**Is development aid to strengthen health systems during protracted conflict a useful investment? The case of South Sudan, 2011-2015**

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**Running title**: Health systems strengthening during conflict

**Key Questions:**

**What is already known?**

* About 1.5 billion people currently living in fragile and conflict affected settings have a heightened need for basic health services.
* Data on maternal, newborn, child and reproductive health service use by their populations is often scarce, reducing the ability of governments and health partners to track if health needs are being met and to effectively develop policies to strengthen the health system.
* Scarce information entrenches a common notion that “war is development in reverse”, which assumes that health systems cannot be strengthened during protracted conflict.

**What are the new findings?**

* Our study, focusing on South Sudan and having had a protracted conflict for 20 years, demonstrated that in 5-years from the year of independence (2011) it made moderate progress in health systems strengthening.
* However, progress varied across the states comprising the country, and coverage of maternal, newborn, child and reproductive health services is still low.

**What do the new findings imply?**

* Health systems strengthening is a context specific non-uniform process and is not necessarily deterred by conflict.
* Aid to highly fragile countries from international agencies can result in important benefits for the intended populations, rather than being a waste of resources.

**Word Count**: 5158

ACT   artemisinin-based combination therapy

AIDS Acquired Immune Deficiency Syndrome

ANC antenatal care

BHI Boma Health Initiative

BSS Behavioral Surveillance Surveys

CD2015 Countdown to 2015

CES Central Equatoria

CI confidence intervals

DPT diphtheria, pertussis and tetanus

EES Eastern Equatoria

EMF Emergency Medicines Fund

FCAS fragile and conflict-affected settings

GARPR Global AIDS Response Progress Reporting indicators

GPAA Greater Pibor Administrative Area

GPAA Greater Pibor Administrative Area

HIV Human Immunodeficiency Virus

HIV SID HIV/AIDS Survey Indicator Database

HMIS Health Management Information System

HSDP health sector development plan

Jong Jonglei

LQAS Lot Quality Assurance Sampling

MDG Millennium Development Goal

MICS Multiple Indicator Cluster Survey

MNCRH maternal, newborn, child and reproductive health

MOC mothers of children

MOH Ministry of Health

MTCT mother to child transmission

NBeG Northern Bahr el Ghazal

NGO non-governmental organisation

ORS oral rehydration salts

PHCC primary health care clinic

PNC post natal care

RSS Republic of South Sudan

SD standard deviation

SDG Sustainable Development Goal

STI sexually transmitted infections

UHC Universal Health Coverage

UN Upper Nile

Warr Warrap

WBeG Western Bahr el Ghazal

WES Western Equatoria

WHO World Health Organisation

# Abstract

**Introduction** Is achievement of Sustainable Development Goal (SDG) 16 (building peaceful societies) a precondition for achieving SDG 3 (health and well-being in all societies, including conflict-affected countries)? Do health systems investments in conflict-affected countries waste resources or benefit the public’s health? To answer these questions, we examine maternal, newborn, child and reproductive health (MNCRH) service provision during protracted conflicts and economic shocks in South Sudan (RSS) between 2011 (at independence) and 2015.

**Methods** We conducted two national cross-sectional probability surveys in 10-states (2011) and 9-states (2015). Trained state-level health workers collected data from households randomly selected using probability proportional to size sampling of villages in each county. County data were weighted by their population sizes to measured state and national MNCRH services coverage. A two-sample two-sided Z-test of proportions tested for changes in national health service coverage between 2011 (n=11,800) and 2015 (n=10,792).

**Results** Twenty-two of 27 national indicators estimates (81.5%) of MNCRH service coverage improved significantly. Examples: malaria prophylaxis in pregnancy increased by 8.6% (p<0.001) to 33.1% (397/1199 mothers, 95%CI ±2.9%), institutional deliveries by 10.5% (p<0.001) to 20% (230/1199 mothers, ±2.6%), and measles vaccination coverage in children age 12-23 months by 11.2% (p<0.001) to 49.7% (529/1064 children, ±2.3%). The largest increase (17.7%, p<0.001) occurred for mothers treating diarrhoea in children 0-59 months with ORS to 51.4% (635/1235 children, ±2.9%). Antenatal and postnatal care, and contraceptive prevalence did not change significantly. Child Vitamin-A supplementation decreased. Despite significant increases, coverage remained low ( Coverage varied considerably by state(mean SD for all indicators and states=11.1%).

**Conclusion** Health systems strengthening is not a uniform process and not necessarily deterred by conflict. Despite the conflict, health system investments were not wasted; health service coverage increased.

(283 words)

# Introduction

The increased global health focus on fragile and conflict-affected settings (FCAS) requires reliable evidence on the progress of health service delivery in FCAS. About 1.5 billion people currently living in FCAS have a heightened need for basic health services[1]. However, data on maternal, newborn, child and reproductive (MNCRH) health service use by their populations are often scarce[2]. The limited information reduces the ability of governments and health partners to track if MNCRH health needs are being met and to effectively develop policies to strengthen the health system[3]. This information scarcity also entrenches a common notion that “war is development in reverse”[4], which assumes that health systems cannot be strengthened during protracted conflict, and can deter government and donor investments in these settings. However, despite their turmoil, FCAS like the Republic of South Sudan (RSS) have national policies guiding them along the world’s ambitious path to achieve the Sustainable Development Goals (SDGs), in which MNCRH and HIV/AIDS are key areas[3,5,6]. Hence, their need for information is acute, despite having challenging conditions. However, SDG 16 targets the building of peaceful societies as essential for sustainable development. Is achieving that goal a precondition in FCAS for the achieving SDG 3 which promotes health and well-being in all societies?

In 2011, the Republic of South Sudan (RSS) became the world’s newest nation. Decades of civil war had destroyed much of the country’s social fabric and physical infrastructure. Child and maternal mortality rates were among the highest in the world, and the highly fragmented health system was managed mostly by non-governmental organisations (NGOs) and humanitarian aid organizations. Despite these extremely challenging starting conditions, RSS and international donors were eager to progress towards the millennium development goals[7,8]. In 2012, RSS became a Countdown to 2015 (CD2015) country for Maternal, Newborn and Child Survival[3], and a pilot country of the New Deal for Engagement in Fragile States, a partnership among donor countries, FCAS, and civil society to create country-led transitions out of fragility[9,10].

However, between 2011 and 2015, RSS experienced unexpected economic and conflict-related shocks which may have slowed their health system development. In 2013, RSS leadership refused to sign the New Deal Compact with donors to establish benchmarks for peace and state building[9,11]. The collapse of global oil prices in 2014/2015 and renewed conflict with Sudan led to a year-long reduction in RSS’s oil production, which contributed to a national economic crisis[12,13]. Domestic conflict erupted in December 2013 when President Salva Kiir accused his ex-Vice-President, Riek Machar, of plotting a coup d’état. This conflict persists into 2019, leaving tens of thousands of people dead and hundreds of thousands displaced, and living with destroyed or limited infrastructure. This event strained relations between the government of RSS and the international community. In oil-producing states, 55% of health facilities no longer functioned in 2016[14]. RSS in 2019 is still a World Health Organization grade 3 emergency country[15] and ranked 1st among 178 countries on the Fragile States Index[16], making it a suitable location to address the question: can a health system strengthen during protracted conflicts?

