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Original Article

Impact of the COVID-19 Pandemic on Under-Five Mortality: An Interrupted Time Series Analysis in Southern Iran

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Abstract

Introduction: The COVID-19 pandemic disrupted healthcare systems globally, potentially impacting the health outcomes of vulnerable populations such as children under five. This study investigated the pandemic's effect on mortality trends in this age group within a healthcare network under the Shiraz University of Medical Sciences.

Methods: In an ecological study, we performed an Interrupted Time Series (ITS) analysis using segmented Poisson regression. We compared the monthly count of deaths among children under five years old for 11 months before and 11 months after the onset of the COVID-19 pandemic (March 2020). Data were extracted from the integrated electronic health record (SIB system) of the Shiraz University of Medical Sciences, covering 32 cities.

Results: For infants under one month of age, there was a significant immediate increase in mortality at the onset of the pandemic ($\beta_2 = 2.16$, $P < 0.001$), followed by a significant post-pandemic declining trend ($\beta 3 = -0.171$, $P < 0.001$). Among children aged 1 month to 1 year, the pre-pandemic trend was not significant, and neither the immediate level change nor the post-intervention trend was statistically significant. For children under five years, there was a non-significant pre-pandemic trend, a significant immediate increase in mortality at pandemic onset ($\beta_2 = 1.23$, $P < 0.001$), and a significant post-pandemic decreasing trend ($\beta_3 = -0.108$, $P < 0.001$).

Conclusion: The COVID-19 pandemic had a dual-phase impact on under-five mortality in the studied population: an initial surge likely linked to healthcare disruptions, followed by a reversal into a decreasing trend, possibly attributable to reduced transmission of common infectious diseases and accidents. This pattern underscores the complex and indirect effects of a global health crisis on child survival.

Keywords: COVID-19, Mortality, Children, Pandemic

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Introduction

The coronavirus was first detected in December 2019 in Wuhan, China, and within a few months, it spread to almost every region of the world, triggering a global pandemic. According to official statistics as of April 13, 2024, the numbers of COVID-19 cases and deaths in Iran were 7,627,186 and 146,811, respectively (1). In any society, mothers and children are considered a priority group. In developing countries, these two groups make up nearly 70% of the total population. Children constitute not only a large group but also a vulnerable group, at special risk for issues related to growth, development, and survival (2).

Although the rate of COVID-19 infection in children is lower than in adults, they are still among the groups affected by the pandemic. The indirect effects of the crisis, including improper diet, psychological effects, social isolation, screen addiction, lack of education, and lack of healthcare, strongly impact this group (3). Studies have shown that, owing to health workers' support during the pandemic, the provision of health services faced serious challenges (4). According to reports from the World Health Organization, the most significant causes of death in children include respiratory infections, diarrheal diseases, measles, malaria, malnutrition, and infant conditions, many of which can be prevented through vaccination, adequate care at home, access to healthcare services, improved breastfeeding, and better nutrition (5).

On the other hand, with the onset of the COVID-19 pandemic, primary care for children (including visits for healthy newborns and follow-up for chronic diseases), counseling, and vaccination have significantly decreased, especially in low- and middle-income countries. This decrease can significantly affect child mortality indicators.

Studies on the trend of child mortality during the first year of the COVID-19 pandemic have produced contradictory results (6-8).

In 2020, Roberton made an early prediction of the indirect impact of the COVID-19 pandemic on maternal and child mortality in low- and middle-income countries. The study revealed that there could be an additional 235,500 children dying in the best-case scenario and 1,157,000 in the worst-case scenario, resulting in an indirect increase in child mortality of 9.8% to 44.7% (9).

A study by Tashrek Ahmad et al. across 18 countries found that the decrease in healthcare utilization during the COVID-19 pandemic exacerbated the virus's negative impacts on health outcomes. This trend poses a threat to the progress made in reducing child mortality rates, as the death rate among children increased by 3.6% during the pandemic (10).

