Diarrhoeal admissions among children aged <5 years in public sector facilities in Western Cape Province, South Africa, before and during the COVID-19 pandemic (2019 - 2021)

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Background. The COVID-19 pandemic in South Africa (SA) had several effects, including the implementation of public health and social measures (PHSM) such as mobility limitations, social (physical) distancing, mask-wearing and hand hygiene promotion. This led to behavioural shifts, and potentially impacted the transmission dynamics of other infectious diseases, including acute diarrhoea among children.
Objective. To investigate changes in acute diarrhoea hospital admissions in children aged <5 years in Western Cape Province, SA.
Methods. We conducted a retrospective analysis of diarrhoea admissions from January 2019 to November 2021. We estimated changes in rates and trends of diarrhoea admissions during the pandemic compared with pre-pandemic periods using interrupted time series analysis, adjusting for key characteristics.
Results. There were 17 204 children admitted for diarrhoea during the study period, of whom 54% were male, and almost half (48%) were aged <1 year. COVID-19 PHSM were associated with a 24% step reduction in diarrhoea admissions compared with the pre-COVID-19 period (incidence rate ratio (IRR) 0.76, 95% confidence interval (CI) 0.69 - 0.84). This was followed by an average 2% per month increase in diarrhoea admission incidence during the pandemic (IRR 1.02, CI 1.01 - 1.02).
Conclusion. There was a marked reduction in diarrhoea admissions during the strictest PHSM implementation. Interventions such as hand hygiene and physical distancing likely contributed to these observed changes. This study underscores the importance of ongoing public health interventions to mitigate diarrhoeal diseases among children and prevent hospitalisation.

Keywords: diarrhoea, hospital admission, children, South Africa, COVID-19 pandemic

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The COVID-19 pandemic prompted several responses in South Africa (SA), including restricted non-essential health services, implementation of public health and social measures (PHSM) and fear of acquiring COVID-19. PHSM were implemented to manage SARS-CoV-2 transmission and to ensure sufficient hospital capacity for COVID-19 cases. These measures included mobility restrictions, physical distancing, wearing of masks and hand hygiene practices.[1,2]

PHSM resulted in marked behaviour change among individuals. Firstly, there was promotion of hand hygiene, emphasising hand washing with soap and water and the widespread provision of alcohol-based sanitisers.[2] Hand hygiene practices were crucial in reducing the spread of other infectious diseases such as lower respiratory tract infections (LRTIs), Ebola, influenza and gastroenteritis.[3-5] Mobility restrictions such as curfews, physical distancing and closures of early childhood development centres and schools were also implemented.[2] These behavioural changes due to PHSM, together with fear of acquiring COVID-19, likely influenced the transmission of other infectious diseases globally and in SA. Prior to the COVID-19 pandemic, diarrhoea cases and hospital admissions persisted among children aged <5 years in SA, with wide geographic variation, typically peaking in the summer season (November - May).[6,7] Understanding the changes in diarrhoea admissions in the context of PHSM, including the potential impact of these measures on healthcare access, is important to effectively plan for future pandemics as well as periods of expected increases in diarrhoea cases.

We examined fluctuations in the number and rates of diarrhoea hospital admissions in children <5 years in relation to COVID-19 surges and associated measures, including PHSM, across Western Cape Province public sector facilities.

Methods

The methods have been described in detail in elsewhere,[8] and are briefly described here. Using data from the Western Cape Provincial Health Data Centre, we included hospitalisation data for children aged <5 years admitted due to diarrhoea from January 2019 to November 2021. We examined the following characteristics of diarrhoea cases: sex, age, admission severity and COVID-19 co-infection. We estimated crude observed diarrhoea admission rates for different time periods, as listed in Table 1. Diarrhoea admission rates were estimated for each time period by dividing diarrhoea admission counts by 80% of the population estimates for children aged <5 years (representing the estimated proportion of the population accessing public sector healthcare services).

