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District variation in the impact of COVID-19 on maternal, neonatal and child health service utilisation, delivery and outcomes in Gauteng province, South Africa: a cross-sectional study

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ABSTRACT

Background This study investigated district-level variations in the impact of COVID-19 on maternal, neonatal and child healthcare (MNCH) service utilisation, delivery and health outcomes in Gauteng, one of the hardest-hit provinces in South Africa.

Study design A cross-sectional quantitative study.

Main outcome measures We collected District Health Information System data for MNCH services from all 493 public healthcare facilities across all five districts in Gauteng province. We applied simple linear regression to assess key performance indicators before (March 2019 to February 2020) and during (March 2020 to February 2021) the COVID-19 pandemic. A pooled multiple linear regression model compared the impact of the pandemic in each district with that of the Johannesburg reference district. The regression models followed the bootstrap approach. Analyses were performed in Stata V.17.0.

Results Regarding service utilisation, primary headcount under 5 years (n) significantly decreased in all five districts during COVID-19. The effect was greater in Johannesburg (−20 954.5, 95% CI −28 913.3 to −12 995.7; p<0.001), and similar to that in Tshwane and Ekurhuleni compared with Sedibeng and West Rand. Postnatal care visits within 6 days (rate) declined in all five districts, with a more pronounced effect in Johannesburg (−24.9, 95% CI −31.8 to −18.0; p<0.001). Antenatal care first visits before 20 weeks (rate) decreased in four districts, with severe effects in Ekurhuleni (−3.6, 95% CI −6.9 to −0.3; p=0.033), Sedibeng (−4.4, 95% CI −7.3 to −1.4; p=0.004) and West Rand (−7.5, 95% CI −11.3 to −3.7; p<0.001) compared with Johannesburg. Service delivery metrics, such as measles second dose coverage (%) and fully immunised under 1 year (%), declined across all five districts, although fully immunised declined remarkably in Johannesburg and Sedibeng only. Health outcomes, like pneumonia case fatality rates for under 5 years (%), declined while facility deaths 0–6 (rate) increased exclusively in Tshwane. Tshwane and Sedibeng suffered the most, with four of the eight selected indicators adversely affected by COVID-19 in each of the districts.

Conclusion In Gauteng province, the COVID-19 pandemic caused a heterogeneous adverse impact on MNCH service utilisation, delivery and health outcomes across the districts. Recognising the geographical differences in the effects of outbreaks and pandemics is critically important for informed decision-making to support healthcare services recovery in affected areas and for planning against future crises.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is the first robust study to examine district differences in the impact of COVID-19 on maternal, neonatal and child healthcare (MNCH) services and outcomes, particularly in low- and middle-income countries (LMICs).
⇒ The research draws from a large sample size of all 493 MNCH public healthcare facilities to provide real-world evidence of district variations in how COVID-19 affected essential MNCH services and outcomes in Gauteng province.
⇒ The strength of the pooled multiple linear regression, supported by the bootstrap approach, was adequate to detect these variations.
⇒ Improving data quality proved challenging because the routine District Health Information System (DHIS) only reports data from public facilities, without a representation of the private health sector.
⇒ District differences may have been influenced by demand and supply-side factors of MNCH services, which are difficult to separate using DHIS data.

INTRODUCTION

The COVID-19 pandemic has had a mixed effect on essential healthcare services globally. In some instances, the pandemic has disrupted the delivery, access to and utilisation of routine healthcare services like immunisation, antenatal, maternal and child healthcare, HIV/AIDS and tuberculosis screening, testing and enrolment into the antiretroviral therapy, cleft services including neonatal audiology and dentistry and cardiovascular health as reported in several studies from the UK, the USA, Africa and Asia-Pacific.[1–6] This deleterious effect of COVID-19 extended to sexual and reproductive health, resulting in lower testing for sexually transmitted infections and condom uptake.[7] In

Gauteng province, where the current study was conducted, the pandemic equally disrupted voluntary medical male circumcision (VMMC) with a disproportionate district variation.[8] The disruption in routine health services during COVID-19 was due to the deployment and reallocation of health resources, including staff, infrastructure and equipment, to fight the pandemic.[9 10] This COVID-19 disruption of essential services is detrimental to health outcomes, with the potential to reverse health gains accumulated from previous decades. For instance, evidence suggests that health services may take years to recover to pre-crisis levels, as experienced with the prolonged measles outbreak that lasted 2 years after the West African Ebola.[11]

Conversely, fewer studies indicate that COVID-19 has not significantly affected routine services. One recent example is the case of childhood vaccination in Gambia, which not only saw an increase in coverage during COVID-19 but also achieved higher coverage over a shorter time frame compared with the pre-COVID-19 period.[12] This was attributed to effective surveillance systems, which could be adapted to other similar settings during future outbreaks. Similarly, and contrary to VMMC disruption in Gauteng,[8] female condom distribution in the province experienced a surge during COVID-19; however, a district variation was observed.[13] While the uptake increased substantially in districts like Tshwane and Ekurhuleni, the West Rand district saw a drastic decline in distribution, despite all districts applying the same COVID-19 preventive measures.[13] Likewise, a global survey conducted in 36 countries concluded that COVID-19 failed to significantly impact routine dental care, which is possibly due to the effective protective measures implemented by dental practitioners.[14] Yet, other studies showing no significant effect of COVID-19 on service disruption often acknowledge slight variations in trends or patterns of service delivery, utilisation and even health outcomes.[15]

Overall, the above two conflicting arms of literature demonstrate that COVID-19 affected routine healthcare services differently in different geographical settings. However, many studies have only assessed the geographical variations in the direct impact of COVID-19-like infection, prevalence, incidence, morbidity and mortality rates of the pandemic. For example, studies on geographical variations in India, the USA and South Africa were limited to exploring the infections and mortality rates of COVID-19 and the associated factors, without any endeavour to examine the geographical variations in healthcare service disruption and the consequence thereof, on health outcomes like maternal and neonatal mortality as a result of the pandemic.[16–18] Nonetheless, studies have recommended robust district analyses to quantify the scale of COVID-19 disruption on maternal and child health services, to drive the prioritisation of interventions.[1 19–22] A South African study attempted to evaluate the district variations in access and delivery of child well-being services during COVID-19, but the study limited its methodology and scope to descriptive analysis, barely 4 months into the pandemic and equally emphasised the importance of robust analysis over a much longer period to better capture the effect of the pandemic for policy interventions.[22] Interestingly, a recent robust study that employed the interrupted time series (ITS) analysis to assess the impact of COVID-19 in the Gauteng province of South Africa found that the pandemic disruption of routine healthcare services delivery like immunisation and antenatal care (ANC or CAN) resulted in an increase in maternal and neonatal mortality, and also highlighted the importance of evaluating the district variations thereof, for services recovery support and caution against future outbreaks.[19]