Furthermore, Tai et al. (2021) reported that during the Ebola epidemic, a reduction in healthcare services resulted in a 21% increase in mortality among children under five years of age (11). Additionally, Sento et al. reported that early death in infants was significantly greater (13.3%) during the COVID-19 period than before (12). Jensen et al. also reported the same results in their study (13). According to a WHO report, COVID-19 can affect global efforts to eliminate preventable child deaths due to reduced access to health services (14).

Child mortality is a common indicator of a population's socioeconomic development. On the other hand, the COVID-19 epidemic has led to changes in resource allocation, quarantine measures, and protective measures, and has placed immense pressure on the health system due to the high volume of coronavirus patients (15). This has led to disruptions in the provision of routine health services and changes in mortality rates across many countries worldwide. By identifying patterns of death in children, health systems can find ways to prevent premature and early deaths. Therefore, the present study was conducted to investigate the mortality rates among children under 5 years of age before and after the onset of the COVID-19 pandemic at health centers affiliated with Shiraz University of Medical Sciences.

Methods

This research is an ecological study examining the mortality of children under 5 years of age before and after the onset of the COVID-19 pandemic. The studied population includes children under the age of five covered by Shiraz University of Medical Sciences, which encompasses 32 cities. The average monthly number of children under study is 4,660. In this study, information on the deaths of children under 5 years of age was collected 11 months before COVID-19 (from April 2019 to February 2020) and 11 months after COVID-19 (from March 2020 to January 2021) from the SIB system (an integrated health system).

The tool used in this study is an Excel form that collects information on child mortality, including the number of children under 5 years of age, categorized by urban and rural areas, on a monthly basis.

Data on the mortality of children under five years of age were collected from April 2019 to February 2020 and from March 2020 to January 2021 at health centers affiliated with Shiraz University of Medical Sciences. The data are aggregated and presented in numbers.

The data were initially entered into SPSS version 26 by the researcher, and the statistical analysis was conducted in STATA version 16. In this study, ecological analysis was utilized for the descriptive analysis of numbers. Owing to the ecological nature of the data, an interrupted time-series analysis was employed, which compares data before and after a significant event such as a flood, earthquake, fire, or COVID-19. This method provides coefficients that indicate decreases (negative values) or increases (positive values) in the variable being studied. For reliable analysis, a minimum of 8 events before and after the event is needed. Ultimately, this study used the interrupted time series (ITS) method to assess changes in child mortality rates among children under 5 years of age.

Segmented Poisson regression was used because the outcome variable (monthly mortality) was count-based. Robust standard errors were applied, and 95% confidence intervals were reported to reflect statistical uncertainty and potential deviations from model assumptions. Autocorrelation and seasonality were not explicitly modeled and are acknowledged as potential limitations.

The interrupted time series models require at least three independent variables:

$$Yt = \beta 0 + \beta 1T + \beta 2Xt + \beta 3(T - Ti)\,Xt$$

Beta (β) coefficients indicate the trend or level of change in each variable, including β1 for the trend before the COVID-19 pandemic, β2 for the early change in level induced by the COVID-19 natural intervention, and β3 for the trend of recovery (or deterioration) during the COVID-19 pandemic. For each β coefficient, a P-value ≤ 0.05 indicates that the trend or change is statistically significant. The time points in this analysis were measured in months, with 11 months before and 11 months after the onset of COVID-19 in Iran.

Results

We examined the monthly death count for children under five years of age during the eleven months prior to and the eleven months following the official onset of the COVID-19 pandemic in Iran, from April 2019 to January 2021. Figures 1, 2, and 3 illustrate the temporal trends for infants under one month old, children under one year old, and children under five years old, respectively. A consistent visual pattern across all age groups shows a marked immediate increase in mortality coinciding with March 2020, the point of pandemic declaration and the implementation of major public health interventions. This initial peak was followed by a subsequent decline in the post-pandemic months.