Negative binomial segmented regression was applied to monthly-level data in an interrupted time series analysis,[9] allowing for both a step and trend change to assess the association between COVID-19 surges, PHSM and diarrhoea admissions. A separate model was fitted to each pair of restriction periods to assess changes in diarrhoea admissions related to each change in restriction level. We adjusted the model for the following potential confounders: proportion male; median age of children with diarrhoea admissions; median duration of diarrhoea admissions; quarterly proxy immunisation coverage; COVID-19 confirmed admissions; and seasonality (measured in quarters using data from 2017 to 2019: December - February, March - May, June - August, September - November), to account for autocorrelation. The consistent seasonal patterns over three years allowed us to use just one year of pre-pandemic data, capturing the patterns while ensuring the model used the most relevant, recent data. Child's place of residence (district or subdistrict for the City of Cape Town) was fitted as a random effect to account for healthcare access differences. Incidence rate ratios (IRRs) and 95% confidence intervals (CIs) were reported for the step change, trend change and the post-interruption trend for each model comparison. The step change refers to the shift in admissions immediately post PHSM introduction compared with immediately pre PHSM. The trend change represents the ratio of the trend in admissions over time after PHSM implementation v. the trend before PHSM. The post-interruption trend is the trend per calendar month in admissions in the period after PHSM implementation.

We used the estimated relationship between covariates and outcome to forecast counterfactual diarrhoea admission rates for the pandemic period. This pre-pandemic period model included the same variables as the full model, with the exception of COVID-19 cases and the interruption variable. Observed, model-predicted and counterfactual diarrhoea admission rates per 1 000 person months were plotted.

Ethical considerations

This study was approved by the Human Research Ethics Committee in the Faculty of Health Sciences at the University of Cape Town (ref. no. HREC REF 197/2021).

Results

Characteristics of diarrhoea admissions

Over the study period, 17 204 children were admitted for diarrhoea, with the majority (9 304, 54%) of admissions being males, and almost half (8 286, 48%) children aged <1 year (Table 1). The median (interquartile range (IQR)) age at diarrhoea admission was 12.5 (6.4 - 22.4) months, and the median (IQR) length of stay was 2 (1 - 4) days. Of the recorded diarrhoeal admissions, 1% (*n*=204) were admitted to the intensive care unit (ICU). These characteristics were similar across the pre-pandemic and pandemic periods. COVID-19 coinfection occurred in 1% of children admitted with diarrhoea (*n*=119) during the pandemic.

Daily diarrhoea admissions and COVID-19 cases

During periods of stricter PHSM, implemented prior to the COVID-19 peaks in waves one and three, diarrhoeal disease admissions were at the lowest levels (Fig. 1). The inter-wave periods saw a steady increase in diarrhoea cases, which was minimally affected by the stricter implementation of PHSM during wave two, although the summer surge (November - May) in diarrhoea cases observed annually pre-pandemic (highlighted in grey in Fig. 1) was not observed during wave two in 2020/2021 of the pandemic. Instead, diarrhoea admissions slowly increased until April 2021, with a peak in May - June 2021, when the surge period should have been declining based on pre-pandemic data. This peak attenuated co-incident with stricter PHSM introduction during wave three in mid-June 2021.

Rates of diarrhoea admissions across PHSM periods

Diarrhoea admission rates decreased from 6.39 (CI 6.25 - 6.53) admissions per 1 000 person months pre-pandemic to 4.62 (CI 4.53 - 4.72) admissions per 1 000 person months during

Table 1. Characteristics of children who were admitted for diarrhoea in a public sector facility in Western Cape Province before and during the COVID-19 pandemic period (January 2019 - November 2021)

