child's health (N=416)	Yes	100 (25.25)	296 (74.75)	1	0.26
	No	2 (12.50)	14 (87.50)	2.36 (0.52, 10.58)	
Immunization benefits (N=324)	Protection against diseases	97 (33.80)	190 (66.20)	1	0.012
	Child growth	4 (11.43)	31 (88.57)	3.96 (1.35, 11.53)	
Vaccinator conduct outreach immunization (N=409)	Yes	67 (32.37)	140 (67.63)	1	< 0.001
	No	34 (17.09)	165 (82.91)	2.32 (1.45, 3.71)	
Vaccinator visit during family livelihood business (N=408)	Yes	17 (14.05)	104 (85.95)	1	0.001
	No	84 (29.58)	200 (70.42)	0.39 (0.21, 0.68)	
Health facility too far and no transportation to going for immunization (N=410)	Yes	13 (9.15)	129 (90.85)	1	< 0.001
	No	89 (33.58)	176 (66.42)	0.20(9.10, 0.37)	
Vaccinator ask for money when visit the facility for services (N=406)	Yes	3 (33.33)	6 (66.67)	1	0.552
	No	97 (24.62)	297 (75.38)	1.53(0.37, 6.23)	
Vaccinator not happy for coming regularly to the community (N=407)	Yes	3 (5.08)	56 (94.92)	1	0.001
	No	99 (28.70)	246 (71.30)	0.13(0.04, 0.43)	
Not completed all the immunization for my child, not informed to come back (N=405)	Yes	12 (13.04)	80 (86.96)	1	0.003
	No	89 (28.71)	221 (71.29)	0.37(0.19, 0.71)	
Inadequate notice about immunization outreach visit to community (N=408)	Yes	13 (9.85)	119 (90.15)	1	< 0.001
	No	88 (32.23)	185 (67.77)	0.23 (0.12, 0.42)	
Girl child don't receive immunization if yes why (N=408)	Yes	3 (30.00)	7 (70.00)	1	0.709
	No	98 (24.81)	297 (75.19)	1.29 (0.32, 5.11)	
Male child don't receive immunization if yes why (N=409)	Yes	3 (33.33)	6 (66.67)	1	0.556
	No	98 (24.69)	299 (75.31)	1.52(0.374, 6.21)	
Relocation history in the past 23 months (N=400)	Yes	19 (29.69)	45 (70.31)	1	0.395
	No	82 (24.62)	251 (75.38)	1.29(0.71, 2.33)	

Times BHW visit household (N=345)	No visitation	10 (13.70)	63 (86.30)	1	<0.001
	1-3 times	24 (13.87)	149 (86.13)	0.98(0.44, 2.18)	
	4-14 times	47 (48.96)	49 (51.04)	0.16(0.07, 0.36)	
Churches discussed immunization importance (N=373)	Yes	71 (44.65)	88 (55.35)	1	<0.001
	No	21 (9.81)	193 (90.19)	7.42(4.28, 12.82)	
Community leaders discussed immunization importance (N=374)	Yes	70 (46.05)	82 (53.95)	1	<0.001
	No	22 (9.91)	200 (90.09)	7.76(4.50, 13.36)	