Due to RSS’s insecurity, current data on its progress towards health-related SDG indicators are scarce. In the final Countdown 2015 report, RSS had the lowest score among 54 countries on the maternal, neonatal, and child health composite coverage index[3]. However, these results are mostly based on pre-independence data, because the most recent Multiple Indicator Cluster Survey (MICS) was conducted in 2010[17]. Similarly, a recent literature review of their MNCRH progress, reported key indicators only for the period from 2000 to 2010[18]. Other recent publications with relevant quantitative results[19-21] also assessed the MICS 2010 data, with a few exceptions[22,23].

Despite the challenging circumstances and widespread civil conflict, the Ministry of Health (MOH) conducted two national household probability surveys: 2011 (the year of independence) and 2015 (the SDG baseline year) providing the most comprehensive national, state and county-level health estimates available. Here, we examine the progress in MNCRH coverage indicators in RSS in the context of a protracted political-military conflict and economy-related shocks. Our findings provide a unique insight on how a fragile health system performs during such conditions and whether or not investment in a FCAS benefits the public’s health rather than wastes resources.

# Methods

## Overall study design

The two national cross-sectional household surveys were stratified random samples of each state in which sub-strata were counties. County-level data were produced with Lot Quality Assurance Sampling (LQAS) and analysed at a state-level as a stratified random sample. Being relatively inexpensive and rapid to carry out at a local level, this established method was well suited to South Sudan for managing state-health services[24]. A detailed description of the sampling design and procedures were reported earlier[23]; the 2015 survey protocol replicated the 2011 design. The national and state MOH selected this method as it permitted classification of each county by national performance benchmarks, and also computation of national and state-level indicator prevalence estimates with 95% confidence intervals. We used the classic LQAS method[25] and training materials[26,27] to build the capacity of state and county health workers to collect the data.

## Sampling and participants

For both surveys we planned to include all 10 South Sudan states and all counties within the states, unless they were highly insecure or inaccessible due to environmental barriers. Despite on-going armed conflict, we surveyed all states in 2011, but excluded Unity state in 2015 which was under rebel control and highly insecure. Armed conflict and political negotiations slightly changed state and county boundaries, so the total number of counties within the states differed between 2011 (79 counties) and 2015 (85 counties). We also subdivided two large counties in Western Bahr-el-Ghazal in 2011 and 2015 to better reflect health system management. Also, in 2015, we aggregated seven small counties to form four bigger counties in the newly designated, semi-autonomous Greater Pibor Administrative Area (GPAA). We excluded 6 counties in 2011 and 4 counties (plus the 9 counties of the excluded Unity state) in 2015 due to insecurity or inaccessibility. In total, this study included 75 of 81 counties/subdivisions in 2011 and 71 of 84 counties/subdivisions in 2015 (Table S1).

We selected villages and households using a standard two-stage sampling procedure. Firstly, we selected 19 interview locations (usually 19 villages) within each county/subdivision of each state using probability proportional to size sampling[23] (2011: n=75 counties x19 villages=1425, 2015: n=71 counties x19 villages=1349, Table S1). We then used segmentation sampling to randomly select households within these villages using a hand-drawn map[28 ,29].

Within households, we used a “parallel sampling” process [26,30], to sample eight different client populations, to ensure a sufficient sample size for assessing each one. Six client populations were mothers of children: 1) <12 months, 2) 12-23 months, 3) 0-59 months, 4) 0-59 months with fever in the last 2-weeks, 5) 0-59 months with diarrhoea in the last 2-weeks, and 6) 0-59 months with suspected pneumonia in the last 2-weeks; two others were 15-49 year-old women and 15-49 year-old men. As each population had its own independent sample, the total sample collected in 2011 was 11,800 (1475 x 8 client populations), and 10,792 (1349 x 8 client populations) in 2015.

Upon arrival at the first randomly selected household, the next closest house was selected to reduce the chance of any house not appearing on the segmentation map having a zero probability for selection. The interviewer listed all household members who met the criteria for any of the eight client populations and selected one person randomly for interview. After the interview the interviewer moved to the next nearest household; the same process continued until one person of each client population was interviewed in each sample location (see [23] for more details). Client populations 4-6 could also be selected in the same house as other client populations due to their low prevalence.

Data collection was supervised by national and state supervisors and some of the authors who were in daily mobile telephone communication with the data collectors whom they had trained. Questionnaires were reviewed daily for missing information by supervisors, and corrected by the corresponding data collector when needed. Data were collected in the dry season using vehicles and boats when needed.

## Study instruments and indicators

Jointly with multiple national stakeholders, we developed separate structured questionnaires for each client population, based on internationally recognized and standardized indicators[31-34] (Table 1). For use in the northern states, questionnaires were translated from English into Arabic and back-translated for verification. In other locations, key terms in the questionnaires were translated into major local languages and back translated into English to ensure consistency with the language used. Questionnaires were refined for the local context during pre-testing.

Table 1- Indicators used during the household surveys in South Sudan, 2011 and 2015

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | | Definition | Client population ∞ (for denominators) | Indicator source § |
| *Maternal & Neonatal care* | |  |  |  |
| 1 | ANC 4+ | % Women that received antenatal care by any health personnel ≥4 times during last pregnancy | MoC<12 m | MDG 5.5, CD 2015, |
| 2 | Malaria prophylaxis | % Women that received ≥2 IPT for malaria during pregnancy | “ | CD 2015 |
| 3 | Tetanus prophylaxis | % Mothers who received ≥2 tetanus toxoid injections before the birth of their youngest child or had lifetime immunity (card confirmed) | “ | Related to CD 2015 |
| 4 | Institutional delivery^ | % Women who delivered in a health facility during last pregnancy | “ | UHC |
| 5 | PNC for mother | % Women with ≥1 postnatal care visit within six weeks postpartum with any health personnel during last pregnancy | “ | Related to CD 2015 |
| *Child immunization* | |  |  |  |
| 6 | Measles vaccination | % Children who received ≥1 dose of measles vaccine | MoC 12-23 m | MDG 4.3; CD 2015; UHC |
| 7 | DPT3 vaccination | % Children who received 3 DPT vaccinations | “ | CD 2015; UHC |
| 8 | All basic vaccines | % Children who received all basic vaccines (1 BCG, 4 OPV, 3 DPT, 1 measles) | “ | UHC |
| *Child care* | |  |  |  |
| 9 | Vitamin A suppl. | % Children aged 6 m. to 5 yrs who received Vit. A supplement in past 6 mo | MoC 0-59 m | Related to CD2015 |
| 10 | Malaria treatment | % Children with fever who received appropriate antimalarial drugs (ACT) | MoC 0-59 m w. fever in past 2 wks | MDG 6.8, CD2015, UHC |
| 11 | Diarrhea treatment | % Children treated with ORS | MoC 0-59 m w. diarrhea in past 2 wks | CD2015 |
| 12 | Pneum. care-seeking | % Children with suspected pneumonia taken to an appropriate health provider | MoC 0-59 m with fast, difficult breathing in past 2 wks | CD 2015; UHC |
| *HIV testing* | |  |  |  |
| 13a/13b | HIV testing, women/ men | % women/men tested for HIV in the last 12 months and received their results | Women/ Men  15-49 yrs | GARPR |
| *HIV-related knowledge* | |  |  |  |
| 14a/  14b | MTCT knowledge, women/ men | % women/men who know 2+ ways in which HIV is transmitted from an infected mother to her child | Women/ Men  15-49 yrs |  |
| 15a/ 15b | Prevention knowledge\*, women/ men | % women/ men who correctly identify using condom and being faithful as ways of preventing sexual HIV transmission | “ | HIV SID 4.1 |
| 16a/ 16b | Misconception knowledge 1\* (mosq.), women/ men | % women/men who correctly reject the misconception that HIV can be transmitted by mosquito bites | “ | HIV SID 4.2.2 |
| 17a/17b | Misconception knowledge 2\* (food), women/ men | % women/men who correctly reject the misconception that HIV can be transmitted by sharing food with infected person | “ | HIV SID  4.2.6 |
| 18a/18b | Misconception knowledge 3\* (witch.), women/ men | % women/ men who correctly reject the misconception that HIV can be transmitted by witchcraft | “ | HIV SID  4.2.3 |
| *STI-related knowledge* | |  |  |  |
| 19a | STI knowledge, women | % Women who know at least two signs/symptoms of STIs in women | Women  15-49 yrs | Related to BSS |
| 19b | STI knowledge, men | % Men who know at least two signs/symptoms of STIs in men | Men  15-49 yrs | Related to BSS |
| *Contraception & HIV-prevention* | | |  |  |
| 20 | Contraception among non-pregnant women (modern)† | % Women of reproductive age, currently not pregnant§, using at least one modern contraception method | Women  15-49 yrs | Related to UHC |
| 21 | Contraception among all married women (modern)† | % Married women of reproductive age, using at least one modern contraception method | “ | UHC |
| 22a/22b | Condom use women/  men | % women/men who reported use of a condom the last time they had sex with non-marital or non-cohabiting partner in past 12 months | Women/ Men  15-49 yrs | Related to MDG 6.2 |