Characteristic	Overall (January 2019 - November 2021)	Pre-COVID-19 (January 2019 - March 2020)	COVID-19 (April 2020 - November 2021)
Total admissions, *n*	17 204	8 490	8 714
Male admissions, *n* (%)	9 304 (54)	4 571 (54)	4 733 (54)
Female admissions, *n* (%)	7 900 (46)	3 919 (46)	3 981 (46)
Age, months, median (IQR)	12.5 (6.4 - 22.4)	12.2 (6.4 - 22.2)	12.7 (6.4 - 22.6)
Age <28 days, *n* (%)	511 (3)	244 (3)	267 (3)
Age 28 days - 1 year, *n* (%)	7 775 (45)	3 922 (46)	3 853 (44)
Age >1 year - <5 years, *n* (%)	8 918 (52)	4 324 (51)	4 594 (53)
Admission severity			
ICU admissions, *n* (%)	204 (1)	104 (1)	100 (1)
Length of stay, days, median (IQR)	2 (1 - 4)	2 (1 - 4)	2 (1 - 4)
COVID-19 co-infection, *n* (%)	n/a	0	119 (1)

IQR = interquartile range; ICU = intensive care unit; n/a = not applicable.

COVID-19 overall (Table 2). Admissions rates were at their lowest during the first and strictest implementation of PHSM (2.55 admissions per 1 000 person months, 95% CI: 2.41-2.70) (Table 1). Following each instance of PHSM easing (second, fourth and sixth implementation), diarrhoea admission rates were higher compared with the preceding time period.

Interrupted time series model: Changes in diarrhoea admissions in relation to PHSM

We estimated that the pandemic period was associated with an initial 24% (IRR 0.76, CI 0.69 - 0.84) step reduction in diarrhoea admissions compared with the pre-pandemic period (Table 3), adjusted for potential confounders. Comparing pre-pandemic and pandemic rates, we found a 2% average monthly increase in diarrhoea admission incidence during the pandemic period (IRR 1.02, CI 1.01 - 1.02), following the initial step reduction. In the models that assessed each PHSM period separately, we estimated that there was an initial 50% step reduction in diarrhoea admissions during the initial, strictest, implementation of PHSM (IRR 0.50, CI 0.43 - 0.59), followed by an average increase of 17% per month (IRR 1.17, CI 1.11 - 1.23). Subsequent implementations of stricter PHSM were either associated with a step decrease (fifth implementation) or a trend decrease (third implementation) in admission incidence. Average post-interruption trend increases were observed early on (first and second PHSM implementation), and there was a step increase in diarrhoea admission incidence when PHSM were relaxed at the end of the third COVID-19 wave (sixth implementation).

Counterfactual and estimated diarrhoea admission rates

Forecasted counterfactual diarrhoea admission rates during the initial PHSM implementation, assuming no effects from PHSM, were higher than the observed rates during the first period of PHSM implementation (Fig. 2). Counterfactual diarrhoea admission rates (determined using pre-pandemic data) remained slightly higher than the observed rates until the fourth implementation (relaxation); thereafter, counterfactual and observed rates were similar.

Discussion

We found that the first and strictest implementation of PHSM was associated with a substantial step reduction in diarrhoea hospital admissions in children aged <5 years, followed by a small trend increase across the entire post-pandemic period thereafter in public sector facilities in the Western Cape Province, SA. Similar but less pronounced step reductions or flattening of increasing trends in diarrhoea admissions followed subsequent tightening of PHSM during COVID-19 surges.

Diarrhoea cases and related deaths declined among children during the pandemic in low- and middle-income settings,[10-13] potentially owing to hand hygiene and physical distancing PHSM, as well as reduced social contact among children due to closures of schools and early childhood development centres. Changes in diarrhoea admission rates were associated with changes in PHSM, with step or trend reductions at the start of stricter PHSM periods. Physical distancing and hand hygiene measures, which were consistent throughout the pandemic, may have contributed to the observed step decreases in comparison with each preceding PHSM implementation, although they may have been executed with varying fidelity by the population. The simultaneous implementation of several PHSM made it difficult to determine the extent to which each measure contributed to the observed changes.

After the initial drop in childhood diarrhoea admissions when the strictest PHSM were first implemented, admissions steadily increased during both the first and second COVID-19 waves, peaking before the third wave. This suggests that PHSM and consequent behavioural changes altered disease transmission, and mobility restrictions, together with a general fear of contracting COVID-19 at healthcare facilities, further affected healthcare utilisation. The fact that the biggest reductions in diarrhoea admissions were co-incident with the stricter implementations of PHSM (March 2020 and July 2021) before the peaks of COVID-19 waves (when health services would have been busiest) suggests that admissions were reduced by reductions in transmission, mobility restrictions and fear of accessing health services, rather than being crowded out by overburdening of other health services such as adult medicine due to COVID-19 admissions..