Table 2 shows the adjusted estimates of the odds ratio for the main exposure

Adjusted estimates of the odds ratio for the main exposures influencing children between 0-23 months old living in South Sudan from being on track with their routine immunisation schedule using Mantel-Haenszel method				
Variables	Crude Estimates		Adjusted Estimates	
	Crude OR (95%CI)	P-value	Adjusted OR (95%CI)	P-value
Parity : Association adjusted for :				
Maternal Age (25-34 years)	0.42 (0.19, 0.93)	0.034	0.40 (0.24, 0.65)	<0.001
Immunization benefits adjusted for :				
Maternal Age (25-34 years)	3.96 (1.35, 11.53)	0.012	3.82 (1.25, 11.60)	0.011
Frequent provision of immunization at health facility on daily bases			3.50(1.18, 10.34)	0.016
Health facility too far and no transportation to going for immunization			3.95 (1.27, 12.23)	0.01
Frequent provision of immunization at health facility on daily basis adjusted for :				
County	1.80(1.11, 2.90)	0.017	1.20 (0.70, 2.03)	0.494
Availability of children immunization card			1.62 (0.97, 2.69)	0.059
Functional health facility in the area			1.64 (0.98, 2.73)	0.054
Health facility conduct routine immunization outreach services			1.33 (0.77, 2.27)	0.303
Health facility too far and no transportation to going for immunization			1.53 (0.92, 2.53)	0.099
Vaccinator not happy for coming regularly to the community			1.54 (0.94, 2.53)	0.083
Inadequate notice about immunization outreach visit to community			1.32 (0.78, 2.22)	0.293
vaccinator conduct outreach immunization adjusted for :				
Maternal Age (25-34 years)	2.32 (1.45, 3.71)	<0.001	2.15 (1.27, 3.63)	0.003
immunization benefits			2.06 (1.231, 3.43)	0.005
Vaccinator visit during family livelihood business			2.23 (1.36, 3.61)	0.001
Health facility too far and no transportation to going for immunization			2.31 (1.40, 3.78)	0.001
Not completed all the immunization for my child, not informed to come back			2.26 (1.39, 3.65)	0.001
Vaccinator visit during family livelihood business adjusted for :				
Availability of children immunization card	0.39 (0.21, 0.68)	0.001	0.35 (0.19, 0.64)	0.001
Functional facility type in the area			0.35 (0.19, 0.64)	< 0.001
Health facility conduct routine immunization outreach services			0.36 (0.19, 0.66)	0.001
Health facility too far and no transportation to going for immunization adjusted for :				

Functional facility type in the area	0.20 (9.10, 0.37)		0.15 (0.07, 0.29)	< 0.001
Inadequate notice about immunization outreach visit to community		<0.001	0.20 (0.10, 0.37)	< 0.001
Inadequate notice about immunization outreach visit to community adjusted for :				
Parity (above 6 children)	0.23 (0.12, 0.42)	<0.001	0.22 (0.11, 0.42)	< 0.001
Availability of children immunization card			0.24 (0.12, 0.45)	< 0.001
Maternal Age			0.11 (0.04, 0.29)	< 0.001
Vaccinator conduct outreach immunization			0.19 (0.09, 0.36)	< 0.001
Health facility too far and no transportation to going for immunization			0.22 (0.11, 0.42)	< 0.001
Vaccinator not happy for coming regularly to the community			0.28 (0.14, 0.53)	< 0.001
Churches discussed immunization importance adjusted for :				
County	7.42(4.28, 12.82)	<0.001	2.42 (1.15, 5.11)	0.016
Availability of children immunization card			6.90 (3.63, 13.06)	< 0.001
Functional facility type in the area			6.60 (3.46, 12.54)	< 0.001
Health facility conduct routine immunization outreach services			6.94 (3.66, 13.15)	< 0.001
Frequent provision of immunization at health facility on daily bases			6.90 (3.94, 12.09)	< 0.001
Vaccinator visit during family livelihood business			6.48 (3.56, 11.76)	< 0.001
Health facility too far and no transportation to going for immunization			6.07 (3.28, 11.21)	< 0.001
Not completed all the immunization for my child, not informed to come back			6.59 (3.58, 12.11)	< 0.001
Inadequate notice about immunization outreach visit to community			6.91 (3.78, 12.61)	< 0.001
Community leaders discussed immunization importance			2.29 (0.98, 5.35)	0.049
Are you Parent/guardian of the child			6.38 (3.26, 12.45)	< 0.001
Community discussed immunization importance adjusted for :				
Availability of children immunization card	7.76(4.50, 13.36)	<0.001	6.43 (3.40, 12.16)	< 0.001
Functional facility type in the area			6.81 (3.50, 13.25)	< 0.001
Health facility conduct routine immunization outreach services			7.61 (3.90, 14.85)	< 0.001
Frequent provision of immunization at health facility on daily bases			7.52 (4.22, 13.41)	< 0.001
Vaccinator visit during family livelihood business			6.86 (3.78, 12.45)	< 0.001
Health facility too far and no transportation to going for immunization			6.57 (3.54, 12.16)	< 0.001
Not completed all the immunization for my child, not informed to come back			6.98 (3.78, 12.84)	< 0.001