Although policies are often established at a higher level, their implementation occurs at the grassroots. Hence, it is crucial to understand the effects of public emergencies at the local level to recommend informed policies. Therefore, recognising the importance of understanding the geographical variations of COVID-19's impact on services such as maternal and child healthcare is vital for prioritising and designing recovery support interventions, as well as assisting in planning against future health outbreaks and crises. Additionally, the evidence from the current study will inform multidisciplinary rethinking on the necessary efforts to achieve the Sustainable Development Goals (SDGs) target 3.1, which focuses on reducing maternal mortality to below 70 per 100 000 live births as well as SDG target 3.2, which aims to substantially reduce preventable deaths of neonates and children under 5 years old to at least 12 per 1000 and 25 per 1000 live births, respectively, by 2030.[23] In this regard, and with the knowledge that Gauteng was one of the most affected provinces in South Africa by the COVID-19 pandemic, the current study aims to investigate district variations in COVID-19's impact on the utilisation, delivery and health outcomes of maternal, neonatal and child healthcare (MNCH) services in Gauteng province, South Africa. This will address the research gap identified in the only study that assessed the impact of the COVID-19 pandemic on MNCH in Gauteng, which limited its scope to the provincial level, yet highlighted the invaluable need for a follow-up study on district variation, thereby providing the necessary literature sought by other studies.[19]

METHODS

Study design

This study employed a cross-sectional study design to investigate the district variations in MNCH service utilisation, delivery and health outcomes as a result of the COVID-19 pandemic from March 2019 to February 2021.

Setting

The study was conducted in the Gauteng province of South Africa. Gauteng province is made up of five districts, namely: Johannesburg, the country's economic capital; Ekurhuleni, which is home to the OR Tambo International Airport, the main air route into the Southern African Development Community (SADC), and Tshwane, the administrative capital of South Africa (these three districts are metropolitan municipalities), and the Sedibeng and West Rand districts. Gauteng is an economically critical and most populous province in South Africa with over 16 million inhabitants[24] served by 493 healthcare facilities, both fixed and mobile, under the

supervision of the Gauteng Department of Health (GDoH). The facilities comprise primary healthcare centres that refer patients to 33 public hospitals in the province, classified as district, regional, provincial/tertiary and national/central hospitals. Most of these health facilities are concentrated in Johannesburg, which is the most populous and densely populated district in Gauteng and the entire South Africa. The high population in Gauteng is attracted by the commercial and industrial characteristics of the province, associated with historical gold mining, particularly in Johannesburg. The high population density in Gauteng was a medium of COVID-19 transmission as the province bore the highest incidence rate of the pandemic in South Africa.[25]

On this backdrop of diverse features of Gauteng, studies conducted in the province provide insightful considerations for policy formulation. Although this study only used public facility data, it is worth noting that the management of the COVID-19 pandemic and the application of preventive measures like lockdowns, curfews and other guidelines were uniformly implemented across private and public healthcare facilities in the province. Hence, it may not be hypothesised that patients who were not seen at the public facilities were possibly seen at private facilities during this critical period of the pandemic. Therefore, any district variations in MNCH services and outcomes in the province may be due to pre-existing inequalities in resources like health personnel, and not because of differences in lockdown or curfew implementation. In Gauteng, like in any other province, healthcare facilities prioritised COVID-19 patients while non-COVID-19 patients or other chronic condition clients were seen at the outpatient department and only aggravated trauma cases were hospitalised.

Study population

The population studied comprised aggregated data of all MNCH clients that attended any of the 493 public healthcare facilities in any of the five districts of the Gauteng province, South Africa, from March 2019 to February 2021. Maternal health refers to the health of women during pregnancy, childbirth and the postnatal period, and besides newborns (neonatal), children were considered minors under the age of 5 years.[26]

Sample size and sampling

Again, the study used data collected from 493 mobile and fixed public facilities (from district to national/specialised hospitals) in Gauteng province that provided MNCH services, from March 2019 to February 2021. In total, Gauteng has 33 public hospitals, of which 27 offer MNCH services, while the remaining 6 provide specialised services such as rehabilitation. Other facilities providing MNCH services include clinics, health centres and mobile units. Therefore, this study did not perform a sample size calculation, as it was a population-level study.

Variables and measurements

Table 1 shows the definition and/or explanation of all eight dependent variables used in the study and their measuring (numerical) units. The independent variables of interest are the two periods before (March 2019 to February 2020) and during COVID-19 (March 2020 to February 2021); and the five districts in Gauteng.

Data collection and management

This study used secondary data, which is routinely captured from all 493 public healthcare facilities in Gauteng province

Table 1 Essential MNCH service indicators

Category	Types of essential healthcare services	Variables	Definition and/or explanation of indicators	Units
Service utilisation	Child health	PHC <5 years.	Total number of children seen at facilities who were less than 5 years old.	Count
	Maternal and neonatal	Mother postnatal (PNC) visit/care within 6 days	The number of mothers who received (or were present for) postnatal visits within 6 days aimed at assessing the health of both mother and newborn. Number of mothers who received postnatal visits within 6 days, divided by the total number of mothers who gave birth, multiplied by 100.	Rate
		Antenatal (ANC) first visits before 20 weeks.	The number of women who present/book antenatal (ANC/CAN) first visit before 20 weeks of pregnancy, to assess their health and that of the unborn child. Number of women who had their first ANC/CAN visit before 20 weeks, divided by the total number of women who had at least one (≥1) ANC visit during their pregnancy, multiplied by 100.	Rate
Service delivery	Child health	Measles second dose coverage.	The percentage of children who have received two doses of MCV2 in a given year. Number of children 12–24 months who receive the measles second dose, divided by the total number of children at 12–24 months within a year, multiplied by 100.	%
	Neonatal	Fully immunised <1 year coverage.	Fully immunised refers to the percentage of children less than 1-year old who have received all the required doses of vaccines for the first year of life. Number of fully immunised under 1 year, divided by the total population under 1 year, multiplied by 100.	%
Health outcomes	Child health	Deaths in facility 0–6 days.	Deaths in the facility within 6 days refer to neonate mortality that occurs in the facility within the first 6 days after birth. Total number of facility deaths 0–6 days after birth, divided by the total number of live births, multiplied by 1000.	Rate
		Pneumonia case fatality rate <5 years.	The percentage of children under 5 years who die from pneumonia. Number of pneumonia deaths under 5 years divided by the total number of pneumonia cases under 5 years and multiplied by 100.	%
	Maternal and neonatal	Maternal mortality.	Maternal mortality refers to the death of a woman while pregnant or within 42 days of the end of pregnancy. Number of maternal deaths divided by the total number of live births in the same period, multiplied by 100 000.	Ratio