Diarrhoea admissions peaked in May 2021 in the observed data, and the timing of this peak was predicted by the counterfactual scenario. There were similar increases in LRTIs in the Western Cape during this time.[8] Historically, the paediatric diarrhoea surge season spans from November to May in the Western Cape and, during this time, tailored interventions are implemented to address the increased case load. The increases in diarrhoea admission incidence in May 2021 occurred before the third COVID-19 wave, and overlapped with an increase in headcount at primary healthcare facilities and a PHSM relaxation, with the fewest restrictions and least school closures, potentially reversing some of the behaviour changes previously observed. Earlier in the year, the expected seasonal peak was disrupted in January 2021, which may have been

Table 2. Crude observed diarrhoea admission rates in public sector facilities in Western Cape Province pre-COVID-19 and during COVID-19 (January 2019 - November 2021)

Period	Diarrhoea admissions	Admission rate per 1 000 person months (95% CI)
Pre-COVID (January 2019 - March 2020)	8 490	6.39 (6.25 - 6.53)
COVID-19 (April 2020 - November 2021)	8 714	4.62 (4.53 - 4.72)
First implementation of PHSM (April - August 2020)*	1 172	2.55 (2.41 - 2.70)
Second implementation of PHSM (September - December 2020)†	1 614	4.39 (4.18 - 4.61)
Third implementation of PHSM (January - February 2021)*	972	5.06 (4.74 - 5.38)
Fourth implementation of PHSM (March - June 2021)†	2 919	7.59 (7.32 - 7.87)
Fifth implementation of PHSM (July - September 2021)*	1 021	3.54 (3.33 - 3.76)
Sixth implementation of PHSM (October - November 2021)†	1 016	5.28 (4.96 - 5.62)

CI = confidence interval; PHSM = public health and social measures.
*Tightening of PHSM.
†Relaxation of PHSM.

