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Trend Analysis of the Impact of Maternal Health Management on Child Health

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ABSTRACT

To evaluate the impact of China's 2009 maternal health management program on service utilization and child health, and examine their association. Using 1998-2020 national time-series data, interrupted time series regression analyzed changes in four maternal service indicators and four child mortality indicators post-implementation. Pearson correlation assessed service-mortality associations. All maternal services showed significant immediate increases post-2009 (systematic management: B=5.53, p<0.01) and accelerated long-term trends (p<0.05). Child mortality continued pre-existing declines; perinatal mortality decreased immediately (B=-0.665, p<0.05). All service indicators correlated strongly and negatively with all mortality indicators (|r|>0.74, p<0.01). The 2009 program sustainably improved maternal service utilization and reinforced declining child mortality trends. Strong negative correlations confirm comprehensive maternal healthcare's critical role in improving child survival.

KEYWORDS

Maternal health management; Child health; Interrupted time series analysis; Maternal health services; Child mortality; Health policy evaluation; China

1. INTRODUCTION

The aims to utilize national time-series data from 1998 to 2020, employing interrupted time series analysis and principal component regression, to evaluate the impact of the maternal health management program implemented in 2009 on maternal service utilization and child health indicators in China. It also explores the association between the utilization rate of maternal health management services and child health.

2. ORGANIZATION OF THE TEXT

2.1. Data Sources

The data source for this study is the China Health Statistical Yearbook (2003-2023). The China Health Statistical Yearbook is an annual data publication reflecting the progress of China's health undertakings and the health status of residents. The yearbook includes data on medical institutions, health personnel, health expenditures, disease control and public health, maternal and child health, and medical insurance in 31 provinces (autonomous regions, municipalities). The data in the China Health Statistical Yearbook originates from the Maternal and Child Health Statistical Annual Report, and mortality data comes from the Maternal and Child Health Surveillance Information System. China's Maternal and Child Health Surveillance System was established in 1989. The system uses

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counties (districts) as the smallest sampling units and covers 31 provinces (autonomous regions/municipalities) nationwide [1]. To ensure the quality and accuracy of mortality data, professionally trained personnel collect and register information on live births, maternal deaths, and child deaths, and investigate and strictly verify the circumstances of each maternal and child death. The data collected by the system is ultimately incorporated into the National Health Statistical Yearbook [2].

From these sources, national maternal service utilization indicators such as the early pregnancy registration rate, prenatal checkup rate, systematic management rate, and postpartum visit rate for 1998-2020 were extracted, along with child health indicators including the neonatal mortality rate, perinatal mortality rate, infant mortality rate, and under-5 child mortality rate. A national time-series database for maternal health management and child health was constructed, covering 23 years of observations.

2.2. Evaluation Indicators

2.2.1. Maternal Health Management Service Utilization Indicators

Based on the Basic Public Health Service Specification [3] and performance assessment indicators, the evaluation indicators for the trend study include: early pregnancy registration rate, prenatal checkup rate, postpartum visit rate, systematic management rate, and maternal mortality ratio.

Early Pregnancy Registration Rate: Refers to the ratio of the number of pregnant women who had their "Mother and Child Health Handbook" established by medical staff before the 13th week of gestation within the year to the number of live births in the same year, expressed as a percentage.

Prenatal Checkup Rate: Refers to the ratio of the number of pregnant women who received one or more prenatal checkups during the year to the number of live births in the same year, expressed as a percentage.

Postpartum Visit Rate: Refers to the ratio of the number of women who received one or more postpartum visits within 28 days after delivery during the year to the number of live births in the same year, expressed as a percentage.

Systematic Management Rate: Refers to the ratio of the number of pregnant women who, according to the systematic management program requirements, received early pregnancy checkups, at least 5 prenatal checkups, new method delivery, and postpartum visits from pregnancy to within 28 days after delivery during the year, to the number of live births in the same year, expressed as a percentage.