ANC or CAN, antenatal care; MCV2, measles-containing vaccine; MNCH, maternal, neonatal and child healthcare; PHC, primary headcount; PNC, postnatal care.

at the district level into the District Health Information System (DHIS). First, the data is collected from both mobile and fixed facilities as records and entered into the electronic system known as DHIS. The DHIS is aggregated monthly at the district, provincial and national levels and is used as a surveillance system for monitoring health conditions and outcomes. Examples of the key indicators in the DHIS are measles immunisation and the primary headcount (PHC) <5 years. The first author made a formal request to the GDoH for the dataset, which was provided in MS Excel 2016 sheets. The extracted data was double-checked independently for accuracy by two GDoH statisticians. As this was aggregated data at the district level, there were no missing data points. The availability of data from all 493 facilities before (March 2019 to February 2020) and during (March 2020 to February 2021) COVID-19 indicates that none of the facilities closed during the pandemic, although they prioritised COVID-19 cases and non-COVID-19 patients were mostly seen at the outpatient department. After data preparation for analysis was completed in Stata V.17.0, the different indicators were merged into a single Excel sheet as the main dataset for the analysis and stored in a password-protected Google Drive, only accessible to the first and last authors who performed the analysis.

Analysis

Simple linear regression

A simple linear regression model was constructed to compare each indicator per district for the period before (March 2019 to February 2020) and during (March 2020 to February 2021) the COVID-19 pandemic, and the outcome was reported as the change in the coefficient between the two periods. In other words, the model determined the change in the indicator due to the COVID-19 pandemic as all the indicators were numerical (counts, rates and ratios). The analysis was conducted using a basic linear regression framework as follows:

$$\mathbf{Y} = \beta_0 + \beta_1 \mathbf{X} + \varepsilon \text{ (Equation 1)}$$

Where:

Y is the district outcome indicator for each period,

X is a binary variable indicating the period (before and during COVID-19),

$\boldsymbol{\beta}_0$ is the intercept,

$\boldsymbol{\beta}_1$ is the coefficient on X and indicates the size of the change due to COVID-19 and

ε is the error term.

For each indicator, an average variation was reported across all five districts.

Multiple linear regression

Furthermore, we extended Equation 1 to a pooled multiple linear regression framework, triggering an interactive effect among the five districts. This enabled us to directly compare the impact of COVID-19 on MNCH services among the five districts while designating Johannesburg municipality as the reference district. That is, to test whether the change caused by COVID-19 in each district indicator was significantly different from the changes in the Johannesburg municipality. This was done using Equation 2 as follows:

$$\mathbf{Y} = \beta_0 + \beta_1 \mathbf{X} + \beta_{2i} \mathbf{D_i} + \beta_{3i} \mathbf{D_i X} + \varepsilon \text{ (Equation 2)}$$

Where: **Y** is the district outcome indicator,

$\boldsymbol{\beta}_0$ is the intercept,

X is the period variable (before and during COVID-19),

$\boldsymbol{\beta}_1$ indicates the change in the indicator due to COVID-19 (as before in Equation 1),

$\mathbf{D}_i$ is a series of dummy variables for the different districts and

$\mathbf{D_i X}$ is the interaction between the district dummies and the period variable.

So:

The $\boldsymbol{\beta}_{2i}$ coefficients indicate district differences compared with the reference district, and the $\boldsymbol{\beta}_{3i}$ coefficients compare the change in each district to the change in the reference district.

Both linear regression models used a 5% alpha level and a 95% CI. Approximate normality was assessed using histograms, normal probability plots and studentised residual plots between −4 and 4 (online supplemental figure 1). The 'bootstrap', a non-parametric method that does not depend on linearity, skewness or sample size (our sample size was sufficient, n>100), was employed to calculate the corrected and unbiased SE and 95% CI. 'Bootstrapping' is used when the ordinary least squares assumptions, including constant variance, are violated.[27 28] The robustness of the 'bootstrap' addresses heterogeneity and other violated assumptions without requiring log transformation, yet achieves homoscedasticity.[27 28] The STATA command option used in the current study was vce(-bootstrap, seed(5) rep(200)). The adjusted R^2 of the respective models was examined for reliability.

Patient and public involvement

Patients and/or members of the public were not directly involved in the design, conduct, reporting or dissemination plans of this research.

RESULTS

Simple linear regression output: district variations in MNCH indicators due to COVID-19 service disruptions

Table 2 presents the variation in the MNCH service utilisation, delivery and outcomes of district performance indicators due to COVID-19 service disruption in Gauteng province, based on the simple linear regression results from Equation 1. The negative signs in the coefficients indicate that the respective indicators performed less (worse) during the COVID-19 period compared with the pre-COVID-19 period, and vice versa. Of the eight key indicators evaluated in this study, five of them statistically significantly declined across the five districts due to the pandemic's indirect effect of service disruption.