§MDG= Millennium Development Goal, CD 2015= Countdown to 2015 for Maternal, Newborn and Child Survival, UHC=Universal Health Coverage, GARPR= The Global AIDS Response Progress Reporting indicators (before 2012 known as UNGASS indicators) , HIV SID= HIV/AIDS Survey Indicator Database, BSS= Behavioral Surveillance Surveys (BSS)

\* We did not combine prevention and misconception knowledge indicators because national stakeholders predicted knowledge to be very low, which would have resulted in extremely low estimates for composite indicators.

† Modern methods of contraception include female and male sterilization, oral hormonal pills, intra-uterine devices, male and female condoms, injectables, implants (including Norplant), vaginal barrier methods and spermicides.

§ For 2015, we computed this indicator with all women (pregnant and non-pregnant) in the denominator, per the UHC indicators and also MDG indicators, although the latter do not restrict contraception to modern methods, but include traditional methods.

∞MoC<12m = mothers of children aged, MoC 12-23m= Mothers of children aged 12-23 months, MoC 0-59m= Mothers of children aged 0-59 months; MTCT= Mother to child transmission of HIV, m= months, yrs= years, mosq=mosquito, witch.=witchcraft

^Institutional delivery means delivery in a hospital, or primary health care clinic (PHCC).

## Data collection and analysis

Immediately before data collection, we held training workshops at sub-regional venues throughout South Sudan for 237 persons in 2011 and 162 persons in 2015, most of whom were county health department staff selected by their respective State MOH. In 2015, as selected health department staff in counties in Upper Nile (UN) and Jonglei, under rebel control, could not travel to training venues due to insecurity, we trained staff of partner NGOs as replacements. All data were collected in the non-rainy season (2011: April and May; 2015: February and March). In 2015, data collection was delayed due to insecurity in UN, Jonglei and GPAA until April-June.

Questionnaire data were entered in CSPro-v4.0.004 in Juba using double data entry for a portion of the data in 2011 and for all data in 2015. We analysed data using Excel-v2013, Stata-v14, and R-v3.2.3. For each indicator, we computed national and state-level coverage proportions and 95% confidence intervals (CI), weighted by county population sizes. We used “Curtailed Sampling”[35] to adjust for missing data in the 2011 dataset, as explained previously[23]. In 2015, missing data were negligible (Table 2). As we did not survey Unity state in 2015, we excluded it from the 2011 dataset for this comparative national-level analysis. We used a two-sample two-sided Z-test of proportions to test for change between 2011 and 2015.

## Ethics Statement

The Ethical Committees of the MOH for the Republic of South Sudan and the authors’ home institution approved the protocol, study instruments and consent procedures. We obtained oral rather than written informed consent from all respondents, because of the high illiteracy rate.

## Patient and Public Involvement

This study does not involve patients. Also, the public were not involved in the design, conduct and reporting of the research. The public was engaged as interviewees. To ensure local engagement all data capture was carried out jointly with the national and state Ministries of Health of the Republic of South Sudan. We also shared the results with them and offered further dissemination of results, and engaged them for data use and action planning activities.

# Results

## Participants and response rate

Data collectors identified eligible respondents in 93.1% of visited households in 2011 (response rate: 96.2%), and 93.3% in 2015 (response rate: 96.4%). Among the eight client populations groups in all nine states included in this study, we completed a total of 9,710 interviews in 2011 and 10,784 interviews in 2015 (Table 2).

The mean age of participants was similar for the eight client populations in both surveys (range: 27 to 33 years) (Table 2). Most mothers (86-91%) and 15-49 year-old women and men (65-77%) were married; the educational status for men and women, defined as having received any formal schooling, was very low especially among women (2011: 18-27%, 2015: 26-32%). Literacy, assessed in 2015 only, was very low with only 11.7% of 15-49 year-old women and 33.0% of 15-49 year-old men able to read a short sentence. Literacy varied substantially by state (range: 3.4% in Northern Bahr-el-Ghazal to 27.1% in Central Equatoria for 15-49 year-old women, Table S2).

Table 2- Study population characteristics (unweighted), South Sudan household survey, 2011 and 2015