Inadequate notice about immunization outreach visit to community			6.83 (3.68, 12.63)	< 0.001
Churches discussed immunization importance			3.14 (1.33, 7.38)	0.006
Are you Parent/guardian of the child			6.71 (3.44, 13.03)	< 0.001
Parity (above 6 children)			7.00 (3.87, 12.65)	< 0.001

Table 3 Factors associated with on track status with immunization by multilevel multivariate logistics regression

Multilevel multivariate logistics regression models to identify the predisposing factors that affected children between 0-23 months old living in South Sudan from being on track with their routine immunisation schedule.				
Variable	Crude Estimate	Model 1a	Model 2b	Model 3c
	cOR (CI)	aOR (CI)	aOR (CI)	aOR (CI)
Individual-level factors				
Maternal and Child Characteristics				
Parity				
1 child	1 (reference)	1 (reference)	1 (reference)	1 (reference)
2-5 children	0.82 (0.40, 1.68)	0.55 (0.23, 1.28)#	0.58 (0.18, 1.85)#	1.01 (0.45, 2.23)#
6 and above	0.43 (0.19, 0.93)	0.28 (0.09, 0.83)	0.32 (0.08, 1.12)#	0.40 (0.16, 0.96)
Community Characteristics				
Immunization benefits				
Protection against diseases	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Child Growth	3.96 (1.35,11.53)	5.94 (1.70, 20.71)	23.05 (2.81,188.68)	7.45 (2.06, 26.87)
Churches discussed immunization importance				
Yes	1 (reference)	1 (reference)	1 (reference)	1 (reference)
No	7.42 (4.28,12.82)	5.75 (2.79, 11.80)	1.62 (0.60, 4.37)#	7.62 (3.90, 14.87)
Community discussed immunization importance				
Yes	1 (reference)	1 (reference)	1 (reference)	1 (reference)
No	7.76 (4.50,13.36)	5.62 (2.6, 11.86)	1.77 (0.58, 5.34)#	8.01 (4.02, 15.92)
State (health system) related factors				
Frequent provision of immunization at health facility on daily bases				
Yes	1 (reference)	1 (reference)	1 (reference)	1 (reference)
No	1.80 (1.11, 2.90)	1.93 (1.04, 3.57)	1.59 (0.80, 3.14)#	1.01 (0.53, 1.89)#
Vaccinator conduct outreach immunization				
Yes	1 (reference)	1 (reference)	1 (reference)	1 (reference)
No	2.32 (1.45,3.71)	2.27 (1.29, 3.98)	4.12 (1.91, 8.88)	7.21 (3.82, 13.5)
Vaccinator visit during family livelihood business				
Yes	1 (reference)	1 (reference)	1 (reference)	1 (reference)
No	0.40 (0.21,0.68)	0.56 (0.29,1.09)	0.32 (0.13, 0.73)	0.43 (0.23, 0.80)
Health facility too far and no transportation to going for immunization				