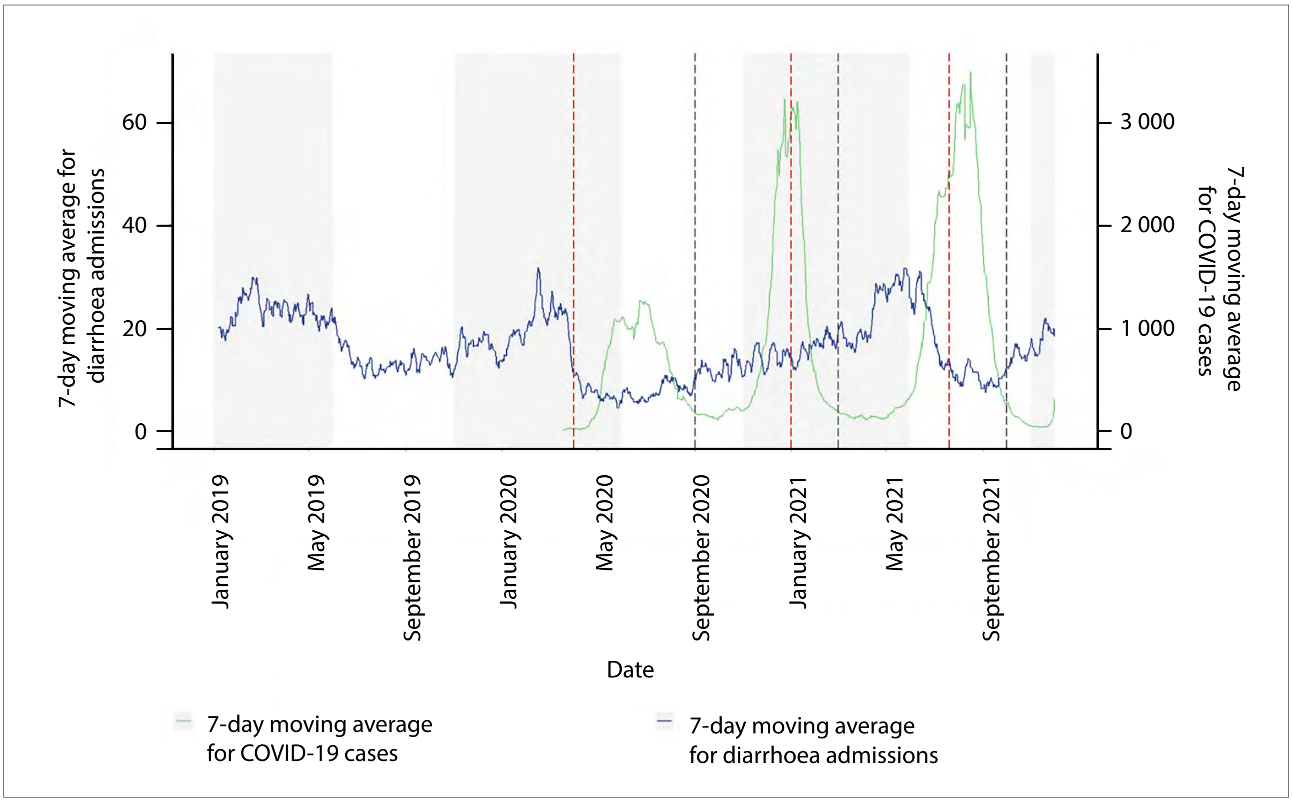

Fig. 1. Daily diarrhoeal admissions among children aged <5 years (blue line) and all COVID-19 cases in Western Cape Province (7-day moving average) (green line) from January 2019 to November 2021. Red dashed vertical lines indicate stricter implementation of public health and social measures (PHSM), whereas dark grey dashed vertical lines indicate the relaxation of PHSM. Stricter implementation of PHSM included restrictions on population mobility and closure of schools, early childhood development centres and other institutions. COVID-19 cases reflect both public and private sector recorded positive SARS-CoV-2 polymerase chain reaction and antigen tests, irrespective of symptoms. The expected seasonality peak periods from November to May, based on historic trends, are highlighted in light grey.

Table 3. Changes in diarrhoea admission incidence among children aged <5 years after the implementation of different COVID-19 PHSM in public sector facilities in the Western Cape Province (January 2019 - November 2021)

		Restriction periods based on PHSM compared with the immediate preceding period					
Model output	**Entire period (COVID-19 v. pre-COVID-19)**	**First implementation of PHSM v. pre-COVID-19***	**Second v. first implementation of PHSM†**	**Third v. second implementation of PHSM***	**Fourth v. third implementation of PHSM†**	**Fifth v. fourth implementation of PHSM***	**Sixth v. fifth implementation of PHSM†**
Time period	January 2019 - November 2021	January 2019 - August 2020	April - December 2020	September 2020 - February 2021	January - June 2021	August 2021	July - November 2021
Interruption	April 2020	April 2020	September 2020	January 2021	March 2021	July 2021	October 2021
Model output							
Step change, IRR (95% CI)	**0.76 (0.69 - 0.84)**	**0.50 (0.43 - 0.59)**	1.00 (0.71- 1.43)	0.89 (0.75 - 1.07)	0.92 (0.59 - 1.41)	**0.49 (0.38 - 0.65)**	**1.42 (1.09 - 1.84)**
Trend change, IRR (95% CI)	**1.02 (1.01 - 1.03)**	**1.17 (1.11- 1.24)**	1.03 (0.91 - 1.17)	**0.69 (0.53 - 0.89)**	1.01 (0.74 - 1.39)	0.78 (0.63 - 1.03)	1.02 (0.81 - 1.28)
Average post-interruption trend, IRR per month (95% CI)	**1.02 (1.01 - 1.02)**	**1.17 (1.11 - 1.23)**	1.09 (1.00 - 1.18)	**0.74 (0.59 - 0.94)**	1.08 (1.00 - 1.17)	0.55 (0.71 - 1.02)	0.94 (0.81 - 1.09)

PHSM = public health and social measures; IRR = incidence rate ratio; CI = confidence interval.
Bold values indicate point estimates with 95% CIs that exclude the null value.
*Tightening of PHSM.
†Relaxation of PHSM.