2.2.2. Child Health Indicators

From a macro perspective on measuring the overall health of child populations, the U.S. Essential Children's Health Indicator System includes indicators such as the low birth weight rate, infant mortality rate, childhood obesity rate, and childhood overweight rate [4]. In its research reports on "The State of the World's Children," UNICEF has constructed a multi-dimensional child health assessment system, including core health indicators such as the under-5 mortality rate and neonatal mortality rate [5]. In reports such as the "China National Program for Children's Development [6] (2021-2030)" and the "Healthy Children Action Plan [7] (2021-2025)," China proposes using relevant indicators such as child mortality rate, vaccination rate, anemia rate, obesity rate, stunting rate, and myopia rate to measure child health. This paper selects child health indicators including neonatal mortality rate, perinatal mortality rate, infant mortality rate, and under-5 child mortality rate.

Perinatal Mortality Rate: Refers to the ratio of the number of fetal deaths (including stillbirths) at ≥28 weeks of gestation or with a birth weight ≥1000g, plus early neonatal deaths (within 7 days after birth) to the number of live births. Generally expressed as per thousand (‰).

Neonatal Mortality Rate: Refers to the number of deaths among live-born infants from birth to 28 days (0-27 days).

Infant Mortality Rate: Refers to the number of deaths of live-born infants under 1 year of age. Expressed as per thousand (‰) in parentheses.

Under-5 Child Mortality Rate: Refers to the probability of a child born in a specified year dying before reaching the age of 5. Calculation formula: (Number of deaths of children under 5 in the same year / Number of live births in the same year) × 1000‰.

2.3. Statistical Analysis Methods

This study employs interrupted time series regression analysis (ITS) to analyze various maternal service utilization indicators and child health indicators. Interrupted time series regression analysis, as a commonly used longitudinal data analysis method, is frequently applied in health economics analysis and health policy evaluation research. It integrates the pre-intervention trend[8,9], the immediate change at the intervention point, and the post-intervention trend to scientifically evaluate the implementation effect of an intervention [10]. This is particularly useful for studies lacking a clear baseline survey before the intervention or a well-defined control group. ITS analysis can adjust for potential serial correlation in the data by controlling for autocorrelated errors at each time point. The specific formula is as follows.

$$Y_t = \beta_0 + \beta_1 preslope + \beta_2 intervention + \beta_3 postslope + \varepsilon_t$$

In the formula, β0 explains the baseline level of the data before the intervention; β1 explains the natural trend of the data before the intervention; β2 explains the immediate (step) change in the data level at the time the intervention begins; β3 explains the long-term trend change in the data after the intervention. This study designates the implementation of maternal health management in 2009 as the intervention point (breakpoint), dividing the entire time series into a pre-implementation period (before 2009) and a post-implementation period (after 2009). Interrupted time series regression analysis is performed on variables such as maternal health management service utilization rates and child health indicators. The implementation effect of the maternal health management service is evaluated by comparing the trends before and after the intervention and the immediate change in the year of intervention. Pearson correlation analysis is used for the correlation analysis between maternal service utilization rates and mortality rates.

3. RESEARCH RESULTS

3.1. Descriptive Overview

From 1998 to 2020, the utilization rate of maternal health management services in China showed an overall continuous upward trend, with significant improvements in all indicators. Specifically:

The maternal registration rate increased from 86.23% to 94.10%. Before the implementation of the 2009 policy (1998-2008), the registration rate fluctuated between 86% and 89%, with an average annual increase of about 0.3 percentage points. After 2009, it rose rapidly, reaching a peak of 96.60% in 2017, then slightly decreased but remained above 94%. The maternal systematic management rate showed the most significant improvement, increasing from 72.27% to 92.70%. Before 2009, this indicator lingered in the 72%-78% range for a long time. After breaking through 80% in 2009, it accelerated, reaching 91.60% in 2016, and has since stabilized around 90%. The prenatal checkup rate increased from 87.10% to 97.40%. The postpartum visit rate increased from 83.90% to 95.50%, a rise of 11.60 percentage points.