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | 2011 survey\* | | | |  |  | 2015 survey | | | |
| Client population | Sample size *n#* | Mean age, years (SD) | Married, n (%) | Received any formal schooling, n (%) | Respondent's child's mean age, months (SD) |  | Sample size *n§* | Mean age (SD) | Married, n (%) | Received any formal schooling, n (%) | Respondent's child's mean age, months (SD) |
| Mothers of children aged <12 months | 1199 | 28.2 (6.6) | 1,094 (91.7) | 287  (23.9) | 6.1  (3.3) |  | 1348 | 27.1 (6.7) | 1179 (87.5) | 414  (30.7) | 6.1 (3.1) |
| Mothers of children aged 12-23 months | 1064 | 28.5 (7.7) | 957  (89.9) | 234  (22.0) | 16.8  (3.8) |  | 1348 | 28.3 (6.9) | 1182 (87.7) | 377  (28.0) | 16.9 (3.7) |
| Mothers of children aged 0-59 months | 1237 | 29.9 (7.0) | 1,123 (90.8) | 274  (21.9) | 27.0  (15.1) |  | 1348 | 29.1 (7.4) | 1160 (86.1) | 350  (26.0) | 29.0  (15.9) |
| Mothers of children age 0-59 months with fever in past two weeks | 1249 | 29.3 (6.8) | 1,118 (90.8) | 230  (18.4) | 25.6  (16.1) |  | 1348 | 28.8 (7.2) | 1153 (85.5) | 351  (26.0) | 23.6  (15.7) |
| Mothers of children aged 0-59 months with diarrhoea in past two weeks | 1235 | 29.6 (6.9) | 1,122 (90.6) | 261  (20.8) | 24.1  (15.4) |  | 1348 | 28.4 (7.3) | 1177 (87.3) | 363  (26.9) | 23.3  (15.7) |
| Mothers of children aged 0-59 months with fast, difficult breathing in past two weeks | 1235 | 29.5 (7.4) | 1,112 (90.4) | 260  (20.8) | 25.0  (16.0) |  | 1348 | 28.4 (6.8) | 1170 (86.8) | 370  (27.4) | 22.0  (14.7) |
| Women 15 to 49 years | 1246 | 28.3 (8.4) | 838 (67.5) | 330 (26.5) | n/a |  | 1348 | 28.4 (8.1) | 1038 (77.0) | 433  (32.1) | n/a |
| Men 15 to 49 years | 1245 | 32.1 (8.8) | 799 (64.8) | 607 (48.8) | n/a |  | 1348 | 32.9 (9.0) | 1041 (77.2) | 695  (51.6) | n/a |

\* The 2011 survey included Unity State, which we exclude here to compare the 2011 and 2015 results; n/a= not applicable;

# the 2011 sample size should have been 66 counties x 19 villages= 1254 for all eight client populations (see Table S1), but was reduced for all of the client populations due to missing data

§ The 2015 sample size should have been 71 counties x 19 villages = 1349 interviews per client population, but was actually 1348, as the records of one village were missing

## National level MNCRH indicators

Between 2011 and 2015, of the 27 national health care indicators measured, 22 improved (81.5%), four remained similar, and one indicator declined (Table 3). For national estimates for antenatal and postnatal care indicators remained unchanged at low levels in 2015, with less than one quarter of women attending ≥4 ANC (ANC4+, 22.4%. 95%CI +2.5) or receiving ≥1 PNC visit (22.8%, 95%CI +2.5). The proportion of mothers having institutional deliveries, however, increased by 10.5% (p<0.001), but overall remained low with only 27.0% (95%CI ±2.5) of mothers delivering at a health facility in 2015. Malaria prophylaxis in pregnancy increased by 8.6% (p<0.001) to  33.1% (95%CI ±2.9%).

Table 3. Progress in health service coverage (2011-2015) and national coverage proportions in 2015

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Indicator** | **2015 versus 2011 difference in weighted coverage proportions [%]**  **(95%CIs [%])\*** | **p-value\*** | | **Weighted National coverage proportions [%], 2015**  **(95%CIs [%])** | | **HSDP§ coverage target [%] for 2015** | |
| **MATERNAL AND NEONATAL CARE** | |  | |  | |  | |
| ANC 4+ | 1.6 (±3.4) | 0.358 | | 22.4 (±2.5) | | 40 | |
| Malaria prophylaxis | 8.6 (±3.9) | <0.001 | | 13.7 (±2.3) | | 40 | |
| Tetanus prophylaxis | 3.1 (±3.1) | 0.047 | | 33.1 (±2.9) | | 80 | |
| Institutional delivery | 10.5 (±3.4) | <0.001 | | 27.0 (±2.6) | | 25 | |
| PNC for mother (any provider) | 1.7 (±3.6) | 0.359 | | 22.8 (±2.6) | |  | |
| **CHILD IMMUNIZATION** |  |  | |  | |  | |
| Measles vaccination | 11.2 (±4.2) | <0.001 | | 49.7 (±2.8) | |  | |
| DPT3 vaccination | 13.1 (±3.6) | <0.001 | | 34.7 (±2.6) | | 85 | |
| All basic vaccines | 11.3 (±3.0) | <0.001 | | 20.8 (±2.3) | | 50§ | |
| **CHILD CARE** |  |  | |  | |  | |
| Vitamin A suppl. | -26.4 (±3.2) | <0.001 | | 4.8 (±1.6) | | 80 | |
| Malaria treatment (ACT) | 15.8 (±3.6) | <0.001 | | 31.3 (±2.8) | |  | |
| Diarrhoea treatment (ORS) | 17.7 (±4.1) | <0.001 | | 51.4 (±2.9) | | 80 | |
| Pneumonia care-seeking | 5.9 (±4.0) | 0.004 | | 66.1 (±2.8) | |  | |
| **HIV TESTING** |  |  | |  | |  | |
| HIV testing, women | 7.3 (±2.8) | <0.001 | | 17.0 (±2.2) | | NA | |
| HIV testing, men | 8.2 (±2.9) | <0.001 | | 18.6 (±2.3) | | NA | |
| **HIV-RELATED KNOWLEDGE** | |  | |  | |  | |
| MTCT knowledge, women | 6.0 (±2.9) | <0.001 | | 17.3 (±2.4) | | NA | |
| MTCT knowledge, men | 6.6 (±3.4) | <0.001 | | 23.1 (±2.7) | | NA | |
| HIV prevention knowledge, women | 0.5 (±1.9) | 0.641 | | 8.9 (±1.6) | | NA | |
| HIV prevention knowledge, men | 1.9 (±3.0) | 0.218 | | 17.6 (±2.3) | | NA | |
| HIV miscon. know. 1 (mosq), women | 7.0 (±4.0) | 0.001 | | 38.5 (±2.9) | | NA | |
| HIV miscon. know. 1 (mosq), men | 6.9 (±4.0) | 0.001 | | 48.8 (±2.8) | | NA | |
| HIV miscon. know. 2 (food), women | 8.8 (±3.6) | <0.001 | | 55.1 (±2.6) | | NA | |
| HIV miscon. know. 2 (food), men | 7.1 (±3.7) | <0.001 | | 64.0 (±2.6) | | NA | |
| HIV miscon. know. 3 (witch.), women | 12.1 (±3.9) | <0.001 | | 60.2 (±2.6) | | NA | |
| HIV miscon. know. 3 (witch.), men | 6.8 (±3.7) | <0.001 | | 68.1 (±2.5) | | NA | |
| **STI-RELATED KNOWLEDGE** | |  | |  | |  | |
| STI knowledge, women | 9.4 (±3.8) | <0.001 | | 48.6 (±2.8) | | NA | |
| STI knowledge, men | 12.0 (±4.0) | <0.001 | | 58.1 (±2.9) | | NA | |
| **HIV PREVENTION & CONTRACEPTION** | | |  | |  | |  | |
| Contraception (non-pregnant) | 0.6 (±2.6) | 0.653 | | 7.1 (±1.9) | | NA | |
| Contraception (all married) | n.c. |  | | 4.9 (±1.6) | | 20 | |
| Condom use, women | n.c. |  | | 18.0 (±9.1) | | NA | |
| Condom use, men | n.c. |  | | 38.2 (±6.7) | | NA | |

\* Results of two-sample two-sided Z-test of proportions to test for significant change between 2011 and 2015