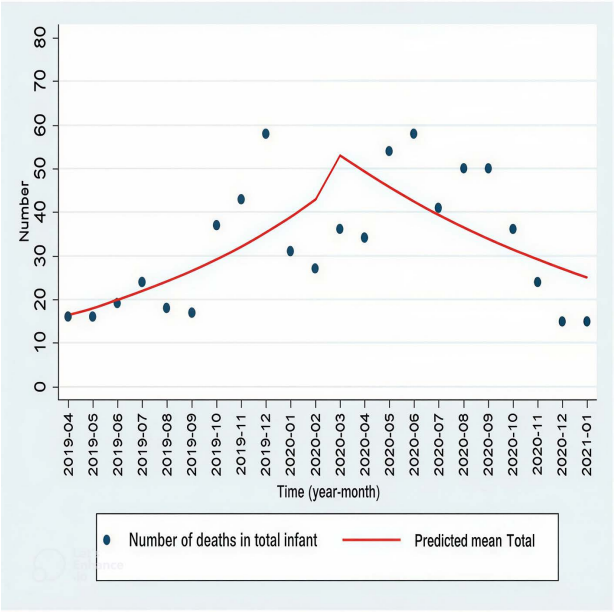

Figure 1. Death count of children under one month of age

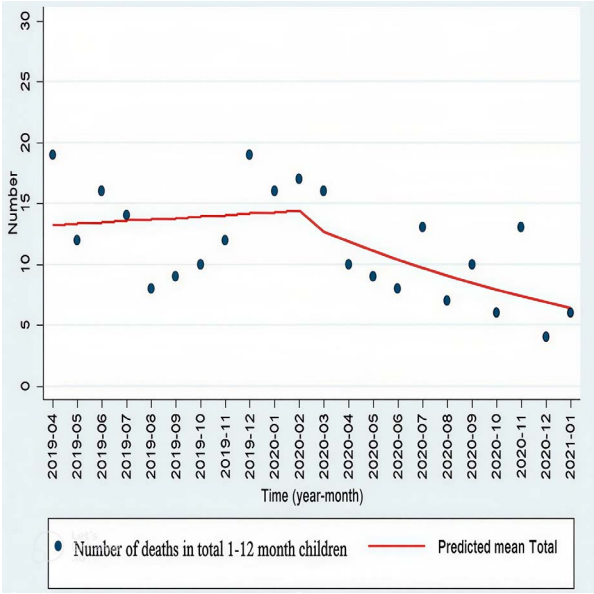

Figure 2. Death count of children under one year of age

Interrupted Time Series Analysis

According to Table 1 for Infants under one month, a significant increase in the pre-pandemic trend was observed ($\beta_1 = 0.096$, $P < 0.001$). The onset of the pandemic was associated with a significant immediate increase in the mortality level ($\beta_2 = 2.16$, $P < 0.001$). Subsequently, a significant downward trend emerged in the post-intervention period ($\beta_3 = -0.171$, $P < 0.001$). For children aged one month to one year: The pre-pandemic trend was not statistically significant ($\beta_1 = 0.008$, $P = 0.739$). Neither the immediate level change at the pandemic's onset ($\beta_2 = 0.790$, $P = 0.155$) nor the change in the post-onset trend ($\beta_3 = -0.060$, $P = 0.060$) reached statistical significance. For children under five years, the analysis indicated a non-significant increasing pre-pandemic trend ($\beta_1 = 0.031$, $P = 0.074$). A significant immediate increase in mortality was detected at the start of the pandemic ($\beta_2 = 1.23$, $P < 0.001$), which was followed by a significant decreasing trend in the subsequent months ($\beta_3 = -0.108$, $P < 0.001$).