Table 1. Utilization rate of maternal health management services by maternal health management service from 2000 to 2018 (%)

Year	Live Births	Early Pregnancy Registration Rate	Systematic Management Rate	Prenatal Checkup Rate	Postpartum Visit Rate
1998	10961516	86.23	72.27	87.10	83.90
1999	10698467	87.93	75.37	89.30	85.90
2000	10987691	88.64	77.16	89.40	86.20
2001	10690630	89.44	78.57	90.30	87.20
2002	10591949	89.22	78.16	90.10	86.70
2003	10188005	87.60	75.50	88.90	85.40
2004	10892614	88.30	76.40	89.70	85.90
2005	11415809	88.50	76.70	89.80	86.00
2006	11770056	88.20	76.50	89.70	85.70
2007	12506498	89.30	77.30	90.90	86.70
2008	13307045	89.30	78.10	91.00	87.00
2009	13825431	90.90	80.90	92.20	88.70
2010	14218657	92.90	84.10	94.10	90.80
2011	14507141	93.80	85.20	93.70	91.00
2012	15442995	94.80	87.60	95.00	92.60
2013	15108153	95.70	89.50	95.60	93.50
2014	15178881	95.80	90.00	96.20	93.90
2015	14544524	96.40	91.50	96.50	94.50
2016	18466561	96.60	91.60	96.60	94.60
2017	17578815	96.60	89.60	96.50	94.00
2018	15207729	92.50	89.90	96.60	93.80
2019	14551298	92.40	90.30	96.80	94.10
2020	12034516	94.10	92.70	97.40	95.50

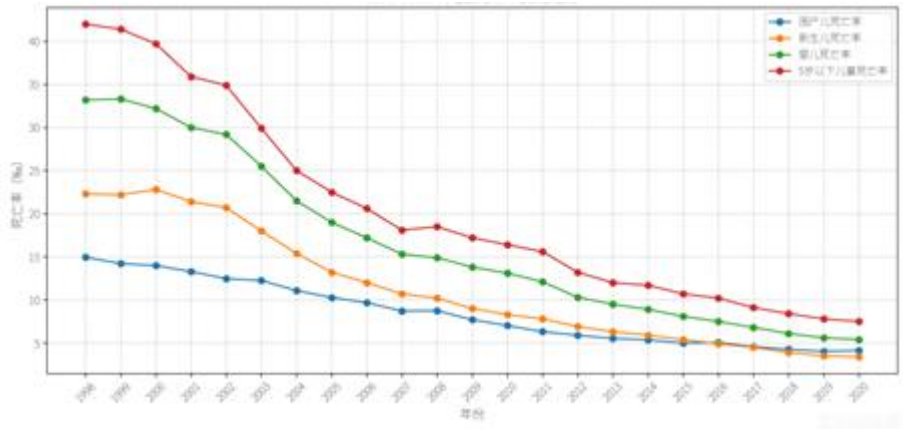

Figure 1. Trend of child mortality from 1998 to 2020

Multiple indicators of child health outcomes also showed positive changes. The perinatal mortality rate decreased from 14.94‰ to 4.14‰. The neonatal mortality rate dropped from 22.3‰ to 3.4‰. The infant mortality rate fell from 33.2‰ to 5.4‰. The under-5 child mortality rate declined from 42‰ to 7.5‰. The urban-rural gap also gradually narrowed; for example, the rural neonatal mortality rate decreased from 25.1‰ to 3.9‰, and the rural under-5 child mortality rate dropped from 47.9‰ to 8.9‰.

3.2. Results of Interrupted Time Series Regression Analysis

Based on provincial panel data from the China Health Statistical Yearbook (1998-2020), this study employed interrupted time series analysis to evaluate the implementation effect of the national public health program centered on "strengthening maternal health management services" (hereafter referred to as "the program"). The analysis focused on four dimensions: maternal health service utilization, child mortality, child health service utilization, and specific child health outcomes. Key results are as follows:

3.2.1. Changes in Maternal Health Service Utilization Rates

The program had a significant and sustained positive impact on increasing maternal health service coverage. All four core service utilization indicators showed a significant immediate level increase at the time of program implementation (the "immediate trend of program implementation" coefficient was positive and $p < 0.05$). Among them, the maternal systematic management rate showed the largest immediate increase ($B = 5.53$, $p < 0.01$), followed by the postpartum visit rate ($B = 4.65$, $p < 0.05$), the early pregnancy registration rate ($B = 3.83$, $p < 0.05$), and the prenatal checkup rate ($B = 2.23$, $p < 0.01$). More importantly, after the program implementation, all four indicators showed a faster positive growth trend compared to the pre-program period (the "post-program trend" coefficient was positive and $p < 0.05$). The annual increases in the systematic management rate ($B = 0.99$, $p < 0.01$) and the prenatal checkup rate ($B = 0.46$, $p < 0.01$) accelerated significantly. This indicates that the program not only immediately raised service coverage levels but also established a long-term mechanism for the continuous improvement of service utilization.