Yes	1 (reference)	1 (reference)	1 (reference)	1 (reference)
No	0.20 (0.10,0.37)	0.26 (0.12, 0.54)	0.19 (0.07, 0.48)	0.17 (0.08, 0.35)
Inadequate notice about immunization outreach visit to community				
Yes	1 (reference)	1 (reference)	1 (reference)	1 (reference)
No	0.23 (0.12, 0.42)	0.15 (0.05, 0.39)	0.39 (0.16, 0.91)	0.68 (0.29, 1.55)#
Multivariable logistic regression models to control for them using forward selection stepwise regression				
	Crude Estimates		Adjusted Estimates	
Variables	Crude Odd Ratio (95% CI)	P-value	Adj Odd Ratio (95% CI)	P-value
Immunization benefits: Association:				
Immunisation benefit adjusted for Frequent provision of immunization at health facility on daily bases	3.96 (1.35,11.53)	0.012	3.53 (1.199, 10.36)	0.022
Immunisation benefit adjusted for (Frequent provision of immunization at health facility on daily bases + Maternal Age (25-34 years))			3.36 (1.12, 10.05)	0.03
Immunisation benefit adjusted for (Frequent provision of immunization at health facility on daily bases + Maternal Age (25-34 years) + Health facility too far and no transportation to going for immunization)			4.34 (1.23, 15.24)	0.022
vaccinator conduct outreach immunization				
vaccinator conduct outreach immunization adjusted for immunisation benefit	2.32 (1.45,3.71)	<0.001	2.05 (1.24, 3.39)	0.005
vaccinator conduct outreach immunization adjusted for (immunisation benefit + Maternal age (25-34 years old))			2.18 (1.25, 3.78)	0.005
vaccinator conduct outreach immunization adjusted for (immunisation benefit + Maternal age (25-34 years old) + Vaccinator visit during family livelihood business)			2.27 (1.29, 3.96)	0.004
vaccinator conduct outreach immunization adjusted for (immunisation benefit + Maternal age (25-34 years old) + Vaccinator visit during family livelihood business + Not completed all the immunization for my child, not informed to come back)			2.26 (1.29, 3.94)	0.004
vaccinator conduct outreach immunization adjusted for (immunisation benefit + Maternal age (25-34 years old) + Vaccinator visit during family livelihood business + Not completed all the			1.81 (1.00, 3.25)	0.046

immunization for my child, not informed to come back + Health facility too far and no transportation to going for immunization)				
Vaccinator visit during family livelihood business :				
Vaccinator visit during family livelihood business adjusted for Availability of children immunization card	0.40 (0.21,0.68)	0.001	0.35 (0.19, 0.64)	0.001
Vaccinator visit during family livelihood business adjusted for Availability of children immunization card + Functional facility type in the area)			0.32 (0.17, 0.59)	<0.001
Vaccinator visit during family livelihood business adjusted for Availability of children immunization card + Functional facility type in the area + Health facility conduct routine immunization outreach services			0.33 (0.17, 0.62)	0.001
Health facility too far and no transportation to going for immunization :				
Health facility too far and no transportation to going for immunization adjusted for Functional facility type in the area	0.20 (0.10,0.37)	<0.001	0.14 (0.07, 0.26)	<0.001
Health facility too far and no transportation to going for immunization adjusted for Functional facility type in the area + Inadequate notice about immunization outreach visit to community)			0.15 (0.07, 0.28)	<0.001
Inadequate notice about immunization outreach visit to community :				
Inadequate notice about immunization outreach visit to community adjusted for Maternal Age	0.23 (0.12, 0.42)	<0.001	0.11 (0.04, 0.28)	<0.001
Inadequate notice about immunization outreach visit to community adjusted for Maternal Age + vaccinator conduct outreach immunisation			0.10 (0.03, 0.25)	<0.001
Inadequate notice about immunization outreach visit to community adjusted for Maternal Age + vaccinator conduct outreach immunisation + Parity (above 6 children)			0.10 (0.03, 0.25)	<0.001
Inadequate notice about immunization outreach visit to community adjusted for Maternal Age + vaccinator conduct outreach immunisation + Parity (above 6 children) + Health facility too far and no transportation to going for immunization			0.11 (0.04, 0.27)	<0.001

Inadequate notice about immunization outreach visit to community adjusted for Maternal Age + vaccinator conduct outreach immunisation + Parity (above 6 children) + Health facility too far and no transportation to going for immunization +child card availability			0.12 (0.04, 0.31)	<0.001
Inadequate notice about immunization outreach visit to community adjusted for Maternal Age + vaccinator conduct outreach immunisation + Parity (above 6 children) + Health facility too far and no transportation to going for immunization +child card availability +Vaccinator not happy for coming regularly to the community			0.14 (0.05, 0.37)	<0.001
Churches discussed immunization importance :				
Churches discussed immunization importance adjusted for county	7.42 (4.28,12.82)	<0.001	2.42 (1.16, 5.01)	0.018
Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation			1.95 (0.92, 4.13)	0.081
Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation + Are you parent or guardian			2.02 (0.87, 4.65)	0.099
Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation + Are you parent or guardian + Vaccinator visit during family livelihood business			1.82 (0.77, 4.24)	0.169
Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation + Are you parent or guardian + Vaccinator visit during family livelihood business + Not completed all the immunization for my child, not informed to come back			1.77 (0.75, 4.18)	0.191
Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation + Are you parent or guardian + Vaccinator visit during family livelihood business + Not completed all the immunization for my child, not informed to come back + Functional facility type in the area			1.93 (0.80, 4.63)	0.139

Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation + Are you parent or guardian + Vaccinator visit during family livelihood business + Availability of children immunization card			2.19 (0.87, 5.47)	0.094
Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation + Are you parent or guardian + Vaccinator visit during family livelihood business + Availability of children immunization card + Frequent provision of immunisation at health facility			2.26 (0.89, 5.72)	0.085
Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation + Are you parent or guardian + Vaccinator visit during family livelihood business + Availability of children immunization card + Frequent provision of immunisation at health facility + Inadequate notice about immunization outreach visit to community			2.19 (0.82, 5.82)	0.115
Churches discussed immunization importance adjusted for county + Health facility too far and no transportation to go for immunisation + Are you parent or guardian + Vaccinator visit during family livelihood business + Availability of children immunization card + Frequent provision of immunisation at health facility + Inadequate notice about immunization outreach visit to community + Health Facility conduct routine immunisation outreach			2.09 (0.78, 5.59)	0.141
Community discussed immunization importance:				
Community discussed immunization importance: adjusted for Churches discussed immunization importance	7.76 (4.50,13.36)	<0.001	3.62 (1.42, 9.18)	0.007
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card			2.22 (0.85, 5.80)	0.103
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization			2.22 (0.85, 5.74)	0.099

Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization + Are you Parent/guardian of the child			1.94 (0.74, 5.07)	0.178
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization + Are you Parent/guardian of the child + Functional health facility types			1.38 (0.47, 3.97)	0.551
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization + Are you Parent/guardian of the child + Functional health facility types + Inadequate notice about immunization outreach visit to community			1.13 (0.36, 3.43)	0.836
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization + Are you Parent/guardian of the child + Functional health facility types + Inadequate notice about immunization outreach visit to community + Vaccinator visit during family livelihood business			1.13 (0.37, 3.364)	0.829
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization + Are you Parent/guardian of the child + Functional health facility types + Inadequate notice about immunization outreach visit to community + Vaccinator visit during family livelihood business + Not completed all the immunization for my child, not informed to come back			1.23 (0.40, 3.71)	0.711
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization			1.18 (0.38, 3.59)	0.777

+ Are you Parent/guardian of the child + Functional health facility types + Inadequate notice about immunization outreach visit to community + Vaccinator visit during family livelihood business + Not completed all the immunization for my child, not informed to come back + Parity (above 6 children)				
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization + Are you Parent/guardian of the child + Functional health facility types + Inadequate notice about immunization outreach visit to community + Vaccinator visit during family livelihood business + Not completed all the immunization for my child, not informed to come back + Parity (above 6 children) + Frequent provision of immunisation at health facility			1.24 (0.39, 3.84)	0.713
Community discussed immunization importance: adjusted for Churches discussed immunization importance + Availability of children immunization card + Health facility too far and no transportation to going for immunization + Are you Parent/guardian of the child + Functional health facility types + Inadequate notice about immunization outreach visit to community + Vaccinator visit during family livelihood business + Not completed all the immunization for my child, not informed to come back + Parity (above 6 children) + Frequent provision of immunisation at health facility + Health facility conduct routine immunisation outreaches			1.29 (0.40, 4.05)	0.665

means it is not statistically significant (p value >0.05)

Model 1: Association is adjusted for Maternal Age + parity + parent/guardian + child availability card

Model 2: Association is adjusted for immunisation benefit + community discussed + church discussed + Vaccinator visit during family livelihood business + BHWs + Health facility too far and no transportation to go for immunization.