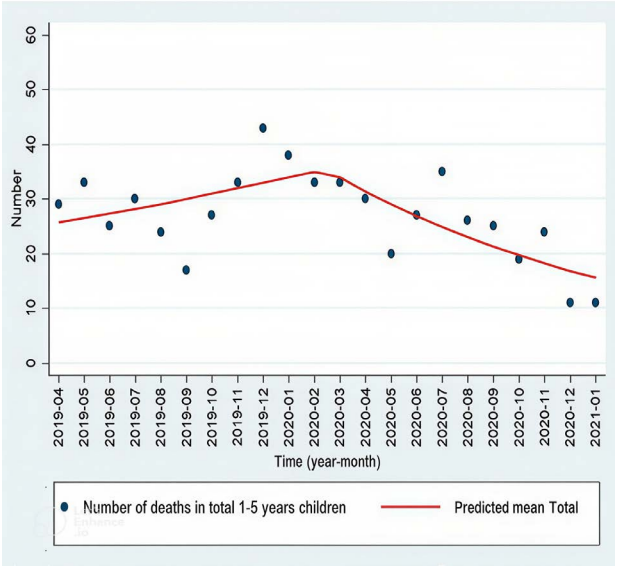

Figure 3. Death count of children under five years of age

Discussion

This study aimed to investigate the impact of the COVID-19 pandemic on mortality trends among children under five within the healthcare network of Shiraz University of Medical Sciences. By employing an Interrupted Time Series analysis, we moved beyond simple pre-post comparisons to capture the dynamic temporal effects of this global crisis on a population. Our analysis revealed a distinct, two-phase pattern that is critical for understanding the pandemic's complex legacy. For infants under one month and children under five years, a significant immediate increase in mortality occurred at the onset of the pandemic, which later reversed into a significant declining trend. For children aged one month to one year, the observed changes were not statistically significant. This bifurcated outcome—a clear shock followed by a sustained recovery in two groups, alongside a neutral effect in another—demands a layered interpretation that considers both systemic vulnerabilities and adaptive societal responses.

The initial surge in mortality, particularly among neonates, is a stark indicator of how external shocks can strain even established healthcare systems. This finding is consistent with reports from other countries that experienced similar crises; studies from England and Turkey documented increases in obstetric emergencies, stillbirths, and neonatal complications like small-for-gestational-age (SGA) births and hypoxic-ischemic injuries during the early pandemic months (16, 17). The underlying causes are likely universal: severe disruptions in prenatal follow-up, reduced access to critical sonography and screening services, and a widespread, fear-driven reluctance to seek timely hospital care (18). In our specific context, this translated to a probable breakdown in the

Table 1. Interrupted time series analysis of all children

Variable	Trend before COVID-19 (β1)		Change from pre- to post-COVID-19 pandemic (β2)		Trend after COVID-19 (β3)	
	Coefficient (95% CI)	*P*	Coefficient (95% CI)	*P*	Coefficient (95% CI)	*P*
Number of deaths in infant	.096 (.05, .13)	<0.001	2.16 (1.58, 2.75)	<0.001	-.171 (-.21, -.12)	<0.001
Number of deaths in children under 1 year	.008 (-.04, .05)	0.739	.790 (-.29, 1.88)	0.155	-.076 (-.15, .003)	0.060
Number of deaths in children under 5 years	.031(-.003, .06)	0.074	1.23 (.55, 1.92)	<0.001	-.108 (-.16, -.05)	<0.001

continuum of care for pregnant women and newborns. The sudden reallocation of medical resources and personnel towards the COVID-19 response, coupled with public health messaging that inadvertently discouraged hospital visits, likely created a dangerous gap. This gap exposed the fragility of systems protecting maternal and neonatal health, leading to the observed immediate increase in mortality. It underscores a vital public health principle: the sustainability of routine care is as crucial as emergency response during a pandemic.

Simultaneously, the subsequent significant decline in mortality presents a compelling counter-narrative that requires careful deconstruction. The implementation of nationwide lockdowns, quarantine measures, mask mandates, frequent hand hygiene, and travel restrictions—while imposing immense social and economic costs—fundamentally altered the ecological landscape of child health risks. These measures are known to have drastically reduced the population-level transmission of common infectious diseases. Pathogens such as influenza and other respiratory viruses, which, according to UNICEF, are leading causes of under-five mortality globally (19), saw their circulation markedly diminished. This likely led to a substantial decrease in severe pneumonia and bronchiolitis cases, directly preventing deaths. Furthermore, statistics from countries like the United States and England show a notable decline in traffic accidents, physical injuries, and child drownings during the pandemic, firmly linking these non-pharmaceutical interventions to a reduction in external causes of death (20). In the Iranian context, these global phenomena were probably amplified by specific cultural adaptations. The widespread restriction of visitation to newborns, a deeply ingrained social custom, may have inadvertently created a protective "cocoon" around infants, drastically limiting their exposure to respiratory and other infections from extended family and community members. This unique socio-behavioral shift, combined with the universal effects of lockdowns on mobility and infection transmission, provides a robust, multifaceted hypothesis to explain the significant downward trend observed in our data. It suggests that the pandemic's legacy on child health is not uniformly negative but is instead shaped by a complex interplay of increased and decreased risk factors.