Table 2. Results of intermittent time series analysis of maternal health service utilization indicators (1998-2020)

Maternal Service Utilization Rate		B	SE	t	p	95% CI	
Early Pregnancy Registration Rate (%)	Constant	88.61	0.99	89.22	0.00	86.50	90.73
	Pre-intervention Trend	0.02	0.18	0.12	0.91	-0.36	0.40
	Immediate Intervention Effect	3.83	1.26	3.05	0.01	1.15	6.51
	Post-intervention Trend	0.36	0.15	2.38	0.03	0.04	0.68
Maternal Systematic Management Rate (%)	Constant	77.36	1.16	66.91	0.00	74.89	79.82
	Pre-intervention Trend	-0.04	0.21	-0.19	0.85	-0.48	0.40
	Immediate Intervention Effect	5.53	1.46	3.78	0.00	2.41	8.64
	Post-intervention Trend	0.99	0.18	5.66	0.00	0.62	1.37
Prenatal Checkup Rate (%)	Constant	89.27	0.46	195.80	0.00	88.30	90.24
	Pre-intervention Trend	0.14	0.08	1.74	0.10	-0.03	0.31
	Immediate Intervention Effect	2.23	0.58	3.87	0.00	1.00	3.46
	Post-intervention Trend	0.46	0.07	6.67	0.00	0.31	0.61
Postpartum Visit Rate (%)	Constant	90.07	1.39	64.74	0.00	87.10	93.03
	Pre-intervention Trend	-0.56	0.25	-2.27	0.04	-1.09	-0.04
	Immediate Intervention Effect	4.65	1.76	2.64	0.02	0.90	8.40
	Post-intervention Trend	0.56	0.21	2.66	0.02	0.11	1.01

3.2.2. Child Health Indicators

Before the implementation of the program, both urban and rural neonatal and infant mortality rates in China were already showing significant declining trends (the "pre-intervention trend" coefficient was negative and $p < 0.01$). After the program implementation, the declining trends in urban and rural neonatal and infant mortality rates continued (the "post-intervention trend" coefficient was negative and $p < 0.01$).

Table 3. Results of intermittent time series analysis of neonatal and infant mortality indicators (1998-2020)

Variable		B	SE	t	p	95%CI	
Urban Neonatal Mortality Rate	Constant	4.993	0.575	8.69	0.000	3.790	6.196
	Pre-intervention Trend	-0.512	0.079	-6.45	0.000	-0.678	-0.346
	Immediate Intervention Effect	-0.204	0.494	-0.41	0.684	-1.238	0.830
	Post-intervention Trend	-0.257	0.072	-3.57	0.002	-0.408	-0.106
Rural Neonatal Mortality Rate	Constant	10.588	1.067	9.92	0.000	8.355	12.820
	Pre-intervention Trend	-1.431	0.148	-9.64	0.000	-1.741	-1.120
	Immediate Intervention Effect	-0.160	0.952	-0.17	0.868	-2.152	1.832
	Post-intervention Trend	-0.626	0.135	-4.66	0.000	-0.908	-0.345
Urban Infant Mortality Rate	Constant	6.323	0.548	11.53	0.000	5.176	7.471
	Pre-intervention Trend	-0.688	0.079	-8.67	0.000	-0.854	-0.522
	Immediate Intervention Effect	-0.073	0.634	-0.12	0.910	-1.400	1.254
	Post-intervention Trend	-0.268	0.071	-3.80	0.001	-0.416	-0.121
Rural Infant Mortality Rate	Constant	15.094	1.259	11.99	0.000	12.458	17.729
	Pre-intervention Trend	-2.180	0.178	-12.22	0.000	-2.553	-1.806
	Immediate Intervention Effect	0.927	1.244	0.75	0.465	-1.677	3.531
	Post-intervention Trend	0.56	0.21	2.66	0.02	0.11	1.01

Neonatal Mortality Rate: Before the intervention, the national neonatal mortality rate was significantly decreasing by 1.46‰ per year ($p < 0.01$). In the year of intervention implementation, there was no significant immediate change in the neonatal mortality rate ($\beta = 0.265$, $p > 0.05$). After the intervention, the neonatal mortality rate continued its significant downward trend, with an average annual decrease of 0.52‰ ($p < 0.01$).