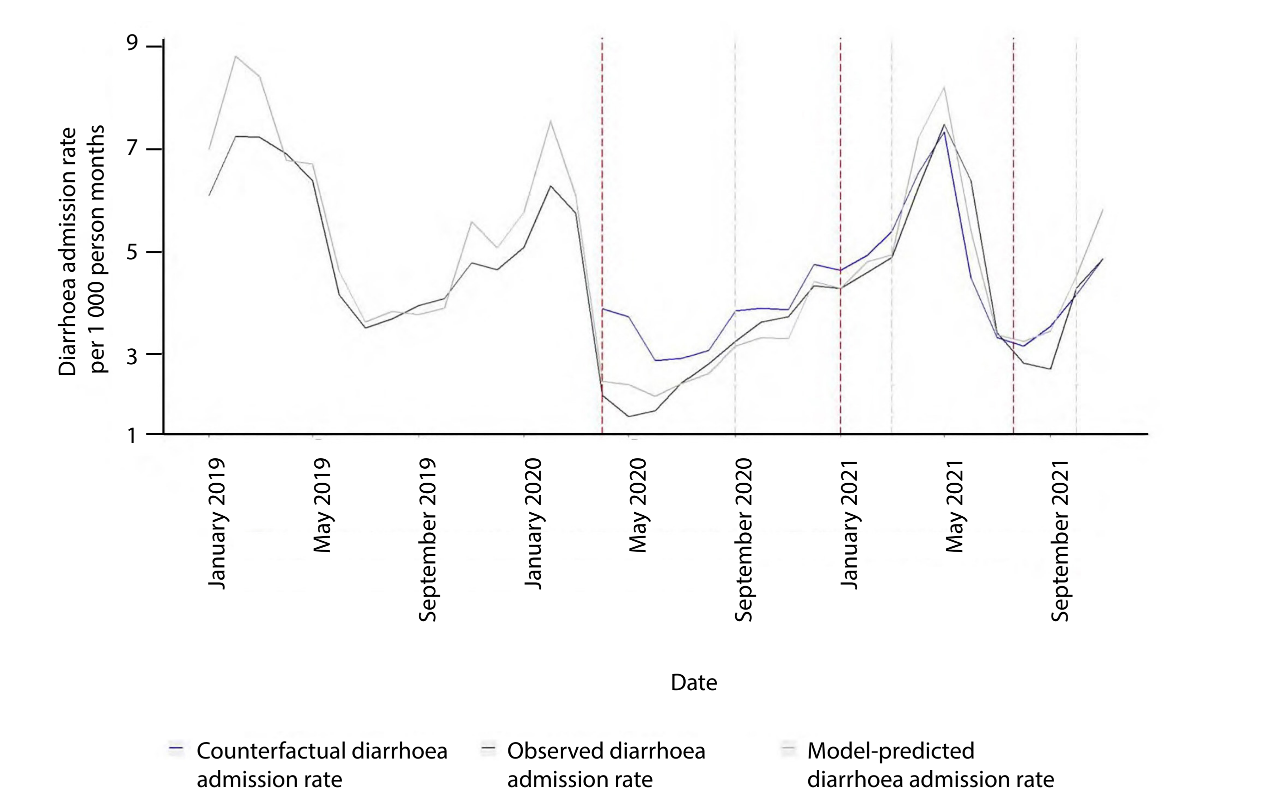

Fig. 2. Counterfactual (blue line), observed (dark grey) and model-predicted (light grey) rates of diarrhoea hospitalisations among children in the Western Cape Province public sector (January 2019 - November 2021). Red dashed vertical lines indicate times of stricter implementation of public health and social measures (PHSM), whereas grey dashed vertical lines indicate times of relaxation of PHSM. Stricter implementation of PHSM included restrictions on population mobility and closure of schools, early development centres and other institutions.