Table 2 Variations in district indicators due to COVID-19 service disruption

Category	Types of essential healthcare services	Indicators	District, coefficient (95% CI)					
			Johannesburg	Tshwane	Ekurhuleni	Sedibeng	West Rand	Across the five districts
Utilisation	Child health	PHC <5 years (n).	**−20 954.5 (−28 994.6 to −12 914.4) p<0.001****	**−15 443.7 (−20 024.8 to −10 862.6) p<0.001****	**−24 934.3 (−32 895.2 to −16 973.5) p<0.001****	**−6721.9 (−8719.7 to −4724.1) p<0.001****	**−9049.5 (−11 870.3 to −6228.7) p<0.001****	**−15 420.8 (−17 768.9 to −13 072.7) p<0.001****
	Maternal and neonatal	ANC first visits before 20 weeks rate.	−1.0 (−2.0 to 0.1) p=0.068	**−2.5 (−4.9 to −0.2) p=0.035***	**−4.6 (−7.3 to −1.8) p=0.001***	**−5.3 (−7.9 to −2.7) p<0.001****	**−8.4 (−11.5 to −5.4) p<0.001****	**−4.4 (−5.5 to −3.2) p<0.001****
		PNC visit within 6 days rate.	**−24.9 (−31.3 to −18.6) p<0.001****	**−6.1 (−9.5 to −2.7) p<0.000****	**−7.9 (−12.4 to −3.3) p=0.001***	**−7.5 (−11.9 to −3.2) p=0.001***	**−4.8 (−7.5 to −2.1) p=0.001***	**−10.3 (−12.1 to −8.4) <0.001****
Service delivery	Child health	Measles second dose coverage %.	−4.8 (−10.9 to 1.4) p=0.128	−4.0 (−10.6 to 2.6) p=0.236	−2.7 (−9.7 to 4.2) p=0.444	−6.0 (−12.8 to 0.8) p=0.081	−4.0 (−16.3 to 8.4) p=0.529	**−4.3 (−8.1 to 0.5) p=0.026***
		Fully immunised <1 year coverage %.	**−7.7 (−14.7 to −0.6) p=0.032***	−4.9 (−11.4 to 1.6) p=0.140	−1.3 (−7.9 to 5.3) p=0.700	**−7.3 (−13.7 to −0.8) p=0.027***	−3.7 (−15.7 to 8.3) p=0.541	**−5.0 (−8.6 to −1.4) p=0.007***
Health outcomes	Child health	Pneumonia case fatality rate <5 years (%).	0.1 (−1.0 to 1.2) p=0.879	**−1.8 (−3.4 to −0.1) p=0.033***	−0.4 (−1.5 to 0.7) p=0.451	−0.2 (−0.6 to 0.3) p=0.459	0.4 (−0.2 to 1.1) p=0.196	−0.4 (−0.8 to 0.1) p=0.118
	Maternal and neonatal	Deaths in facility 0–6 day rate.	2.8 (−5.8 to 11.5) p=0.522	**9.3 (2.4 to 16.1) p=0.008***	−1.4 (−7.8 to 4.9) p=0.661	0 (−2.2 to 2.2) p=1.000	−0.9 (−2.9 to 1.1) p=0.366	2.0 (−0.8 to 4.7) p=0.170
		Maternal mortality ratio.	18.9 (−16.9 to 54.8) p=0.301	25.2 (−31.9 to 82.3) p=0.387	−3.5 (−35.6 to 28.6) p=0.829	42.4 (−24.8 to 109.5) p=0.217	1.2 (−67.7 to 70.0) p=0.974	16.8 (−8.2 to 41.8) p=0.187

*p<0.05 and **p<0.001 for statistical significance.
ANC, antenatal care; PHC, primary headcount; PNC, postnatal care.

From table 2, only two indicators, particularly service utilisation indicators, namely: PHC <5 years (n) and postnatal care (PNC) visits within 6 days (rate) declined statistically significantly (p<0.05) in all five districts during the COVID-19 pandemic. First, PHC <5 years (n) saw a significant decline (−15 420.8, 95% CI −17 768.9 to −13 072.7; p<0.001) across all five districts during COVID-19. The largest decrease in PHC <5 years (n) (−24 934.3, 95% CI −32 895.2 to −16 973.5; p<0.001) was recorded in the Ekurhuleni district. While the lowest decline (−6721.9, 95% CI −8719.7 to −4724.1; p=0.021) was in the Sedibeng district. The decline in the three metropolitan districts of Ekurhuleni, Johannesburg and Tshwane, respectively, was greater than the decline across the five districts.

Second, PNC also declined significantly (−10.3, 95% CI −12.1 to −8.4; p<0.001) across all five districts. The highest decline in PNC (−24.9, 95% CI −31.3 to −18.6; p<0.001) was experienced in the Johannesburg district. Whereas, the West Rand district had the lowest decline in PNC (−4.8, 95% CI −7.5 to −2.1; p=0.001). Other statistically significant changes were more sporadic. For example, except for the Johannesburg districts, ANC/CAN first visits before 20 weeks (rate) reduced significantly in the other four districts with an overall decline across the five districts (−4.4, 95% CI −5.5 to −3.2; p<0.001). The largest decline in ANC (−8.4, 95% CI −11.5 to −5.4; p<0.001) occurred in the West Rand district, while the lowest occurred in the Tshwane district (−2.5, 95% CI −4.9 to −2.0; p<0.035). Notably, the change in ANC in Johannesburg was at the margin (p=0.068).

For child health service delivery indicators, measles second dose coverage (−4.3, 95% CI −8.1 to 0.5; p=0.026) significantly declined across all five districts during COVID-19, although none of the individual districts was significantly affected. Fully immunised <1 year (%) significantly declined in the Johannesburg (−7.7, 95% CI −14.7 to −0.6; p=0.032) and Sedibeng (−7.3, 95% CI −13.7 to −0.8; p=0.027) districts, and across all five districts −5.0, 95% CI −8.6 to −1.4; p=0.007).

Regarding health outcomes, pneumonia case fatality <5 years (rate) only declined significantly in the Tshwane district (−1.8, 95% CI −3.4 to −0.1; p=0.033). Contrarily, but still in the Tshwane district, deaths in facilities 0–6 days (rate) significantly increased (9.3, 95% CI 2.4 to 16.1; p=0.008) during COVID-19. Nonetheless, the two indicators did not witness any significant difference across the five districts. Exceptionally, the maternal mortality ratio (MMR) was the sole indicator that did not record any statistically significant variation during COVID-19, either at the individual district levels or across all five districts. However, the nature of the change, though not significant, suggests an increase in MMR across all five districts during the pandemic.

Of the eight evaluated indicators in this study, Tshwane and Sedibeng appeared to be the most affected districts by COVID-19, with significant adverse changes in four indicators in each of the two districts (table 2). Four of the indicators showed a decline, and the rise in deaths in facilities 0–6 (rate) was equally an adverse effect of COVID-19. The Johannesburg, Ekurhuleni and West

Rand districts experienced disruption in three indicators each.

Multiple linear regression output: comparison of district indicators to the Johannesburg-referenced district

The results of the multiple linear regression are summarised in table 3, which compares the performance of each indicator per district to the Johannesburg reference district. The margin plots from the analysis are shown in figure 1. There was no significant difference in PHC under 5 years (n) in Tshwane and Ekurhuleni districts when compared with Johannesburg (−20 954.5, 95% CI −28 913.4 to −12 995.7; p<0.001) (table 3). However, the interaction terms were significantly different, with a decline, though positive, for the Sedibeng (14 232.6, 95% CI 6069.0 to 22 396.2; p<0.001) and West Rand (11 905.0, 95% CI 3.382.1 to 20 427.9; p<0.001) districts. This indicates that the decrease in PHC under 5 years (n) due to COVID-19 was much smaller in these two districts compared with Johannesburg, Ekurhuleni and Tshwane. From a dual perspective, PHC under 5 years (n) significantly declined in the three metropolitan districts compared with the two non-metropolitan districts (figure 1a).