§ The HSDP target refers to card-confirmed vaccinations, while our indicators include mothers’ oral report of vaccinations

CI= confidence interval, HSDP= Health sector development plan for the Republic of South Sudan, miscon. know.= misconception knowledge, mosq.= mosquito, witch.=witchcraft

n.c.= comparative results not computed, as explained above

Three of four childcare indicators showed significant improvement, with the highest increase being among children with malaria treated with a first-line antimalarial (15.8% increase, p<0.001) and diarrhoea treatment (17.7% increase, p<0.001) (Table 3). Child immunisation coverage improved significantly by 2015 (p<0.001) but remained low with about half of the children obtaining a measles vaccination (49.7%, 95%CI ±2.8), and about one-fifth receiving all basic vaccinations (20.8%, 95%CI ±2.3). Nevertheless, the proportion of children with first-line malaria and diarrhoea treatment remained low at 31.3% (95%CI ±2.8) and 51.4% (95%CI ±2.9), respectively. The only indicator displaying a decreased coverage was child Vitamin A supplementation (26.4% decrease, p<0.001), which fell to a very low 4.8% (95%CI ±1.6) in 2015.

Estimates for most HIV/AIDS and STIs indicators improved only slightly, albeit significantly. HIV-testing coverage among 15-49 year-old women increased by 7.3% (p<0.001) reaching 17.0% (95%CI ±2.2) coverage by 2015 (Table 3). The only HIV-related indicator that did not increase was the proportion of women and men who knew how to prevent sexual HIV transmission through condom use and staying faithful to one partner; it remained low (8.9% and 17.6%). Similarly, the modern contraceptive prevalence rate among non-pregnant 15-49 year-old women remained unchanged at a low 7.1% (95%CI ±1.9). We were unable to compute differences in the condom use indicator during high-risk sexual contacts, because of a small number of people who responded positively in 2011 and 2015 to the question for the denominator (having had extra-marital sex), and a relatively large number of missing values in 2011. Nevertheless, the 2015 national coverage estimates were very low.

Although 81.5% of the indicators improved, their values remained low with a median value of 31.3% (SD=19.7) (Table 3).

## State level MNCRH indicators

Coverage in the 9 states varied considerably for the 27 indicators. On average the state coverages varied by 11.1% for each indicator (Table 4).

Table 4 - Weighted state proportions for MNCRH, HIV and STI indicators, South Sudan household survey, 2015