due to a combination of hand hygiene, extended school closures (the normal end of school holidays in mid-January was delayed to mid-February 2021) and mask-wearing PHSM. Furthermore, immunity to diarrhoea pathogens may have also been altered due to PHSM in 2020 and January 2021, so that by May 2021 younger children would have been less exposed than previously, as they stayed home and had less social exposure, making them more vulnerable when PHSM were relaxed. Shortly after the May 2021 peak, diarrhoea admissions decreased to a similar number of cases observed at the start of the pandemic, when PHSM were tightened, just before the peak of cases in the third COVID-19 wave.

Strengths and limitations

The strengths and limitations of this study have been described elsewhere,[8] and are summarised below, with emphasis on how these factors pertain to diarrhoea admissions (as compared with LRTIs). Strengths of this analysis included the use of an individual-level dataset for aggregation, linking admission outcomes for children.[14] There was comprehensive data coverage of the Western Cape for all time periods, increasing study generalisability. We believe there was thorough case identification with a comprehensive list of ICD-10 codes for diarrhoea hospital admissions.

There were several limitations. Firstly, monthly data aggregation meant that the interruption analysis was at the closest month to the PHSM change, not on the exact date of implementation. Secondly, we were reliant on electronic health records, which may have limited the ability to assess the impact of PHSM-related reductions in diarrhoea admissions. However, it is believed that the electronic data were reasonably complete, and this completeness increased over time, with more complete data in more recent years. Thirdly, our analysis was limited to diarrhoea hospital admissions, considered severe cases, hindering a comprehensive understanding of COVID-19 surges and associated factors on mild diarrhoea cases in the community, which would only require outpatient or ambulatory care. Lastly, some data variables, including rotavirus vaccination status and socioeconomic status, were constrained by availability. Socioeconomic status was only adjusted for crudely, using subdistrict or district of the child's residence. Hospital data and population estimates reflect where children live, while immunisation, birth and COVID-19 data pertain to healthcare locations. Population estimates, used for calculating rates, assume that a certain percentage of children use public services, impacting rates but not estimated changes over time. We adjusted for available potential confounders, but there may be residual confounding present as we were not able to adjust for all confounders.

Conclusion

This study highlights the impact of PHSM on diarrhoea hospital admissions among children aged <5 years during the COVID-19 pandemic in the Western Cape Province, SA. There were substantial reductions in diarrhoea admissions coinciding with the implementation of stricter PHSM, suggesting combined effects of measures such as hand hygiene and physical distancing, as well as the impact of reduced healthcare access due to mobility restrictions and fear of acquiring COVID-19. Although subsequent relaxation of PHSM led to modest increases in diarrhoea admissions, the overall trend did not return to pre-pandemic levels. The disruption of the expected seasonal diarrhoea peak in November 2020 - May

2021, and the vulnerability of younger children to diarrhoea pathogens during periods of PHSM relaxation, highlight the importance of continued monitoring in public health interventions to prevent diarrhoeal diseases and subsequent hospital admissions in this population.

Data availability. The data that support the findings of this study are available from the Western Cape Provincial Health Data Centre, but restrictions apply to the availability of these data, which were used under licence for the current study, and so are not publicly available. Data are available, however, from the corresponding author upon reasonable request and with permission of the Western Cape Provincial Health Data Centre.

Declaration. This study was carried out as part of KK's PhD in Public Health, jointly between the University of Cape Town and University of Bristol.

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Author contributions. KK conceptualised the research study with guidance from MAD, MTR, SRW, HEJ and BE. KK was responsible for data management with assistance from NZ and AH. KK was responsible for data cleaning, statistical analyses and the initial draft manuscript. SRW, HEJ, BE, MAD and MTR supervised data analysis. All authors (KK, EM, TJ, NZ, AH, JRM, HB, SRW, BE, HEJ, MTR and MAD) reviewed, revised and approved the final manuscript.

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Conflicts of interest. None.

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