Model 3: Association is adjusted for Functional facility type in the area + Health facility conduct routine immunization outreach services + vaccinator not happy + did not inform to come back + frequent provision of immunisation at the health facilities + inadequate notice + health facility conduct routine immunisation

FIGURES

Figure 1. A Framework To Tackle The Predisposing Factors That Affects Children Living in South Sudan From Being on Track With Their Routine Immunisation Schedule.

Figure 1. A Framework to Tackle the Predisposing Factors That Affects Children Living in South Sudan from Being on Track with Their Routine Immunisation Schedule.



Key Points to Tackle the Predisposing Factors of Children Being Off-Track with Their Immunisation Schedule in South Sudan

Figure 2: This figure contains 2 maps of the former Western Lakes state. The left map shows the geography location of the former Western Lakes in South Sudan and its four counties - Rumbek Centre, Rumbek North, Rumbek East, and Wulu. The Western Lakes State is known to be an area of protracted conflict, affecting health related outcomes including immunisation timeliness. The second map shows the percentage of the sampled children aged 0-23 months living in the 4 counties in the Western Lakes State of South Sudan who were on track with their routine immunisation schedule during the survey.

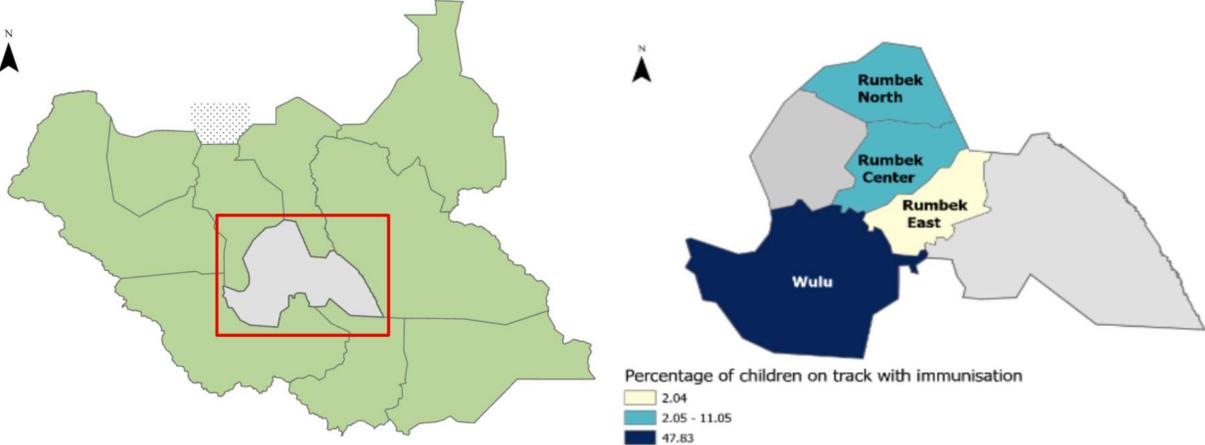
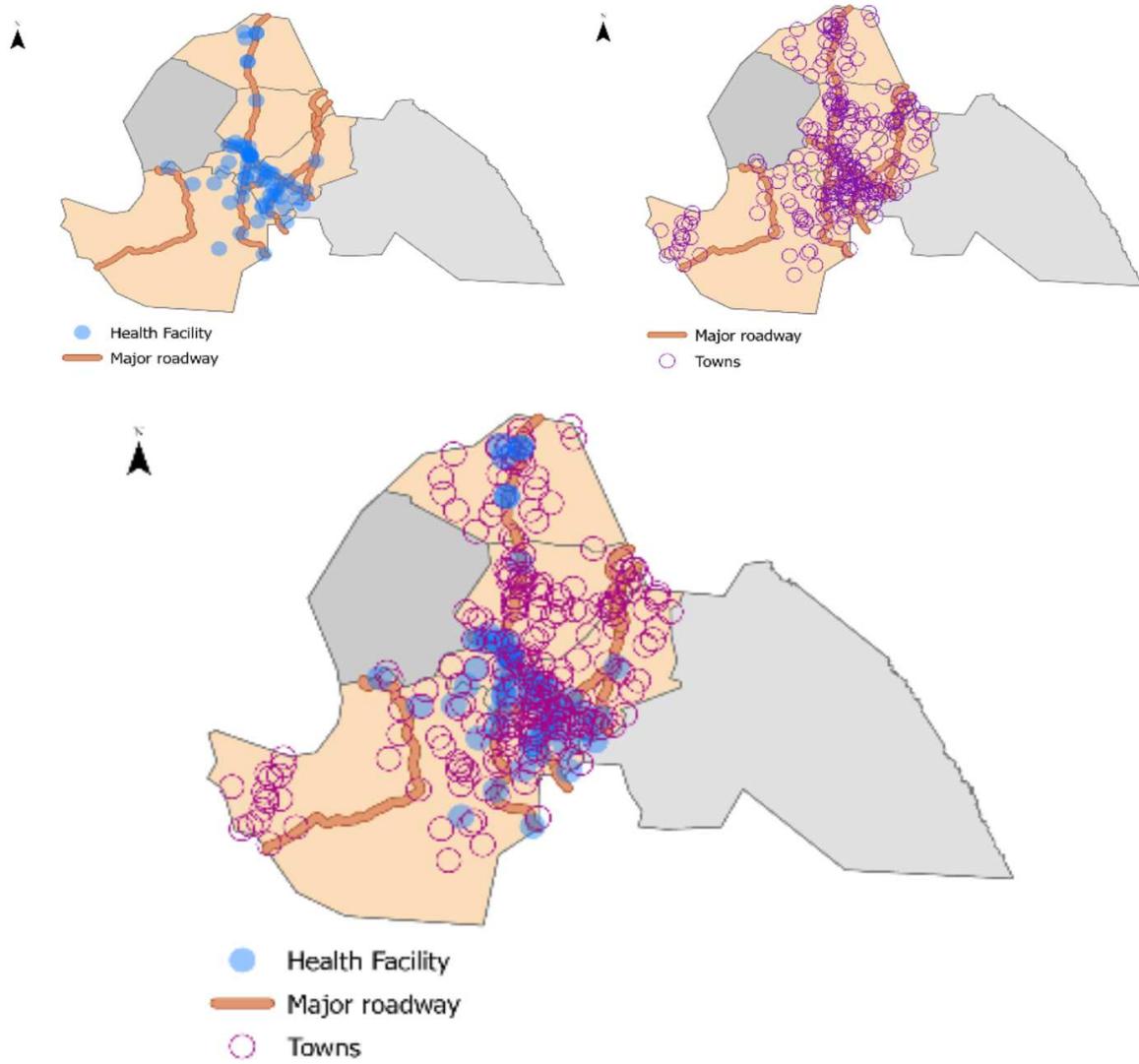