Perinatal Mortality Rate: Before the intervention, the perinatal mortality rate was significantly decreasing by 0.667‰ per year ($p < 0.01$). In the year of intervention implementation, the perinatal mortality rate experienced a significant immediate decrease of 0.665‰ ($p < 0.05$). After the intervention, the perinatal mortality rate continued to significantly decrease by 0.311‰ per year ($p < 0.01$).

Infant Mortality Rate: Before the intervention, the infant mortality rate was significantly decreasing by 2.165‰ per year ($p < 0.01$). In the year of intervention implementation, there was no significant immediate change in the infant mortality rate ($\beta = 1.612$, $p = 0.093$). After the intervention, the infant mortality rate continued its significant downward trend, with an average annual decrease of 0.791‰ ($p < 0.01$).

Under-5 Child Mortality Rate: Before the intervention, the under-5 child mortality rate was significantly decreasing by 2.770‰ per year ($p < 0.01$). In the year of intervention implementation, the under-5 child mortality rate showed a significant immediate increase of 3.433‰ ($p < 0.05$). After

the intervention, the under-5 child mortality rate resumed its significant downward trend, with an average annual decrease of 0.914‰ ($p < 0.01$).

After the implementation of maternal health management in 2009, all child mortality indicators continued their pre-existing downward trends. Notably, the perinatal mortality rate showed a significant immediate decrease in the intervention year, while neonatal, infant, and under-5 mortality rates maintained their stable declining trends post-intervention. Detailed results are presented in Table 4.

Table 4. Results of interrupted time series analysis of child health outcomes (1998-2020)

Variable		B	SE	t	p	95%CI	
Neonatal Mortality Rate	Constant	8.413	0.720	11.68	<0.001	6.905	9.921
	Pre-intervention Trend	-1.460	0.148	-9.87	<0.001	-1.770	-1.150
	Immediate Intervention Effect	0.265	0.732	0.36	0.721	-1.266	1.797
	Post-intervention Trend	-0.520	0.027	-19.31	<0.001	-0.577	-0.464
Perinatal Mortality Rate	Constant	7.781	0.172	45.37	<0.001	7.422	8.140
	Pre-intervention Trend	-0.667	0.024	-27.57	<0.001	-0.718	-0.616
	Immediate Intervention Effect	-0.665	0.275	-2.42	0.026	-1.240	-0.090
	Post-intervention Trend	-0.311	0.036	-8.62	<0.001	-0.387	-0.235
Infant Mortality Rate	Constant	11.671	0.861	13.55	<0.001	9.869	13.473
	Pre-intervention Trend	-2.165	0.148	-14.64	<0.001	-2.475	-1.856
	Immediate Intervention Effect	1.612	0.912	1.77	0.093	-0.296	3.521
	Post-intervention Trend	-0.791	0.059	-13.50	<0.001	-0.914	-0.668
Under-5 Child Mortality Rate	Constant	13.244	1.261	10.50	<0.001	10.604	15.884
	Pre-intervention Trend	-2.770	0.168	-16.46	<0.001	-3.122	-2.418
	Immediate Intervention Effect	3.433	1.286	2.67	0.015	0.742	6.124
	Post-intervention Trend	-0.914	0.066	-13.80	<0.001	-1.053	-0.775

3.3. Results of Correlation Analysis

To comprehensively assess the impact of maternal health management on child health, Pearson correlation analysis was conducted between maternal service utilization rates and infant mortality rate, perinatal mortality rate, neonatal mortality rate, and under-5 child mortality rate. The results showed statistically significant negative correlations between the utilization rates of various maternal services and each child mortality indicator ($P < 0.01$). As the utilization rates of various maternal services increased, child mortality rates showed a declining trend. Detailed correlation coefficients are presented in Table 5.