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Indicator\*** | **Weighted State coverage proportions [%] and in parenthesis 95% CIs [%]** | | | | | | | | | | | | | | | | |
|  | **UN** | **Jong/ GPAA** | | **Warr** | | **NBeG** | | **WBeG** | | **Lakes** | | **WES** | | **CES** | | **EES** | |
| **MATERNAL & NEONATAL CARE** | | | | |  | |  | |  | |  | |  | |  | |
| ANC 4+ | 21.4 (±7.2) | 11.0 (±3.6) | | 9.9 (±5.1) | | 27.6 (±10.7) | | 37.7 (±9.3) | | 18.6 (±6.6) | | 30.7 (±7.7) | | 40.0 (±9.7) | | 19.4 (±6.2) | |
| Malaria prophylaxis | 36.0 (±8.9) | 29.8 (±6.3) | | 24.3 (±6.4) | | 43.1 (±12.3) | | 36.4 (±10.9) | | 33.7 (±8.2) | | 36.7 (±8.2) | | 42.4 (±10.1) | | 22.3 (±6.4) | |
| Tetanus prophylaxis | 6.7 (±4.1) | 8.8 (±4.1) | | 8.0 (±5.3) | | 12.0 (±8.3) | | 17.6 (±9.2) | | 8.9 (±4.9) | | 16.6 (±6.8) | | 32.4 (±10.0) | | 9.7 (±5.0) | |
| Institutional delivery | 13.0 (±5.7) | 14.9 (±4.9) | | 14.1 (±6.0) | | 25.3 (±11.0) | | 42.6 (±10.9) | | 26.5 (±7.5) | | 37.6 (±8.0) | | 55.1 (±9.4) | | 21.7 (±6.2) | |
| PNC for mother | 20.0 (±7.2) | 11.8 (±4.3) | | 25.1 (±7.7) | | 36.2 (±11.7) | | 6.2 (±2.9) | | 10.8 (±5.5) | | 37.8 (±7.5) | | 27.9 (±8.7) | | 26.9 (±6.9) | |
| **CHILD IMMUNIZATION** | | |  | |  | |  | |  | |  | |  | |  | |
| Measles vaccination | 46.7 (±9.0) | 56.5 (±6.4) | | 27.7 (±8.3) | | 26.6 (±9.3) | | 48.5 (±8.8) | | 49.4 (±8.5) | | 55.4 (±7.7) | | 73.1 (±8.7) | | 51.7 (±7.8) | |
| DPT3 vaccination | 25.5 (±8.0) | 23.1 (±5.8) | | 21.0 (±7.4) | | 19.3 (±8.1) | | 51.1 (±10.0) | | 23.1 (±6.9) | | 42.8 (±8.0) | | 70.1 (±8.3) | | 39.0 (±6.8) | |
| All basic vaccines | 18.8 (±7.4) | 9.6 (±4.3) | | 7.6 (±4.4) | | 11.3 (±5.9) | | 41.1 (±9.0) | | 16.4 (±6.3) | | 19.0 (±7.0) | | 48.6 (±9.4) | | 23.9 (±6.4) | |
| **CHILD CARE** |  |  | |  | |  | |  | |  | |  | |  | |  | |
| Vitamin A suppl. | 5.0 (±4.6) | 4.6 (±4.1) | | 0.9 (±1.1) | | 2.7 (±2.6) | | 9.7 (±10.1) | | 3.2 (±3.2) | | 12.9 (±8.0) | | 3.5 (±5.1) | | 8.4 (±6.6) | |
| Malaria treatment | 30.9 (±8.5) | 21.7 (±5.8) | | 24.8 (±6.9) | | 38.4 (±11.7) | | 24.1 (±8.9) | | 25.8 (±7.4) | | 27.2 (±7.0) | | 53.4 (±10.2) | | 29.1 (±7.2) | |
| Diarrhoea treatment | 50.9 (±8.2) | 55.6 (±6.2) | | 38.9 (±8.1) | | 64.6 (±10.7) | | 36.3 (±10.1) | | 49.7 (±8.1) | | 56.6 (±7.4) | | 60.5 (±10.3) | | 40.8 (±7.7) | |
| Pneum. care seeking | 57.2 (±8.1) | 64.9 (±6.1) | | 54.4 (±8.7) | | 59.7 (±12.4) | | 52.0 (±10.8) | | 72.6 (±7.1) | | 81.6 (±6.1) | | 82.2 (±7.8) | | 61.1 (±7.7) | |
| **HIV TESTING** |  |  | |  | |  | |  | |  | |  | |  | |  | |
| HIV testing, w. | 4.9 (±3.5) | 10.4 (±4.3) | | 2.8 (±2.9) | | 3.7 (±5.6) | | 33.2 (±7.8) | | 6.9 (±4.3) | | 52.2 (±7.6) | | 29.1 (±9.3) | | 21.7 (±6.6) | |
| HIV testing, m. | 9.6 (±5.5) | 11.6 (±4.5) | | 4.6 (±3.8) | | 8.1 (±5.5) | | 18.6 (±8.6) | | 12.2 (±5.7) | | 50.5 (±7.8) | | 34.3 (±9.8) | | 20.0 (±6.4) | |
| **HIV-RELATED KNOWLEDGE** | | |  | |  | |  | |  | |  | |  | |  | |
| MTCT knowledge, w. | 20.4 (±7.2) | 15.0 (±5.0) | | 16.4 (±6.9) | | 20.0 (±9.8) | | 6.3 (±6.5) | | 18.1 (±6.5) | | 29.7 (±7.0) | | 17.9 (±7.6) | | 11.5 (±5.2) | |
| MTCT knowledge, m. | 31.4 (±7.2) | 21.6 (±5.7) | | 24.1 (±8.2) | | 19.9 (±10.4) | | 18.4 (±10.0) | | 23.1 (±7.2) | | 30.2 (±7.1) | | 21.5 (±8.5) | | 20.8 (±6.4) | |
| Prevention know., w. | 13.6 (±6.8) | 10.5 (±4.5) | | 0.3 (±0.6) | | 4.5 (±6.1) | | 3.8 (±4.0) | | 2.1 (±2.5) | | 29.8 (±6.9) | | 11.3 (±4.3) | | 6.6 (±4.1) | |
| Prevention know., m. | 23.0 (±7.6) | 18.1 (±5.4) | | 7.9 (±5.6) | | 12.1 (±8.8) | | 11.1 (±7.5) | | 18.0 (±6.9) | | 39.2 (±7.4) | | 23.2 (±7.2) | | 8.6 (±4.2) | |
| Misconception know.1, (mosquito), w. | 44.3 (±8.4) | 31.7 (±6.4) | | 25.8 (±8.3) | | 47.7 (±11.9) | | 35.4 (±7.4) | | 21.3 (±7.2) | | 39.3 (±7.9) | | 60.1 (±9.7) | | 39.0 (±7.4) | |
| Misconception know.1, (mosquito), | 60.0 (±7.5) | 41.0 (±6.7) | | 37.8 (±9.3) | | 40.8 (±12.0) | | 43.7 (±7.2) | | 34.0 (±8.4) | | 43.4 (±8.3) | | 82.2 (±6.1) | | 48.2 (±7.4) | |
| Misconception know. 2 (food), w. | 45.0 (±8.5) | 40.7 (±6.4) | | 25.1 (±8.0) | | 55.6 (±11.4) | | 70.7 (±9.0) | | 49.1 (±8.6) | | 74.9 (±6.8) | | 84.4 (±5.6) | | 64.1 (±6.4) | |
| Misconception know. 2 (food), m. | 58.1 (±8.3) | 51.5 (±6.7) | | 51.2 (±8.6) | | 58.1 (±11.8) | | 65.4 (±9.5) | | 57.2 (±8.4) | | 81.5 (±5.9) | | 91.3 (±4.7) | | 63.8 (±6.5) | |
| Misconception know. 3 (witchcraft), w. | 47.0 (±8.7) | 51.3 (±6.1) | | 50.4 (±8.8) | | 73.1 (±9.5) | | 73.2 (±10.0) | | 54.9 (±8.7) | | 42.5 (±5.8) | | 86.0 (±6.6) | | 62.0 (±6.6) | |
| Misconception know. 3 (witchcraft), m. | 63.0 (±7.4) | 56.2 (±6.2) | | 67.9 (±8.6) | | 84.9 (±7.9) | | 81.3 (±9.3) | | 62.8 (±8.2) | | 49.6 (±6.1) | | 87.6 (±6.5) | | 64.1 (±6.6) | |
| **STI-RELATED KNOWLEDGE** | | |  | |  | |  | |  | |  | |  | |  | |
| STI knowledge, w. | 31.7 (±8.0) | 45.4 (±5.4) | | 45.7 (±7.7) | | 49.4 (±10.9) | | 38.4 (±11.2) | | 45.2 (±8.2) | | 58.8 (±7.5) | | 68.9 (±9.5) | | 40.7 (±6.8) | |
| STI knowledge, m. | 37.8 (±8.3) | 60.4 (±6.5) | | 63.3 (±7.5) | | 62.9 (±9.4) | | 46.8 (±11.9) | | 53.3 (±7.7) | | 69.2 (±7.5) | | 65.9 (±9.9) | | 48.5 (±8.0) | |
| **HIV-PREVENTION & CONTRACEPTION** | | | | |  | |  | |  | |  | |  | |  | |
| Contraception among non-pregnant w. | 4.3 (±3.5) | 0.4 (±0.6) | | 1.8 (±2.8) | | 5.5 (±6.0) | | 3.0 (±5.0) | | 3.3 (±3.9) | | 26.4 (±8.4) | | 16.7 (±9.9) | | 6.0 (±4.5) | |
| Contraception among all married w. | 2.5 (±2.5) | 0.4 (±0.5) | | 1.6 (±2.4) | | 5.0 (±5.5) | | 2.3 (±4.5) | | 2.7 (±3.1) | | 16.3 (±7.1) | | 12.4 (±7.9) | | 4.4 (±3.8) | |

\* For indicator definitions see Table 1

Note: We do not report state-level results for the condom use indicators, because sample sizes for this indicator were too small due to a combination of the low number of persons responding affirmatively to the related questions for the construction of the denominator (having engaged in extra-marital sex) and numerator (having used a condom at last extra-marital sex) and missing values.

ANC= antenatal care; ACT= Artemisinin-based combination therapy; PNC= postnatal care; DPT= diphtheria/ pertussis/ tetanus; ORS= oral rehydration salts, m.= men, w.= women, prev.= prevention, know.= knowledge, int. ind.= international indicator, ad. ind.= adapted indicator definition (including both married and unmarried women, excluding pregnant women)

UN=Upper Nile, Jong=Jonglei, GPAA=Greater Pibor Administrative Area, Warr= Warrap, NBeG=Northern Bahr el Ghazal, WBeG=Western Bahr el Ghazal, Lakes=Lakes, WES= Western Equatoria, CES= Central Equatoria, EES= Eastern Equatoria

Central Equatoria state (CES) displayed the highest coverage rates for almost all MNCRH indicators; the performance of the other states and their improvement rates varied considerably across the different indicators(Table 4, S-Figures 1-28). Four of the nine states significantly increased their rate for institutional delivery with the highest (26.0% increase, p<0.001) being CES. Overall, coverage with MNCRH services remained low for most states, ranging from 13.0% (95%CI ±5.7) in Upper Nile (UN) to 55.1% (95%CI ±9.4) in CES for institutional delivery, from 6.7% (95%CI ±4.1) in UN to 32.4% (95%CI ±10.0) in CES for mothers of infants having received at least two tetanus toxoid vaccinations during pregnancy, from 7.6% (95%CI ±4.4) in Warrap to 48.6% (95%CI ±9.4) in CES for completed basic vaccinations for children 12-23 months of age, and 21.7% (95%CI ±5.8) in Jonglei/GPAA to 53.4% (95%CI ±10.2) in CES for treatment of children <5-years with malaria with an appropriate antimalarial. The highest coverage was found in CES for seeking health-care for a child 0-59 months with suspected pneumonia (82.2%, 95%CI ±7.8).