The decline in ANC/CAN was significantly larger in Ekurhuleni (−3.6, 95% CI −6.9 to −0.3; p=0.033), Sedibeng (−4.4, 95% CI −7.3 to −1.4; p=0.004) and West Rand (−7.5, 95% CI −11.3 to −3.7; p<0.001) than in Johannesburg, with the largest decrease occurring in the West Rand district. However, the impact of COVID-19 was not significantly different in Tshwane compared with Johannesburg (figure 1b).

The decline in PNC was significantly lower in all four other districts compared with the Johannesburg reference district. Implying that COVID-19 highly disrupted PNC in Johannesburg (−24.9, 95% CI −31.8 to −18.0; p<0.001) than in any of the remaining four districts (figure 1c).

Lastly, no other remarkable changes were noted, except that the change in pneumonia case fatality rate <5 years (%) during COVID-19 was a decline at the margin (−1.8,

Table 3 Multiple regression-comparison of district indicators to Johannesburg reference district

	PHC <5 years	Antenatal first visits before 20 weeks	Mother postnatal visits 6 days	Measles second dose	Fully immunised <1 year	Pneumonia case fatality <5 years	Deaths in facility 0–6 days	Maternal mortality ratio
	Coef p-value	Coef p-value	Coef p-value	Coef p-value	Coef p-value	Coef p-value	Coef p-value	Coef p-value
Period								
Before lockdown	—	—	—	—	—	—	—	—
After lockdown	**−20 954.5**	−1.0	**−24.9**	−4.8	−7.7	0.1	2.8	18.9
	<0.001**	0.105	**<0.001****	0.138	0.052	0.887	0.564	0.324
Districts								
COJ Metro	—	—	—	—	—	—	—	—
Tshwane Metro	**−47 927.3**	−1.6	**−45.9**	−1.9	−0.6	**3.1**	**−16.8**	2.7
	<0.001**	0.060	**<0.001****	0.520	0.836	**<0.001****	**<0.001****	0.877
Ekurhuleni Metro	**−22 727.8**	0.3	**−44.7**	**−9.5**	−4.5	**1.9**	**−15.4**	20.2
	<0.001**	0.653	**<0.001****	**0.004***	0.122	**<0.001****	**<0.001****	0.244
Sedibeng	**−87 272.7**	**2.7**	**−44.4**	2.0	−1.6	**−0.9**	**−54.9**	12.3
	<0.001**	**0.002***	**<0.001****	0.536	0.618	**0.003***	**<0.001****	0.562
West Rand	**−85 477.1**	**7.1**	**−53.0**	**6.0**	**10.7**	**−0.9**	**−57.7**	33.4
	<0.001**	**<0.001****	**<0.001****	**0.027***	**<0.001****	**0.003***	**<0.001****	0.220
Period*District								
COJ*After	—	—	—	—	—	—	—	—
Tshwane*After	5510.8	−1.6	**18.8**	0.8	2.8	−1.8	6.4	6.3
	0.251	0.224	**<0.001****	0.867	0.592	0.053	0.281	0.858
Ekurhuleni*After	−3979.8	**−3.6**	**17.1**	2.1	6.4	−0.5	−4.3	−22.5
	0.482	**0.033***	**<0.001****	0.672	0.224	0.558	0.497	0.356
Sedibeng*After	14 232.6	**−4.4**	**17.4**	−1.3	0.4	−0.3	−2.8	23.4
	0.001*	**0.004***	**<0.001****	0.796	0.938	0.681	0.575	0.526
West Rand*After	11 905.0	**−7.5**	**20.1**	0.8	4.0	0.3	−3.8	−17.8
	0.006*	**<0.001****	**<0.001****	0.912	0.598	0.611	0.450	0.692
Constant	109 912.7	**66.2**	**119.6**	**80.7**	**88.0**	**1.3**	**64.7**	**95.4**
	<0.001**	**<0.001****	**<0.001****	**<0.001****	**<0.001****	**0.001***	**<0.001****	**<0.001****
N	120	120	120	120	120	120	120	120
Adjusted R^2	0.955	0.496	0.893	0.162	0.206	0.489	0.908	0.030

Again, the bolded figures represent the statistically significant (p<0.05) changes due to the COVID-19 pandemic.
COJ, City of Johannesburg; PHC, primary headcount.