Figure 3: The figure has three maps showing the major towns, road and health facilities in the four counties (Rumbek North, Rumbek Centre, Rumbek East and Wulu) of the Western Lakes state.



Appendices

Table 1: Current immunization schedule route of administration

Antigen	Minimum age	Dose to be administered	Route of administration
OPV 0	At birth	2 drops	By mouth-use provided dropper
BCG	At birth	0.05 ml (infants 0-11 months)	Intradermal (within the skin): left arm
		0.01 ml (children above 11 months)	
PENTA 1	6 weeks	0.05 ml	Intramuscularly in the upper outer part of the thigh
OPV 1	6 weeks	2 drops	By mouth-use provided dropper
PENTA 2	10 weeks	0.05 ml	Intramuscularly in the upper outer part of the thigh
OPV 2	10 weeks	2 drops	By mouth-use provided dropper
PENTA 3	14 weeks	0.05 ml	Intramuscularly in the upper outer part of the thigh
OPV 3	14 weeks	2 drops	By mouth-use provided dropper
IPV	14 weeks	0.05 ml	Intramuscularly in the upper outer part of the thigh
Measles	9 months	0.05 ml	Measles vaccine is given subcutaneously in the outer aspect of the deltoid muscle (Lt) at 9 months. However, during supplementation activities, the target group may increase to 15 years as advised by WHO

Supplementary Files

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- [Appendices.docx](#)