The modern contraception prevalence rate among non-pregnant women remained low at ≤6% in seven states; however, in WES and CES it increased to 26.4% (95%CI ±8.4) and 16.7% (95%CI ±9.9), respectively (Table 4). For most states, coverage proportions for HIV-, and STI-related indicators either did not change significantly or increased, with one of the biggest increases (22.9%, p<0.001) noted for the HIV-testing indicator among men in Western Equatoria State (WES) reaching 52.2% by 2015. WES performed best for most HIV-, and STI-related and contraception indicators, except for the indicators on HIV-related misconceptions. For example, the proportion of women who correctly rejected the misconception that HIV can be transmitted by witchcraft decreased by 31.1% (p<0.001) to 49.6% in WES. Conversely, in CES this indicator increased by 24.4% (p<0.001) to 87.6% (data on the state level statistical tests not shown).

The modern contraception prevalence rate among non-pregnant women remained low level at ≤6% in seven states; however, in WES and CES it increased to 26.4% (95%CI ±8.4) and 16.7% (95%CI ±9.9), respectively (Table 4).

# Discussion

## National level performance

Despite severe economic and political-military crises, RSS displayed increases in health service coverage for 22 of 27 indicators since its independence in 2011. The increase in vaccination, and malaria prophylaxis and treatment coverage has also been found in other developing countries[3,36]. The increased rate of females having an HIV test is consistent with the increase noted in facility data among pregnant women[37]. This is a welcomed result since RSS has a generalized HIV epidemic (adult HIV prevalence: 2.7%, 2014 estimate) and high levels of STIs[38]. Knowledge of one’s HIV status is a pre-requisite for accessing anti-retroviral therapy (ART). While ART-targets for 2015 have been met globally[39], RSS has only recently begun scaling up ART. In 2013, RSS had the second highest death rate among people living with HIV in 30 countries[40]. Since 2013, the number of people living with HIV/AIDS on ART in RSS has increased by 260% from 7,755 to 28,086[41].

The increases we detected among the 22 indicators took place whilst both local and international efforts had been focusing on health system strengthening (HSS). Following independence, and in line with new international agreements, the MOH implemented a policy of unifying the highly fragmented health system under its control, which after decades of war and humanitarian assistance had been managed mainly by non-governmental organisations (≥76 NGOs and 6 UN agencies)[37]. Whilst NGOs still maintained an essential role in the health system, donors mainly focused on strengthening the entire health system, including the central level.

The HSS support to RSS included improving MOH’s capacity in human resources for health, health financing, governance, and information systems[42], and strengthening service delivery and informatics. The World Bank’s funding for the Umbrella Program for Health System Development (2009-2012) financed improvement in delivery of the Basic Package of Health Services in four states including immunization coverage, skilled birth attendance, use of insecticide-treated bednets, antenatal coverage, Vitamin A supplementation, and tuberculosis case detection[43], and galvanized stakeholders around common health service coverage goals and prioritized funding for these areas. It also intended to strengthen key MOH stewardship functions such as establishment of a management team to coordinate and monitor service delivery, organising monthly coordination meetings among the UN and bilateral agencies, NGOs, the World Bank, and other development partners. It financed additional staffing, renovation, and equipped county-level Health Departments. It supported review and updating of the national Health Sector Policy, and development of a Five-Year Health Sector Development Plan. It also introduced nationally, structured supervision of health facilities using supervisory checklists, developed HMIS tools and provided training on their use, and financed training of MOH staff on health management, information communication technology, and monitoring and evaluation. Further support came during in 2011-17 through Health Rapid Results Project[44-46]. Further progress concerned health financing where health worker’s salaries were harmonised and payrolls were screened to remove so-called “ghost workers” who received salaries without working in the system. Although leadership and governance reportedly improved at the county level, trust between the government and international community had broken down due to political and ethnic tensions with open discrimination observed in the health sector[42,47].

The human resource shortage in RSS continues to be dire with recent data showing the health system having <2 doctors and <20 nurses/midwives per 100,000 population compared to WHO’s recommended 230 doctors, nurses/midwives per 100,000 population[48,49]. The MOH has attempted to strengthen human resources for health (HRH) since 2012, by introducing task-shifting, and prioritizing frontline health workers for skills development[50,51]. The MOH has also tried to increase public health workers’ salaries through an “Infection Allowance” to be paid if county health departments implemented the Human Resources Information System (HRIS)[52]. Despite these efforts, the shortage of skilled health workers is still one the biggest health sector challenges in RSS [42].” The MOH also introduced a routine Health Management Information System (HMIS)[42,53], and periodic LQAS household and health facility assessments to improve state and national health system management, to track health service delivery progress and to inform policy and action[42]. These efforts were supported by World Bank and bi-lateral funding; improvements would not have been feasible without their partnership.

The development assistance for RSS before 2015, and health system improvements may have contributed to the positive trends we observed. For example, the increased use of institutional delivery, also reported by a qualitative study[54], is associated with a 62% increase in the number of health facilities newly constructed from 1,080 in 2011 to 1,747 in 2016 [22,55]. In 2011/2012, international donors agreed with the MOH on a new harmonized donor funding mechanism with three main donor programmes (The World Bank, USAID and DFID) supporting health systems strengthening and health service delivery in their assigned states. In addition to the World Bank’s Umbrella Program for Health System Strengthening, five donors (Australia, Canada, the European Union, Sweden and the UK) provided funding through the Health Pooled Fund (HPF). HPF, which was managed by DFID, worked in six states on strengthening maternal, newborn and children health services during phase I (2012-2016)[56,57]. USAID had a similar programme targeting two states[47]. These three donor programmes, with specific lead implementing partners assigned to each county, were commissioned to support the transition from an NGO-led to a Government-led health service. Together they were to develop a county-based health care model. However, progress has been hampered by continued economic and political-military shocks. USAID and the two states they support, joined HFP for phase II (2016-2018). HPF continues to support South Sudan through its phase-III programme (2018-2023)[57].

Performance remained very low overall, much lower than global and regional averages and failed to meet HSDP targets with only one indicator (institutional delivery: 27%) achieving the 2015 HSDP target of %, a rate well below the 44% average reported for least developed countries[50,58,59]. The stagnation in antenatal care but improvements in measles vaccination coverage were corroborated by health facility assessments in RSS[22,60]. Nevertheless, RSS coverage is much lower than global and regional averages[6] and failed to meet HSDP targets[50]. ANC4+ was consequently stagnant as well remaining unchanged from 2010[61]; this deficiency was associated with geographic region, polygamy status, maternal literacy and knowledge of maternal danger signs.In 2014 UNICEF observed a decline in Vitamin A supplementation, which rendered children more vulnerable to diarrhoea and measles especially in areas most affected by food scarcity[62-65]. Severe drug shortages linked to the termination of the Emergency Medicines Fund (EMF) in July 2015 and disruption in drug delivery, especially Vitamin A supplementation intensified the poor outcomes[23,66,67]. These events further indicate that the conditions and circumstances in which children and their mothers live play a role in understanding their morbidity and mortality[19].