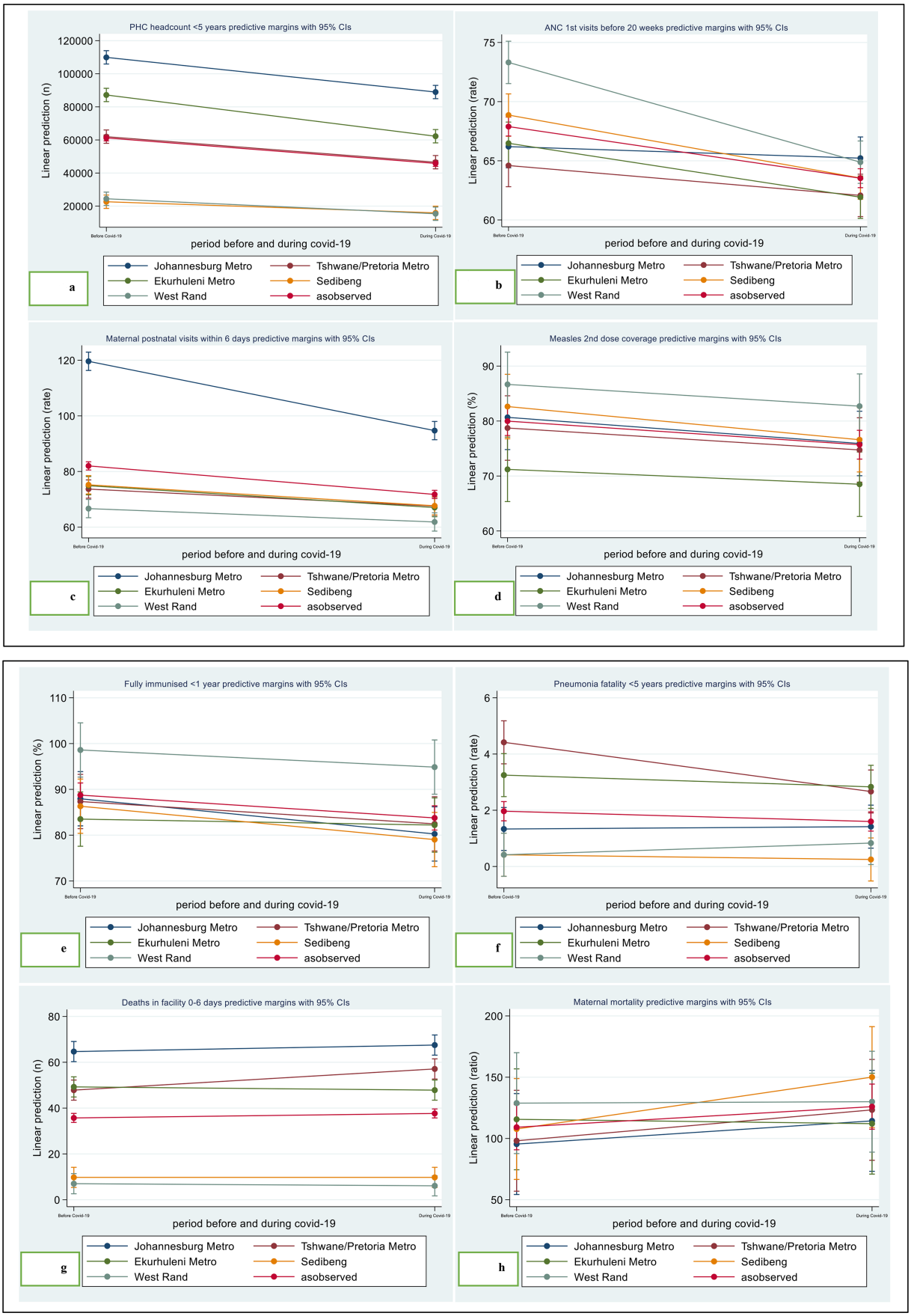

Figure 1 Margin plots of district indicators' performance before and during COVID-19 (March 2019 to February 2021).

95% CI −3.7 to 0.0; p=0.053) in the Tshwane districts compared with the Johannesburg referenced district (figure 1f).

The middle part of table 3, 'Districts', merely compares the overall changes in the indicators over time, from March 2019 to February 2021, to the Johannesburg reference district, without particular focus on the impact of the pandemic, which is the central theme of the current study. Thus, the output is informative but of little interest regarding the current study's aim.

DISCUSSION

This study investigated district variations in the impact of COVID-19 on MNCH service utilisation, delivery and health outcomes in Gauteng province. The findings indicate that COVID-19 significantly disrupted MNCH service utilisation, resulting in a decrease in PHC <5 years (n) across all five districts, with a more pronounced effect in Johannesburg (reference), Tshwane and Ekurhuleni districts. The impact on PHC was comparatively smaller in the two non-metropolitan districts of Sedibeng and West Rand. Similarly, the decline in PNC visits within 6 days (rate) affected all five districts, but was most severe in Johannesburg. ANC first visits before 20 weeks (rate) declined substantially across all five districts, and in Ekurhuleni, West Rand and Sedibeng districts compared with Johannesburg. The service delivery indicator measles second dose coverage (%) and fully immunised <1 year (%) declined across all districts; however, fully immunised declined significantly in two districts. Regarding health outcomes, the pneumonia case fatality rate <5 years decreased significantly in Tshwane, while facility deaths within 0–6 days (rate) increased in Tshwane. The changes in service delivery and health outcome indicators in the other four districts remained statistically insignificant compared with Johannesburg.

First, the current study indicates that the COVID-19 pandemic has significantly harmed MNCH services across all five districts in Gauteng province. Notably, PHC for children under 5 (n) and postnatal visits within 6 days (rate) sharply declined in all five districts in Gauteng (table 2). This was due to the indirect effects of COVID-19, such as the prioritisation of COVID-19 cases over routine healthcare. There was also a further decrease in ANC first visits before 20 weeks (rate) in four districts. Similarly, pneumonia case fatality rates in children under 5 declined, while deaths in facilities within 0–6 days (rate) increased in one district (Tshwane). The Tshwane and Sedibeng municipalities experienced the highest number of declining indicators, four out of eight (table 2). These findings support earlier studies highlighting COVID-19's disruptive impact on essential MNCH services in Rwanda, Northern Ethiopia and, notably, the study from KwaZulu-Natal province of South Africa.[1 3 16] Additionally, an ITS analysis conducted across 18 low- and middle-income countries using administrative data found similar patterns, showing that COVID-19 led to adverse changes in maternal and child service utilisation, resulting in increased mortality linked to the severity of service disruption and the stringency of movement restrictions.[29]

Our findings also demonstrate that immunisation efforts were profoundly compromised across the districts in Gauteng province, notably, in Johannesburg and Sedibeng, during the COVID-19 pandemic. This interruption in service provision and utilisation (eg, fully immunised, ANC and PNC) explains the observed increase in neonatal mortality. It emphasises a key concept indicating a high likelihood of neonatal mortality when pregnant women default on medical follow-ups to monitor their health and that of their unborn children. The decline in immunisation observed in this study contrasts with the improvements in coverage and timeliness reported in Gambia during the same pandemic period, likely due to country-specific responses to the pandemic and disparities in healthcare resources.[12]

A significant implication of the disruption in measles vaccination across all districts in Gauteng, which was the hardest-hit province by COVID-19 in South Africa, is evidenced by the series of measles outbreaks in the country after the pandemic, predominantly occurring in Gauteng. A previous study[19] cautioned against a potential measles outbreak, which materialised in 2022 with most cases originating from Gauteng (Ekurhuleni district).[30] As of 14 August 2025, the South African National Institute of Communicable Diseases reported a second severe measles outbreak post-COVID-19 involving 620 cases, the majority of which (429 (69.2%)) were from Gauteng.[31] Notably, Tshwane, the district most severely impacted by COVID-19 in this study, recorded the highest number of measles cases (208), followed by Johannesburg (121), Ekurhuleni (87), Sedibeng (10) and West Rand.[3 31] The variation in measles outbreak distribution across districts reflects the differing degrees of COVID-19-related service disruption. Consequently, this study remains relevant as it highlights the long-term repercussions of essential service interruptions caused by COVID-19, such as the current measles outbreak, and emphasises the need for caution in managing future outbreaks through preventive measures like lockdowns and prioritisation of the most affected districts during future crises.