Table 5. Pearson correlation coefficient between the utilization rate of maternal health management services and child mortality indicators

Service Indicator	Infant Mortality Rate	Perinatal Mortality Rate	Neonatal Mortality Rate	Under-5 Child Mortality Rate
Maternal Registration Rate	-0.91**	-0.77**	-0.92**	-0.91**
Systematic Management Rate	-0.89**	-0.93**	-0.88**	-0.88**
Prenatal Checkup Rate	-0.92**	-0.74**	-0.92**	-0.92**
Postpartum Visit Rate	-0.93**	-0.80**	-0.93**	-0.93**

4. DISCUSSION

Based on national time-series data from 1998 to 2020, this study systematically evaluated the implementation effect of the national public health program centered on strengthening maternal health management using interrupted time series regression analysis.

The study found that after the program's implementation in 2009, the early pregnancy registration rate, prenatal checkup rate, systematic management rate, and postpartum visit rate all showed significant immediate increases, with the maternal systematic management rate experiencing the largest increase ($B = 5.53$, $p < 0.01$). This result is consistent with findings from numerous previous policy evaluation studies. For example, an interrupted time series analysis by Ilboudo et al. on Burkina Faso's free maternal and child healthcare policy showed similar significant immediate increases in prenatal checkup rates and facility delivery rates after policy implementation [11]. This suggests that public health policies aimed at enhancing service coverage can rapidly alter service utilization behavior in the short term, producing immediate effects.

More importantly, this study found that after the program implementation, all four service utilization rates exhibited a faster positive growth trend compared to the pre-intervention period. The annual increases in the systematic management rate ($B = 0.99$, $p < 0.01$) and the prenatal checkup rate ($B = 0.46$, $p < 0.01$) accelerated significantly. This finding reveals the program's long-term mechanism – not only did it increase service coverage in the short term through policy mobilization and resource investment, but it also laid an institutional foundation for the continuous improvement of service utilization through system strengthening and capacity building. Similarly, Basinga et al.'s evaluation of a performance-based payment policy in Rwanda found that the introduction of incentives not only increased service utilization but also improved the quality of prenatal care [12].

Regarding child health outcomes, this study found that urban and rural neonatal and infant mortality rates were already significantly declining before the program implementation. This is closely related to concurrent economic and social development, advancements in medical technology, and the cumulative effects of prior maternal and child health efforts [13]. After program implementation, these declining trends continued, but aside from the perinatal mortality rate, no significant immediate decreases were observed for other indicators. This result suggests that reducing child mortality is a long-term, gradual process [14]. The contribution of strengthened maternal health management primarily lies in consolidating and maintaining the pre-existing downward trend, rather than producing an abrupt, cliff-edge effect.

Notably, the perinatal mortality rate showed a significant immediate decrease in the year of program implementation ($B = -0.665$, $p < 0.05$). Perinatal mortality encompasses stillbirths, late fetal deaths, and early neonatal deaths, and is highly sensitive to the quality of perinatal care. Strengthened maternal health management, by increasing the coverage and quality of prenatal checkups, promoting the screening and management of high-risk pregnant women, and increasing facility delivery rates, may have produced a direct protective effect on perinatal survival in a relatively short period. This finding confirms the crucial role of prenatal care in improving fetal and neonatal outcomes. A recent meta-analysis covering 14 studies showed that high-quality prenatal care can reduce neonatal mortality by 41% [15].

Through Pearson correlation analysis, this study found that the four maternal service utilization rates were significantly negatively correlated with infant mortality, perinatal mortality, neonatal mortality, and under-5 child mortality ($|r| > 0.74$, $P < 0.01$). Among them, the postpartum visit rate showed the strongest correlation with each child mortality indicator (r ranging from -0.93 to -0.80), followed by the prenatal checkup rate (r ranging from -0.92 to -0.74). The maternal systematic management rate (r ranging from -0.93 to -0.88) and maternal registration rate (r ranging from -0.92 to -0.77) also demonstrated high negative correlations. This result suggests that higher utilization levels of maternal

healthcare services are associated with lower risks of child mortality, indicating a close inverse relationship between them.

The theoretical basis for this result lies in the fact that the service network and health records established through maternal health management create conditions for children to receive continuous health management services after birth. The effective coverage framework emphasizes that service utilization is only a prerequisite for generating health benefits; service quality and continuity are equally crucial [16]. Early pregnancy registration, standardized prenatal checkups, systematic management, and postpartum visits constitute a continuous service chain covering the entire pregnancy and postpartum period. The integrity of this chain directly influences maternal and child health outcomes.

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