The low levels of service coverage also reflect South Sudan’s fragility which after 20 years of war had minimal infrastructure [50]. Additional improvements are crucial given that armed conflict and environmental conditions in RSS favour outbreaks of measles, malaria, and other infectious diseases[68]. The recently launched Boma Health Initiative (BHI) [43], a community-oriented health system initiative that seeks to improve access to health promotion and disease prevention services at community level, is a step in this direction[48,69]. BHI organize health workers from the local community into health teams to provide primary health care services and is expected to further increase the access of people to the health system[70,71]. However, the success of the BHI depends on improved security of health workers and their communities, and stronger support systems for the decentralized health service delivery. It is also crucial that the MOH coordinates with international donors to ensure uninterrupted funding for medicines and health supplies, and to improve the management of drugs and supply chain logistics[72,73].”

## States level performance

Progress was variable across the nine states. Central Equatoria State, where the capital city, Juba, is located, displayed the greatest progress. While discussion of the variation of all indicators and states exceeds the scope of this paper, we present three examples below to highlight the importance of different socio-economic, political, environmental and cultural factors for the interpretation of state-level results.

Upper Nile (UN), in the north-east, is one of RSS’s three oil-producing states and has the country’s lowest poverty prevalence (26%) and highest literacy rate among 15-24 year-olds (65%) in 2009. However, from 2011 to 2015 it also had the most armed conflict events in RSS [74] including targeted attacks on health facilities[67]. The conflict events may explain why, in contrast to national results, the institutional delivery rate did not increase in UN, and was the lowest in RSS (13%, national range: 13%-55%) in 2015. The true coverage might be even lower, because armed conflict prevented us from accessing four of UN’s 13 counties, including Malakal, which had been RSS’s second largest city. Large parts of the city are now destroyed or looted, including the teaching hospital, one of only four in the country[75]. Despite the 2015 peace agreement, with increased ethnic tensions, partly due to controversial plans to divide RSS’s 10 states into 28 new states[76].

Northern Bahr-el-Ghazal state (NBeG) in the north-west had RSS’s highest poverty prevalence (76%) in 2009 [77], and the lowest female literacy (≤5%) in 2015. NBeG also had relatively few armed conflict events between 2011 and 2015[74], possibly accounting for its increased rates of institutional delivery, malaria prophylaxis during pregnancy, malaria and diarrhoea treatments, and other indicators[56]. However, we found that the measles and DPT3 vaccination coverage had not increased in NBeG since 2011 and remained the lowest (measles:27%, DPT3:19%) in the country in 2015. Annual routine facility data from NBeG recorded a renewed positive trend after a steep decrease in vaccination rates during 2012[78]. It is possible that some health services are sensitive to contextual factors, displaying higher rates in some years and returning to lower levels at other points in time.

Western Equatoria state in the south-west had RSS’s third lowest poverty prevalence in 2009 [77] and the fewest conflict events between 2011 and 2015[74], but RSS’s highest HIV prevalence (6.8% in 2012). In our study WES exhibited the highest rate for HIV-testing and several other HIV-and STI-related indicators, but surprisingly and conversely to the national trend deteriorated substantially for knowledge of HIV-related misconceptions, especially relating to witchcraft. Cultural beliefs in witchcraft are common among the Azande people living in WES; for many Azande the acceptance of messages about sexual HIV-transmission does not necessarily contradict witchcraft lore[79].

Our results show that national results often mask sub-national inequities on state or lower levels. They underscore the importance of using methods that measure sub-national variation and avoid the ecological fallacy that all sub-national regions perform at the national mean[80]. We have not reported county-level LQAS classification results for reasons of space and to maintain a state-level analysis. Although county-level results are a strength of the LQAS method, and allow equity-sensitive tracking of progress[23], we chose a state-level analysis to maintain a higher-level health system focus for this research. LQAS typically uses relatively small sample sizes and is administered locally mostly by public sector or NGO health workers, which enabled us to conduct a national survey under very challenging circumstances that impeded implementation of other national surveys, such as the MICS. Further, social desirability and recall bias might have led to over-or under-reporting of some coverage indicators, which is a common limitation for surveys that assess self-reported behavioural data. Our results may not reflect the situation in internally displaced population camps, which can be assessed by separate LQAS studies, as shown elsewhere[81].

Other organisational factors also play a role. Part of the sub-national variation might be explained by the differing performance of implementing organizations and the varying types of private and public providers, which may vary for some of the indicators[82,83]. However, comparing the quality of different provider types is a complex study and context-dependent, and exceeds the scope of our study. Also, the political situation in South Sudan is volatile, and geographical areas of conflict can shift rapidly which may lead to changes in future sub-national results[84]. Our national-level results may also not be easily generalized to other conflict-affected countries, as the political environment and nature of civil war can be extremely complex and context-dependent[85].

Despite these limitations, our results demonstrate progress in HSS in a country with protracted conflict. This conclusion contradicts the common notion that “war is development in reverse”[4]. Our findings coincide with a recent report that under-five mortality rates declined during the majority of wars fought between 1970 and 2008[86]. While we do not measure mortality, we do measure the improved health services associated with such declines. The public health policies made during peacetime South Sudan and international donor support created a momentum for improving infrastructure during wartime. Even though much support to RSS has been humanitarian aid, broader HSS has been evident. In Afghanistan, for example, the substantial increase in international humanitarian and development aid after the overthrow of the Taliban in 2001, allowed progress in education and MNCRH despite ongoing conflict[86,87]. South Sudan may display a similar pattern.

National surveys using the decentralised approach presented here provided valuable information for county, state and central level health system managers to identify priority health interventions needing improvement. Managers valued it at each level of the health system because the data aided them to know the condition of their own programmes, rather than only the average value of an indicator at a national or regional level. Previous research has shown that the values of an indicator can vary substantially within a region.[80] Whilst these data are valued in the health system, the frequency with which they are collected is context specific. Although some countries carrying out these surveys semi-annually[88], others do so annually or biennially[89]. Fragile countries experiencing conflict may have longer intervals due the higher costs and logistical challenges of carrying out a national survey in a humanitarian setting.

# Conclusions

Our results documented moderate improvement in several key indicators: institutional delivery, immunizations, malaria prophylaxis during pregnancy, malaria and diarrhoea treatment, and HIV-testing. They demonstrated that a health system can strengthen during a protracted conflict. However, in 2015, the baseline year for the SDGs, RSS was still far from achieving national and international targets for these and other services. Since 2015, the instability in RSS has persisted due to domestic political-military conflict. Without continued international support, health systems improvement could be threatened and health service delivery would deteriorate, as seen with the widespread stock-outs of essential medicines after the termination of the Emergency Medicines Fund [56,66]. Donors need to carefully coordinate development aid for HSS with parallel humanitarian aid so they are mutually supportive [42,90]. The collective concerted efforts of international and national stakeholders are required so that the measurable gains in South Sudan are not threatened and the World’s newest and most fragile country is supported on its ambitious path towards sustainable development.

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**Supplementary Material**

Table S1 Numbers of counties and villages sampled per state, South Sudan household surveys 2011 and 2015

Table S2 Weighted literacy results for eight client populations of South Sudan household survey, 2015

Figures S1-28 National and state-level difference in weighted coverage proportions, South Sudan household survey 2011 versus 2015

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