However, the current findings indicate that the level of disruption varied among the five districts, leading to differences in COVID-19's impact on MNCH services in Gauteng province. These results align with earlier studies showing variations in COVID-19's disruptive effect on health service utilisation, emphasising that some geographical areas were more affected than others. Empirical evidence from Nigeria, other parts of sub-Saharan Africa and North America supports this, revealing regional differences in how COVID-19 disruptions impacted service utilisation and delivery, mainly due to the diversion of health resources from routine healthcare to address the pandemic,[12 20 21] causing the

rise in neonatal mortality observed in the current study. Similarly, an ITS analysis of COVID-19's impact on essential service utilisation across 10 regions in Ethiopia found that urban areas experienced greater disruption, with declines of 54% in Addis Ababa and 58% in Harari in outpatient visits, along with a significant reduction in child-pneumonia visits across these regions. However, the authors noted that maternal and child health services were less affected.[32] In this study, these urban regions correspond to the three metropolitan districts (Johannesburg, Ekurhuleni and Tshwane), where notable disruption was observed in PHC <5 years (n) and postnatal visits within 6 days (rate) in Johannesburg only. One plausible explanation for this marked MNCH disruption in the metropolitan cities could be that they experienced more severe COVID-19 cases requiring increased attention. Moreover, these cities house the most specialised hospitals in Gauteng, which attracted COVID-19 cases from other districts, thereby worsening the negative impact on healthcare services.

Furthermore, our findings reveal a significant decline in certain MNCH services in only a few districts, further confirming that COVID-19 caused variation in MNCH services across districts in Gauteng province. For example, ANC first visits before 20 weeks (rate) decreased significantly only in four districts (Tshwane, Ekurhuleni, Sedibeng and West Rand) out of five districts (table 2). These districts experienced greater disruption in MNCH service utilisation compared with the Johannesburg district (table 3). Additionally, the pneumonia case fatality rate <5 years (%) varied significantly, with a decline (p=0.002, table 3) observed only in the Tshwane Metropolitan district during COVID-19, while Johannesburg saw no significant change. Deaths in facilities within 0–6 days (rate) increased in the Tshwane district. The status or size of the district, whether metropolitan or not, did not influence the impact of COVID-19 on service disruption, because, contrary to expectations, the highest disruption in ANC first visits before 20 weeks (rate) occurred in West Rand, a district that is less densely populated and industrialised compared with Johannesburg. Moreover, the present findings support a Nigerian study demonstrating that COVID-19 affected antenatal and skilled birth attendant services differently across Nigeria's northern and southern regions.[21] This is also comparable to regional variations observed in Britain and Northern Ireland, where the volume of cleft surgeries on the waiting list after lockdown was impacted as an indirect effect of the pandemic.[2]

Although the current study only demonstrated district variation in the impact of COVID-19 on MNCH services in Gauteng province, there appears to be no research investigating the reasons or factors behind the geographical variation in the indirect effects of COVID-19 on essential MNCH services. However, existing literature highlights several factors responsible for geographical differences in COVID-19 infections and mortality, which can be linked to the indirect effects of COVID-19 on district variations in MNCH services in Gauteng province, due to this knowledge gap. For instance, pre-existing inequalities in health services and resource distribution may have contributed to the district variation in COVID-19's impact on MNCH services in Gauteng, as seen in Nigeria and the USA.[20 21] Furthermore, differences in the implementation of non-pharmaceutical interventions and response times to COVID-19 across different regions contributed to variations in service disruptions. Nine regions in Britain and Northern Ireland imposed lockdowns on different dates, leading to differences in how these regions were affected by the pandemic.[2] Although South Africa had a single date for the National Lockdown on 27 March, health service management and the availability of Personal Protective equipment (PPE) may have varied at district levels, resulting in district-specific disruptions to MNCH services among the five districts in Gauteng, as reflected in the current findings. Nonetheless, for context-specific understanding, the actual factors explaining the district variation in MNCH service disruption in Gauteng remain to be elucidated by future research.

Our study offers key recommendations. Further research should explore the factors driving district differences in COVID-19's effect on MNCH services. Additionally, as COVID-19 ceases to be a public health emergency and normality returns, studies must assess how effectively affected MNCH services recover in each district. We cannot emphasise enough the importance of maintaining the continuity of essential MNCH services during future outbreaks. Our findings also reveal that some districts managed to sustain health services more effectively during COVID-19, experiencing less disruption in MNCH service utilisation, delivery and deterioration of health outcomes. Therefore, local district collaboration is crucial for districts to learn from each other about managing MNCH services during emergencies,[29] to strengthen health systems against future uncertainties.

LIMITATIONS

A major limitation was the inability to enhance data quality, which is common in secondary analyses, such as the absence of confounders in the DHIS data to account for district differences. Furthermore, the study only used DHIS data without including information from private facilities, which could have broadened the scope of the findings. Nonetheless, the sampling of all 493 public facilities from the five districts within the province is appropriate for internal validity, although the findings may not be generalisable to a wider context. Unlike Afolabi *et al*,[21] we argue that the selected indicators from the

DHIS data, such as ANC, PHC and PNC, are highly sensitive in detecting COVID-19's impact. Lastly, this study is among the few worldwide that have sought to investigate district or geographical variations in COVID-19's effects on MNCH services. As a result, our findings can only be compared with the limited available studies[2 20 21]; however, this does not constitute a limitation of the current research. Instead, it lays a foundation for future studies.

CONCLUSION

In Gauteng province, the COVID-19 pandemic caused a heterogeneous variation across districts in the disruption of maternal, neonatal and child healthcare service utilisation, delivery and health outcomes. Some MNCH services were more affected in metropolitan municipalities than in their counterparts, and vice versa. Although some healthcare services and health outcomes in the study were not statistically significantly impacted, they remained concerning, as most performance indicators declined, highlighting an adverse effect of the pandemic. Understanding the mechanism and geographical variations of the impact of outbreaks and pandemics like COVID-19 is critically important for decision-making to support the recovery of routine healthcare services in affected areas and for strategic planning against future outbreaks. Finally, this study has demonstrated a key concept, showing that the disruption of essential MNCH services like ANC and PNC and immunisation has a catastrophic effect on neonatal mortality; therefore, essential MNCH services should be prioritised during future crises.