It is also important to consider the role of pervasive psychosocial stress, which adds another layer of complexity to this narrative. The pandemic induced high levels of chronic stress in families through social and economic upheavals, fear of contagion, enforced isolation, school closures, and the dissolution of support networks (21, 22). Such toxic stress, without adequate buffering, can have profound long-term effects on children's cardiovascular, neurological, and immune system development, potentially increasing morbidity and mortality in vulnerable groups over time. This creates a scenario of competing vulnerabilities: while immediate mortality from infections and accidents fell, the long-term trajectory of child health may be negatively influenced by these sustained stressors and by interruptions in essential preventive care.

This leads to the crucial integration of future risks into our interpretation of the current data. The reorganization of health services and the eventual lifting of strict quarantine measures facilitated a return to more stable healthcare access, as reflected in the declining mortality trend. Studies such as the one by Odd et al. (2022) in the UK reported a similar significant reduction in child mortality from various causes during the first pandemic year (16). Similarly, analyses of global data have indicated that in 2020, mortality among children under five in some countries was lower than expected based on historical trends (23), reinforcing the idea that the pandemic's net effect was multifaceted. However, this encouraging trend exists alongside deferred threats. The same healthcare disruptions that caused the initial surge also led to missed prenatal screenings and delayed routine childhood vaccinations. Therefore, the observed decline should not be viewed in isolation as an unqualified success. Rather, it may represent a transient phase where the immediate protective effects of reduced environmental exposure temporarily overshadow the latent risks from deferred healthcare. In our setting, where accidents are a notable cause of child mortality, the decline in trauma-related hospital visits post-pandemic powerfully aligns with this global pattern. The overall findings suggest that the pandemic's impact resulted from a tense equilibrium between two opposing forces: the initial negative shock of healthcare system disruption and the later, potent protective effect of radically reduced exposure to infections and accidents. The lack of significant findings in the 1-12-month age group may indicate that these children were somewhat insulated from the specific perinatal complications that severely affected neonates, while possibly experiencing a more balanced mix of risks and benefits from the altered environment.

This study has several limitations. First, due to its ecological design, causal inference at the individual level is not possible. Second, potential autocorrelation in the time-series data was not formally assessed, which may have influenced the standard errors. Third, the analysis did not adjust for seasonal variation in child mortality, which

may affect temporal patterns. Fourth, overdispersion in the Poisson model was not formally tested. Despite these limitations, the interrupted time series design provides a robust framework for evaluating population-level changes before and after a defined intervention period.

Conclusion

In conclusion, the COVID-19 pandemic exerted a dual and time-varying influence on under-five mortality in southern Iran. It was characterized not by a simple increase or decrease, but by an initial shock to healthcare access followed by a period of reduced environmental and infectious risks. This pattern underscores the non-linear and often paradoxical nature of population health outcomes during a global crisis. It highlights the critical, non-negotiable need to maintain accessible, high-quality maternal and neonatal healthcare services during public health emergencies to prevent immediate surges in mortality. Concurrently, the potential child survival benefits of sustained public health measures—such as those that reduce traffic injuries and respiratory pathogen transmission—warrant serious consideration in future health policy and resilience planning. Our findings ultimately reveal that child mortality is governed by a delicate balance between access to continuous care and exposure to environmental risk, a balance that was dramatically and instructively reconfigured by the pandemic.

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethical Approval

Ethical approval for this study was granted by the Ethics Committee of Shiraz University of Medical Sciences (Code: IR.SUMS.NUMIMG.REC.1400.047). As the research involved the analysis of existing, de-identified data from the electronic health record (SIB) system, the requirement for informed consent was waived by the committee.

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