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REFERENCES

1 Wanyana D, Wong R, Hakizimana D. Rapid assessment on the utilization of maternal and child health services during COVID-19 in Rwanda. *Public Health Action* 2021;11:12–21.
2 Arnaout A, Martin S, Hill C, *et al*. The impact of COVID-19 on cleft services in Great Britain & Northern Ireland. *J Plast Reconstr Aesthet Surg* 2022;75:1689–95.
3 Desta AA, Woldearegay TW, Gebremeskel E, *et al*. Impacts of COVID-19 on essential health services in Tigray, Northern Ethiopia: A pre-post study. *PLoS One* 2021;16:e0256330.
4 Niu J, Sareli C, Eckardt PA. Impact of the COVID-19 pandemic on an emergency department-based opt-out HIV screening program in a South Florida hospital: An interrupted time series analysis, July 2018-March 2021. *Am J Infect Control* 2022;50:994–8.
5 Marti M, Zürcher K, Enane LA, *et al*. Impact of the COVID-19 pandemic on TB services at ART programmes in low- and middle-income countries: a multi-cohort survey. *J Int AIDS Soc* 2022;25:e26018.
6 Adu PA, Stallwood L, Adebola SO, *et al*. The direct and indirect impact of COVID-19 pandemic on maternal and child health services in Africa: a scoping review. *Glob Health Res Policy* 2022;7:20.
7 Mitchell KR, Willis M, Dema E, *et al*. Sexual and reproductive health in Britain during the first year of the COVID-19 pandemic: cross-sectional population survey (Natsal-COVID-Wave 2) and national surveillance data. *Sex Transm Infect* 2023;99:386–97.
8 Fonka CB. A comparative analysis of voluntary medical male circumcision before and during the COVID-19 pandemic in Gauteng province, South Africa. *S Afr Fam Pract (2004)* 2004;67:e1–8.
9 Nonaillada J, Martin RA. Applying Situational Leadership to Redeployment Duties During COVID-19: Lessons Learned. *Qual Manag Health Care* 2022;31:274–7.
10 Kennedy E, Kennedy P, Hernandez J, *et al*. Understanding Redeployment During the COVID-19 Pandemic: A Qualitative Analysis of Nurse Reported Experiences. *SAGE Open Nurs* 2022;8:23779608221114985.
11 Masresha BG, Luce R Jr, Weldegebriel G, *et al*. The impact of a prolonged ebola outbreak on measles elimination activities in Guinea, Liberia and Sierra Leone, 2014-2015. *Pan Afr Med J* 2020;35:8.
12 Wariri O, Utazi CE, Okomo U, *et al*. Impact of the COVID-19 pandemic on the coverage and timeliness of routine childhood vaccinations in the Gambia, 2015-2021. *BMJ Glob Health* 2023;8:e014225.
13 Fonka CB, Christofides N. A surge in female condom distribution during the COVID-19 pandemic in Gauteng province, South Africa. *Contracept Reprod Med* 2025;10:4.
14 COVIDental Collaboration Group. The COVID-19 pandemic and its global effects on dental practice. *An International Survey J Dent* 2021;114:103749.
15 Michalowsky B, Hoffmann W, Bohlken J, *et al*. Effect of the COVID-19 lockdown on disease recognition and utilisation of healthcare services in the older population in Germany: a cross-sectional study. *Age Ageing* 2021;50:317–25.
16 Tamrakar V, Srivastava A, Saikia N, *et al*. District level correlates of COVID-19 pandemic in India during March-October 2020. *PLoS One* 2021;16:e0257533.

17 Feldman JM, Bassett MT. Variation in COVID-19 Mortality in the US by Race and Ethnicity and Educational Attainment. *JAMA Netw Open* 2021;4:e2135967.
18 Hussey H, Zinyakatira N, Morden E, *et al*. Higher COVID-19 mortality in low-income communities in the City of Cape Town - a descriptive ecological study. *Gates Open Res* 2021;5:90.
19 Fonka CB, Khamisa N, Worku E, *et al*. Impact of the COVID-19 pandemic on maternal, neonatal and child health service utilisation, delivery and health outcomes in Gauteng province, South Africa: an interrupted time series (ITS) analysis. *BMJ Open* 2024;14:e090645.
20 Ad N, Luc JGY, Nguyen TC, *et al*. Cardiac surgery in North America and coronavirus disease 2019 (COVID-19): Regional variability in burden and impact. *J Thorac Cardiovasc Surg* 2021;162:893–903.
21 Afolabi RF, Salawu MM, Bamgboye EA, *et al*. Regional differences in the utilisation of antenatal care and skilled birth attendant services during the COVID-19 pandemic in Nigeria: an interrupted time series analysis. *BMJ Glob Health* 2023;8:e012464.
22 Jensen C, McKerrow NH. Child health services during a COVID-19 outbreak in KwaZulu-Natal Province, South Africa. *S Afr Med J* 2021;111:114.
23 Sustainable development goal 3: good health and well-being | United Nations in South Africa. Available: https://southafrica.un.org/en/sdgs/3 [Accessed 29 Jul 2025].
24 STATS SA. Mid-year population estimates, 2022. Statistics South Africa - Google Search; 2023.
25 Update on COVID-19 - Wednesday 01 February 2023 - SA corona virus online portal. SA Corona Virus Online Portal; 2023. Available: https://sacoronavirus.co.za/2023/02/02/update-on-covid-19-wednesday-01-february-2023/ [Accessed 27 Feb 2023].
26 Maternal health. Available: https://www.who.int/health-topics/maternal-health [Accessed 24 Jun 2024].
27 McGuinness D, Bennett S, Riley E. Statistical analysis of highly skewed immune response data. *J Immunol Methods* 1997;201:99–114.
28 Bennett S, Riley EM. The statistical analysis of data from immunoepidemiological studies. *J Immunol Methods* 1992;146:229–39.
29 Ahmed T, Roberton T, Vergeer P, *et al*. Healthcare utilization and maternal and child mortality during the COVID-19 pandemic in 18 low- and middle-income countries: An interrupted time-series analysis with mathematical modeling of administrative data. *PLoS Med* 2022;19:e1004070.
30 South African measles outbreak update 2023. NICD; 2023. Available: https://www.nicd.ac.za/south-african-measles-outbreak-update-2023-26-january/ [Accessed 21 Aug 2025].
31 Weekly measles situation report (week 32 of 2025). NICD; 2025. Available: https://www.nicd.ac.za/weekly-measles-situation-report-week-32-of-2025/ [Accessed 21 Aug 2025].
32 Mebratie AD, Nega A, Gage A, *et al*. Effect of the COVID-19 pandemic on health service utilization across regions of Ethiopia: An interrupted time series analysis of health information system data from 2019-2020. *PLOS Glob Public Health* 2022;2:e0000843.